SIGACCESS
NEWSLETTER
A regular publication of ACM SIGACCESS: Special Interest Group on Accessible Computing

Virtual Cursors to Enhance Web Accessibility for People with Limited Dexterity

J. Eduardo Pérez and Myriam Arrue

Eduardo Pérez and Myriam Arrue write the first article of the 115th issue of the SIGACCESS Newsletter. Following their Best Communication Award at Web for All 2016 (W4A'16) conference, the authors present their work on designing virtual cursors to assist motor-impaired users during web browsing tasks.

Towards Screen Readers with Concurrent Speech: Where to go Next?

João Guerreiro

In the second article, João Guerreiro talks about his research on changing the status quo of screen readers by leveraging concurrent speech feedback to speed-up blind people's scanning for digital information.

Hugo Nicolau
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Virtual Cursors to Enhance Web Accessibility for People with Limited Dexterity: Usability Test Results and Future Directions

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Abstract

Basic web interactions, such as pointing and clicking links with an on-screen cursor, can be highly challenging for people with a lack of dexterity in their hands or arms. Much research has been done on studying point and click interactions, but most of this has focused mainly on able-bodied people interacting with standard pointing devices. In this paper, we present the design and the usability evaluation of two virtual cursors for assisting motor-impaired users when pointing and clicking links while browsing the Web. Results of a usability study involving nine motor-impaired and six able-bodied users applying their usual pointing device in a web-based experiment are presented. According to their self-reported assessments, the results show the acceptance and usefulness of both virtual cursors compared to the original unassisted one, underlining the importance of providing motor-impaired people with virtual enhancements to improve their web browsing ability.

Introduction

The ubiquity of the World Wide Web has provided undeniable benefits for people with motor impairments, particularly by enhancing their independence in their daily life. Among many other activities, nowadays the Web enables anyone with Internet access to run their own business, manage their own finances, do their own shopping, access education and leisure and socialize without needing to leave home. Taking into account the countless barriers that people with motor impairments face in the real world, this population group relies to a great extent on computers and the Internet to be able to participate in society, for instance with regard to having a job [7]. However, neither computers nor the Web are universally accessible, and basic web interactions such as pointing and clicking links with an on-screen cursor can be highly challenging for people with a lack of dexterity in their hands or arms. Spasm, poor coordination, low strength and rapid fatigue are some features related to dexterity impairments that can affect, to a greater or lesser degree, performance when hitting targets on a graphical user interface (GUI) [11][4] and, consequently, their experience for web browsing.

Much research has been done on studying point and click interactions with on-screen cursors, but most of this has focused mainly on able-bodied people interacting with standard pointing devices. Concerning physically impaired users interacting with alternative pointing devices on desktop computers, studies tend to be based on supervised laboratory experiments and repetitive pointing and clicking tasks in order to get precise data about those two actions. However, in order to understand how they interact with computers during real world use over time, studies must head towards unsupervised experiments and free navigation tasks [3]. Our research is aimed at this very purpose, studying how people with motor-impairments using diverse pointing devices interact during their daily lives with desktop computers and how virtual cursors can help them to browse the Web.

In this paper, we present the design and the usability evaluation of two virtual cursors to assist people with limited dexterity when pointing and clicking links while browsing the Web. In a previous study about web navigation strategies with 11 motor-impaired people [10], results showed that performance on point and click interactions was differently affected depending on the assistive technology (AT) used by participants. Hence, joystick or trackball users found the action of clicking on a target more difficult due to their lack of precision. By contrast, keyboard users found the pointing actions more tiring, especially when long distances had to be covered to reach the target. Both virtual cursors presented here aim to assist each one of these types of users by reducing either the accuracy required for clicking, or the target distance for pointing. Usability results are obtained from nine motor-impaired and six able-bodied users using their usual pointing devices in a web-based experiment [8]. According to their self-reported assessments, results show the high acceptance and usefulness of both virtual cursors compared to the original unassisted cursor, evidencing the importance of providing motor-impaired users with virtual aids for improving their web browsing experience. In addition, some ongoing performance studies on cursor trajectories and future work are presented.

Related Work

Many cursor enhancements have been created to facilitate pointing and clicking in GUIs even though only a few of them have been specifically focused on assisting motor-impaired people in web browsing. Let us mention some of those, which inspired us to define the basis of our research.

Findlater et al. [1] introduce four enhanced area cursors to reduce correction-phase pointing and mitigate the effects for motor-impaired users of small target sizes on target acquisition. Two of them rely on magnification while the other two use goal crossing. A study with users showed that motor-impaired subjects lowered their selection times for small targets along with the number of required corrective sub-movements using two assisted cursors by magnification and goal crossing paradigms respectively. They also improved their error rate in comparison to the unassisted cursor. However, these alternatives were not formally evaluated in a web-browsing scenario.

Grossman and Balakrishnan evaluated the *Bubble Cursor* [2] with motor-impaired people. The results revealed improved performances, although participants unanimously preferred other interaction methods. The *Bubble Lens* [6] proved to enhance performance of the *Bubble Cursor* by magnifying targets when these are small and dense, but those findings were based only on able-bodied users.

Virtual Cursors to Assist Pointing and Clicking Links

Two different virtual cursors to enhance pointing and clicking accessibility have been implemented (Figure 1). As explained below, each virtual cursor aims to assist different motor-impaired navigational behaviors when pointing and clicking links. Following a previous study on motor-impaired navigational strategies on the Web [10], the "circular cursor" (Figure 1a) aims at assisting joystick and trackball users (less accurate when pointing close to the link and clicking on it), while the "cross cursor" (Figure 1b) aims at assisting keyboard-only users (more affected by target distance).

Circular Cursor

The "circular cursor" (Figure 1 left) reduces the accuracy of movements required for clicking links by creating a virtual "active" area around the moving cursor. In this way, the "circular cursor" enables link selection without requiring the cursor to be positioned precisely over the target link. If more than one link is inside the "circular cursor", only the nearest one to the arrow cursor is highlighted and therefore is clickable. For this first approach, we used fixed values for the circle diameter (130 pixels) and circumference appearance (10 pixels width and 90% translucent grey color).

Cross Cursor

The "cross cursor" (Figure 1 right) reduces target distance for pointing by assigning a letter to each link virtually crossed by the horizontal and vertical axes converging in the arrow cursor. In this way, direct keyboard access is provided to those links by typing their associated character. Therefore the "cross cursor" enables link selection with a single keystroke. Characters are automatically assigned to each crossed link starting from the right side of the keyboard, using the nearest letters to the numeric keypad first. As with the "circular cursor", this first prototype of the "cross cursor" uses similar fixed values for its visual appearance (10 pixels width and 90% translucent grey color).

Figure 1: (left) The "circular cursor" allows the highlighted link (*Today's News*) to be clicked within the featured circle without needing to place the arrow cursor over it. (right) The "cross cursor" assigns a letter to each link crossed by the featured vertical and horizotal lines converging in the arrow cursor. A letter keystroke (*P* or *L*) allows link selection.

Browser Plug-in Implementation

Both virtual cursors have been implemented as browser plug-ins compatible with Firefox and Chrome browsers. We used Scalable Vector Graphics (SVG) data inserted within each visited web page in order to render in the user browser all graphical elements of both virtual cursors (circle, vertical and horizontal lines and shortcut letters for links). We used *JavaScript* language with *jQuery* library in order to handle all the *SVG* elements reacting to the user cursor movements and the links' locations, as well as for triggering link virtual selections.

Experiment

In order to evaluate both virtual cursor prototypes, a web-based experiment was carried out with motor-impaired and able-bodied users applying their usual pointing devices [8]. The experimental study characteristics are detailed below, as well as the main results from the usability questionnaires and the first visual insights on point and click trajectories.

Participants

Fifteen subjects took part in the study (seven females and eight males). Three groups were defined based on the input device used for pointing and clicking actions: (a) 4 keyboard users (KU group), (b) 1 trackball and 4 joystick users (JU group), and (c) 6 mouse users (MU group).

Table 1: Detailed information about experiment participants, divided by user group.

Keyboard users group (KU)						Joystick & trackball users group (JU)						Mouse users group (MU)				
Subject	*Gender*	*Age*	*Device*	*Exp.*	*Use*	*Subject*	*Gender*	*Age*	*Device*	*Exp.*	*Use*	*Subject*	*Gender*	*Age*	*Exp.*	*Use*
KU1	F	58	keyboard	+7	daily	JU1	M	45	trackball	+7	daily	MU1	F	30	+7	daily
KU2	F	53	keyboard	+7	daily	JU2	M	42	joystick	+7	daily	MU2	F	33	+7	daily
KU3	M	42	keyboard + head wand	+7	daily	JU3	M	46	joystick	+7	daily	MU3	M	30	+7	daily
						JU4	F	41	joystick	+7	daily	MU4	M	28	+7	daily
KU4	F	43	keyboard + head wand	1-3	daily	JU5	F	77	joystick	4-6	weekly	MU5	M	36	+7	daily
												MU6	M	42	+7	daily

All subjects from the KU and JU groups had motor-impairments (Figure 2 shows 3 of them during the experimental session), while the MU group only included users without disabilities. Table 1 shows information about the participants, including gender, age, used input device, years of experience with the pointing device and regularity of use of the device. Depending on their preference, KU and JU groups' participants performed the experiment at their home (6 out of 9), in a laboratory of the University of the Basque Country (2 out of 9) or on the premises of Elkartu (1 out of 9), a local association of people with physical disabilities. All sessions with participants in the MU group were carried out in a laboratory (6 out of 6).

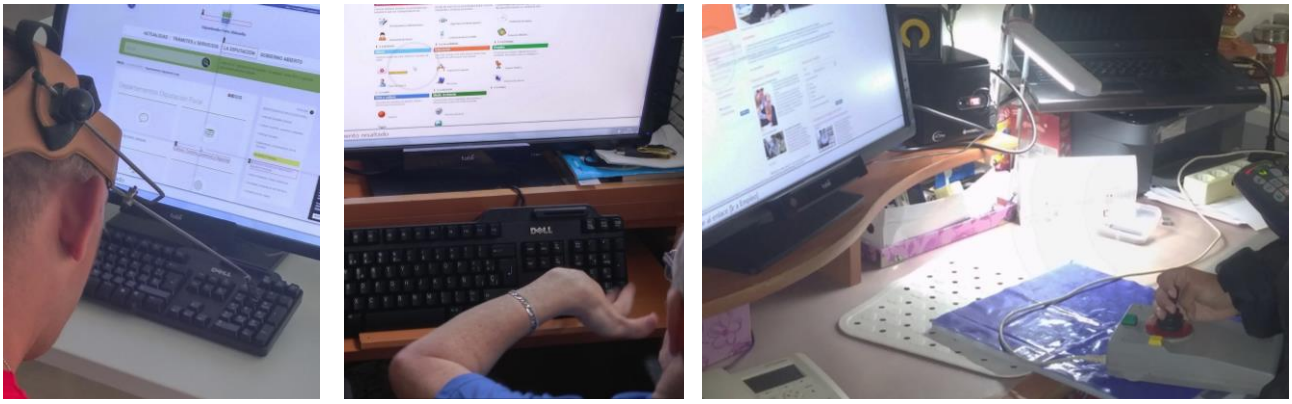

Figure 2: Three motor-impaired participants performing the web-based experiment at their home.
(left) Subject KU3 using a head pointer to move the "cross cursor" with the numeric keypad interface.
(center) Subject KU2 using her left hand to move the "circular cursor" with the numeric keypad interface.
(right) Subject JU4 using her right hand to move the "circular cursor" with a joystick.

Materials

The same laptop was used in all sessions to run the experiment alongside an additional 24 inch widescreen LCD monitor to present stimuli to participants. Before starting the study, participants were encouraged and helped to adjust the pointer motion behavior to meet their preferences. Subjects from the KU and JU groups used their own personal input devices to complete the study. Non-disabled participants (MU group) used the same optical USB mouse. All sessions were video and audio-recorded. A platform called RemoTest [12] was used to specify and conduct the experimental sessions, as well as to gather complete interaction data logs from every participant.

Two different websites were selected as stimuli for the experiment: the Discapnet website [http://www.discapnet.com], which provides information to people with disabilities, and the institutional website from the Council of Gipuzkoa [http://www.gipuzkoa.eus/es/hasiera/]. A third informational website [http://www.bidasoaturismo.com] featuring tourism information for the Bidasoa local area was used for training purposes, so participants could learn how to use the new cursor virtual enhancements. All three websites claim, within their accessibility sections, to conform to a particular level of the WCAG 1.0 guidelines (Discapnet to Level AA, Gipuzkoa and Bidasoa to Level A).

Procedure

Firstly, participants were briefed on the purpose of the experiment and signed a consent form before proceeding. Prior to testing, the experiment tasks and cursor variants were presented to the participants through demonstration and practice on the training website.

After the training session, participants were asked to perform a set of tasks with each cursor type (circular, cross and unassisted). Each set of tasks consisted of four search tasks followed by 48 target acquisition tasks, half of which were performed on each of the two different websites. At the end of each set of tasks for a particular cursor, participants were interviewed about the use of the cursor variant and asked to rate it on a seven point Likert scale based on eight categories (*Learnable*, *Rememberable*, *Accurate*, *Easy to Use*, *Effortless*, *Natural*, *Fun* and *Not Frustrating*). After all the tasks were completed with the three cursor types, participants were asked to rank them in order from most to least favorite for web browsing purposes.

Results on Usability Evaluation

About the Eight Usability Categories

For the *Learnable*, *Rememberable* and *Natural* categories, the original cursor, as expected, obtained better results than the other cursor variants, as all participants were already used to it. However, all the users groups also generally rated very highly both the enhanced cursor variants for these three categories. The "cross cursor" got lower ratings from the JU and MU user groups but higher results from the KU user group for the three categories, as expected considering that the cursor variant is designed to assist keyboard-only users and some JU users were not even able to access the keyboard. This circumstance was generally repeated for the remaining categories.

For the *Accurate*, *Effortless* and *Not Frustrating* categories, virtual cursors were very positively rated by both motor-impaired target groups. Several motor-impaired users rated the unassisted cursor negatively for these three categories.

For the *Easy to Use* category, the "circular cursor" was the best rated option for participants with motor-impairments. The "cross cursor" got low ratings from the JU and MU user groups, whereas it was highly rated by the keyboard-only users (KU user group).

Participants felt some insecurity when rating the *Fun* category and values did not differ significantly among cursor variants. Nevertheless, several users preferred virtual cursors for this category due to the novelty.

About the Overall Preferred Cursor

Rankings about preferred cursor variant for web browsing (Figure 3) show two interesting outcomes. Firstly, motor-impaired participants mainly preferred one of the two virtual cursors to the unassisted pointer. Seven out of nine motor-impaired participants selected the "circular cursor" or the "cross cursor" as their preferred option for web browsing. Secondly, opposing assessments were given for cursor variants depending on the pointing device used. For instance, the "cross cursor" was unanimously the third option for the JU user group, while it was the preferred choice for half of the KU user group.

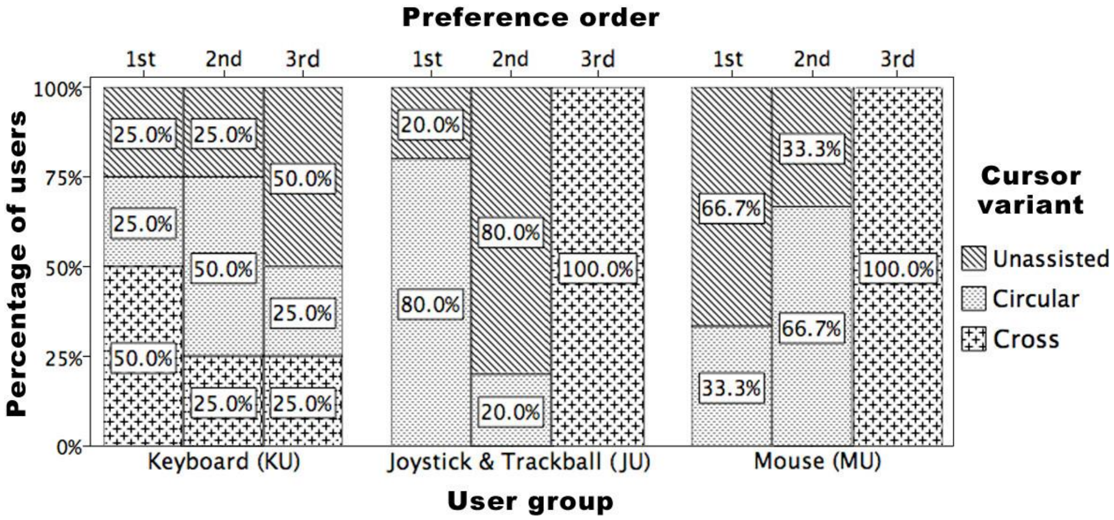

Figure 3: Cursor variants from most to least favorite by user group.

Participants Comments

One keyboard-only user (KU4) chose the "circular cursor" as the least favorite of the three variants, stating that it was difficult to use. This user commented that clicking was confusing due to the way the target link is highlighted on approaching, and that the pointing was more difficult when various links were close to each other. Another keyboard-only user (KU2) ranked the "cross cursor" as the least interesting of the cursor variants. She stated not remembering that she could click distant links by automatically provided keystrokes and that automatic letter assignment to links was confusing. Only two motor-impaired subjects (KU4 and JU4) out of nine opted for the unassisted cursor as their preferred variant for web browsing, arguing that it was the method they were used to. Three out of four participants from the KU group showed interest in the "circular cursor" stating that it facilitated pointing.

Preliminary Cursor Trajectories Study

A way to measure the usage of cursor variants during the experiment presented in this article is by studying cursor motion behavior along pointing trajectories. For this purpose, on-screen cursor coordinates were recorded in the interaction logs for every cursor movement performed in experimental sessions. So far only cursor trajectories from target acquisition tasks are being studied (considering those paths as fully representative of pointing and clicking interactions). A first visual analysis of these pointing trajectories has brought to light encouraging results concerning the benefits of both virtual cursors for motion-impaired participants. Point and click trajectories displayed in Figure 4 show the "circular cursor" probes to be beneficial for the current task (Figure 4 left) for subject JU1 (using a trackball). The reason is that he can select the target link more easily without needing to place the cursor over it. Subject KU3 (using a keyboard with a head wand) also benefits from the "cross cursor" in the current task (Figure 4 right), needing fewer keyboard interactions for selecting the target link.

In order to obtain meaningful insight from studying the current experiment point and click trajectories, a comprehensive set of cursor measures on performance and accuracy are being evaluated [5].

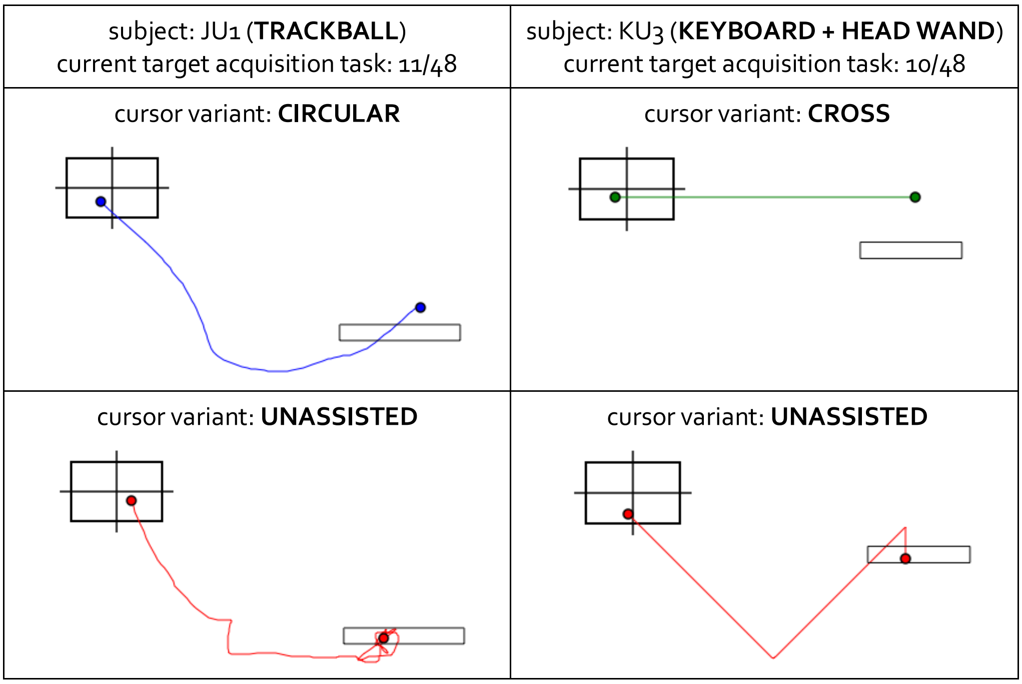

Figure 4: Point and click trajectories from two participants using different cursor variants. Trajectories correspond to a target acquisition task (TAT) with home button on the left side and target link on the right side. (left-up) Trackball user JU1 using the "circular cursor" and (left-down) using the unassisted cursor to perform the same TAT. (right-up) Keyboard-only user KU3 using the "cross cursor" and (right-down) using the unassisted cursor to perform the same TAT.

Ongoing Research and Future Work

Following the experimental study described above, further research is currently been done to gain insight about the usage of both of the virtual cursors by motor-impaired participants, and ultimately to look for user behaviors and web features that improve or worsen pointing and clicking links. The objective of this analysis combined with usability results is to improve both prototypes presented here in order to provide motor-impaired people with better assistance for point and click links when browsing the Web.

In addition, we plan to perform a long-term study with several motor-impaired users by supplying them with a browser plug-in to be installed in their desktop computers. That plug-in will implement virtual cursors to assist point and click on the Web, as well as recording those users' cursor interactions during real world use and over time. The objective for this long-term unobtrusive study is to better understand point and click interactions from motor-impaired people during web interaction, and relate those findings to different features such as the pointing device used, the type of web page visited (according to the number of on-screen links or their layout distribution), the chronological progression, etc.

Long-term Study with Plug-in

The initial objective of this stage is to build an efficient and effective plug-in that remains as unobtrusive as possible to the users (they should be able to easily switch cursor enhancements on and off during navigation), and which records valuable data from participant's day to day life about virtual cursor usage habits, and point and click web interactions. The plug-in should essentially record the following four events related to pointing and clicking links:

- Pointer position over time (to track cursor movements within the browser window).
- Clicks performed with the pointing device (to track clicking within pointing trajectories)
- Keystrokes related to operation of the "cross cursor"
- Every link position and dimension for each visited page (to classify web pages by the number of links and also their graphical arrangement).

Although not directly related to pointing and clicking links, it is also important to track other interactions within the participant's browser such as page scrolls, tab changes and page zooms, as these actions help to discard useless cursor paths from the link selection trajectories.

In addition to further studies on the virtual cursors presented here, recorded data with this plug-in will be used to define web GUI design recommendations for alternative pointing devices such as a keyboard, to improve previous work on estimating the beginning of pointing trajectories [12], and to build a predictive model from the bases defined here [9] for cursor pointing with the numeric keypad interface.

Acknowledgments

We would like to thank all participants enrolled in the study, as well as the Elkartu association of people with physical disabilities. We also thank our colleague at the EGOKITUZ laboratory Xabier Valencia for his work on the RemoTest platform [12].

J. Eduardo Pérez holds a PhD scholarship from the University of the Basque Country (UPV/EHU). This work is also funded by the Ministry of Economy and Competitiveness of the Spanish Government and by the European Regional Development Fund – ERDF (eGovernAbility project, TIN2014-52665-C2-1-R).

References

1. Findlater, L., Jansen, A., Shinohara, K., Dixon, M., Kamb, P., Rakita, J., and Wobbrock, J. O. (2010). Enhanced area cursors: reducing fine pointing demands for people with motor impairments. In *Proceedings of the 23rd annual ACM symposium on User Interfaces Software and Technology.* (UIST'10). New York: ACM, Pages 153-162.

2. Grossman, T. and Balakrishnan, R. (2005). The bubble cursor: enhancing target acquisition by dynamic resizing of the cursor's activation area. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.* (CHI'05). New York: ACM, Pages 281-290.

3. Hurst, A., Mankoff, J. and Hudson, S.E. (2008). Understanding pointing problems in real world computing environments. In *Proceedings of the 10th international ACM SIGACCESS conference on Computers and Accessibility.* (ASSETS'08). New York: ACM, pp. 43-50.

4. Hwang, F., Keates, S., Langdon, P. and Clarkson, P.J. (2004). Mouse movements of motion-impaired users: A submovement analysis. In *Proceedings of the 6th International ACM SIGACCESS conference on Computers and Accessibility.* (ASSETS'04). New York: ACM, pp. 102-109.

5. Keates, S., Hwang, F., Langdon, P., Clarkson, P.J. and Robinson, P. (2002). The use of cursor measures for motion-impaired users. *Universal Access in the Information Society.* (UAIS). Volume 2, Issue 1, November 2002, Pages 18-29.

6. Mott, M.E. and Wobbrock, J.O. (2014). Beating the bubble: using kinematic triggering in the bubble lens for acquiring small, dense targets. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.* (CHI'14). New York: ACM, Pages 733-742.

7. Murphy, K.P., Molnar, G.E. and Lankasky, K. (2000). Employment and social issues in adults with cerebral palsy. *Archives of Physical Medicine and Rehabilitation*. Volume 81, Issue 6, June 2000, Pages 807-811.

8. Pérez, J.E., Valencia, X., Arrue, M. and Abascal, J. (2016). A Usability Evaluation of Two Virtual Aids to Enhance Cursor Accessibility for People with Motor Impairments. In *Proceedings of the 13th International Cross-Disciplinary Conference on Web Accessibility.* (W4A'16). ACM Press.

9. Pérez, J.E., Valencia, X., Arrue, M. and Abascal, J. (2015). Depicting the Keypad Mouse Interface: Exploring Pointing Behaviors of Three Input Devices. In *Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility.* (ASSETS'15). New York: ACM Press, Pages 413-414.

10. Pérez, J.E., Valencia, X., Arrue, M. and Abascal, J. (2014). Exploratory Study of Web Navigation Strategies for Users with Physical Disabilities. In *Proceedings of the 11th Web for All Conference.* (W4A'14). New York: ACM Press, Article 20.

11. Trewin, S. and Pain, H. (1999). Keyboard and mouse errors due to motor disabilities. *International Journal of Human-Computer Studies.* (IJHCS). Volume 50, Issue 2, February 1999, Pages 109-144.

12. Valencia, X., Pérez, J.E., Muñoz, U., Arrue, M. and Abascal, J. (2015). Assisted Interaction Data Analysis of Web-based Users Studies. In *Proceedings of the 15th IFIP TC13 International Conference on Human-Computer Interaction.* (INTERACT 2015). Vol. 9296 of LNCS, Springer, Pages 1-19.

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Towards Screen Readers with Concurrent Speech: Where to Go Next?

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Introduction

Blind people rely mostly on the auditory feedback of screen readers to consume digital information. Despite the browsing strategies employed by blind users [3], how fast can information be processed remains a major problem. Sighted people use scanning as a strategy to achieve this goal, by glancing at all content expecting to identify information of interest to be subsequently analyzed with further care. In contrast, screen readers rely on a sequential auditory channel that is impairing a quicker overview of the content, when compared to the visual presentation on screen.

We proposed taking advantage of the *Cocktail Party Effect* [6], which states that people are able to focus their attention on a single voice among several conversations, but still identify relevant content in the background. Therefore, oppositely to one sequential speech channel, we hypothesized that blind users can leverage concurrent speech to quickly get the gist of digital information. Grounded on literature reviews (e.g. [4,5,7,8]) that documented several features (e.g. spatial location, voice characteristics) that increase speech intelligibility, we investigated if and how we could take advantage of concurrent speech to accelerate blind people's scanning for digital information.

Results confirm that blind (and sighted [13]) people are able to scan for relevant content with two or three simultaneous voices [9]. Most importantly, we show [11] that two or three voices with speech rates slightly faster than the default rate, enable a significantly faster scanning for relevant content, while maintaining its comprehension. In contrast, to keep-up with concurrent speech timings, a single voice requires a speech rate so fast that it causes a considerable loss in performance. We then investigated and explored other prospective scenarios for concurrent speech interfaces. Besides scenarios that focus on information consumption, we explored the use of concurrent speech to support two-handed exploration in multitouch scenarios [10,12]. Overall, results show that concurrent speech is able to speed up the consumption of digital information in scanning scenarios, but that in tasks that require a greater physical coordination with the speech sources, the benefits are more dependent on the task itself and on user strategies.

Finally, we present a set of scenarios that emerged from a formative user study with blind participants and a set of open challenges in the use of concurrent speech to speed-up blind people's information consumption.

Scanning for Relevant Content with Concurrent Speech

Sighted people's fast reading skills enable them to quickly get a general idea of the content – skimming – or to find specific information – scanning [1]. In our research, we refer to *Relevance Scanning* as the process of exploring the content and determine which pieces of information are relevant and deserve further attention.

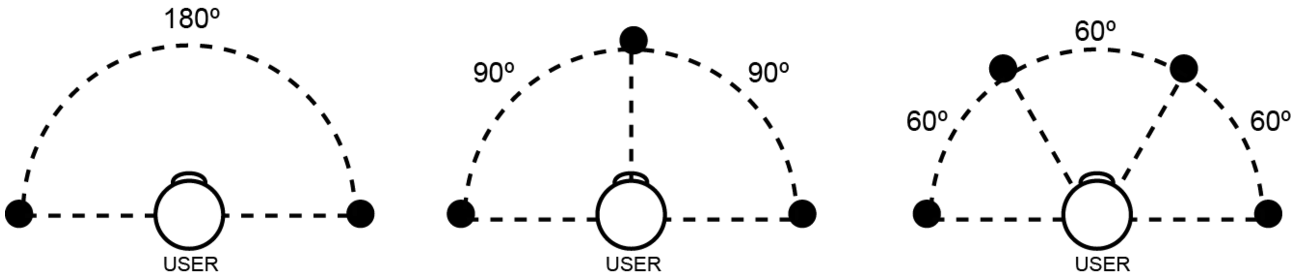

Figure 1. The spatial locations of the different speech sources used in the user studies reported in [9,11]

Literature reviews have documented the human ability to listen to concurrent speech and focus on a specific voice through selective attention. However, most of the previous experiments were performed with sighted users and used very short texts as input (e.g. from just using syllables to using 5-6 words). More often than not, digital information may comprise larger sentences whereas the conclusions of previous experiments cannot be applied. In our first study [9], we conducted an experiment aiming to understand blind people's ability to identify and understand relevant digital content listening to two, three and four concurrent speech channels (Figure 1). Results revealed that it is easy to identify one relevant sentence with two and (for most people with) three concurrent voices. Moreover, both two and three sources may be used to understand the relevant source content depending on the task intelligibility demands and user characteristics.

Considering the increasing popularity of auditory media among sighted people, we conducted a comparative analysis of blind and sighted people's perception of concurrent speech, where sighted people performed the exact same experiment previously performed by blind people [13]. Results support that both user groups are able to process concurrent speech in scanning scenarios. Moreover, the analysis showed no significant differences between groups, suggesting that sighted people may as well use two or three concurrent voices when there is the need to identify and/or understand the content of one relevant sentence. The absence of significant differences between these user groups promotes new approaches and interfaces that target wider audiences, rather than very specific solutions focused exclusively on blind people.

The ability to listen to two or three simultaneous sentences suggested that current screen readers might be imposing limitations on the way auditory feedback is being provided. While these results pointed out concurrent speech as a proper alternative to faster speech rates, only a direct comparison could determine their relative benefits and limitations. Therefore, we compared the use of concurrent speech against the use of faster speech rates when scanning for relevant digital information [11]. Moreover, we combined these two approaches by gradually increasing the speech rate with one, two, and three voices. Results showed that concurrent voices with speech rates slightly faster than the default rate, enable a significantly faster scanning for relevant content, while maintaining its comprehension. In contrast, to keep-up with concurrent speech timings, a single voice requires a speech rate so fast that it causes a considerable loss in performance. Overall, results suggest that the best compromise between efficiency and the ability to understand each sentence is the use of two voices with a rate of 1.75*default-rate (approximately 278 words per minute).

Leveraging Two-Handed Exploration on Touchscreens

With a better understanding of how concurrent speech behaved in scanning scenarios, we started to investigate other contexts that could potentially benefit from the use of simultaneous audio sources. In particular, we wanted to investigate this approach in scenarios that require more user interaction and control in order to receive the concurrent speech signals. A particular goal was to explore the usage of concurrent speech in multitouch interaction in touchscreen devices. While touchscreens support multitouch interaction, current screen readers are limited to a single, sequential auditory channel. However, the growing dimensions of touchscreen surfaces enable two-handed interaction and exploration of the screen. First, we supported two-handed exploration of large touch surfaces, using simultaneous, spatial audio feedback [12]. Then, we supported two-handed interaction in non-visual text entry on tablet devices through multitouch exploration and spatial, simultaneous audio feedback [10]. In these two scenarios we tried to understand and compare how blind people interact with one and two input (and feedback) points. Most importantly, we wanted to understand how concurrent speech could be used to support an additional input point in multitouch interaction. Results showed some advantages for the two-handed interaction regarding the ability to leverage the spatial knowledge of the screen. However, they have also shown that it is not trivial to coordinate the exploration of the screen with the simultaneous feedback, which may be explained by the high cognitive demands of both tasks. However, such demands seem to decrease when blind people use structured exploration strategies, which increases the benefits of concurrent speech.

Prospective Scenarios for Concurrent Speech Interfaces

The first user studies revealed that the use of (faster) concurrent speech is able to speed-up the consumption of digital information while maintaining the basic understanding of the content. The results that posed concurrent speech as a strong alternative for Relevance Scanning scenarios, led us also to explore other interaction scenarios where it could be used to enhance blind users' digital experience. We built a user interface (The Cocktail Application) that supported Relevance Scanning in the contexts of news sites, Google search results, and e-mail. This application worked as a prompt to qualitative semi-structured interviews with 12 blind users to discuss and gather a set of scenarios that may take advantage of concurrent speech. Results revealed a tendency for Relevance Scanning scenarios when browsing lists of items, but they also exposed other scenarios where the use of a single auditory channel may be imposing limitations in the way users consume digital information. Herein, we describe potential scenarios mentioned by the participants of the user study, as well as other emergent scenarios brought out by discussions with other researchers in the field.

Relevance Scanning

Listening carefully to documents, news, or blog posts require a person's attention and the use of concurrent speech would most likely hamper the full comprehension of the text. However, a preliminary selection task where users assess the worthiness of an information item does not require understanding the entire content. Among several news items, Google search results, e-mails, posts, links, or podcasts lies a decision of which are relevant and deserve further attention. This Relevance Scanning task is the scenario addressed in our first user studies and is currently done via the sequential audio of screen readers. Yet, the use of concurrent speech can accelerate this task in comparison to current solutions such as a single voice with faster speech rates [11].

The web accommodates a multitude of platforms that comprise numerous summarized, or already small per se, information items that (try to) provide the gist of the content to help deciding if they need further attention. These platforms may contain titles or small descriptions/snippets and include, for example, search engines, SNS such as Facebook and

Twitter, blogs, RSS feeds, news sites, and e-mail platforms. In this user study, besides the aforementioned applications and other specialized scenarios (e.g. shopping websites), participants' suggestions included site navigation through lists of links or headings. This scenario covers a multitude of websites and applications where blind users may navigate through menus or different sections, by listening to them simultaneously and selecting the one of interest. This user study suggests that in these scenarios users may process such lists for immediate consumption, to mark a set of relevant items for further analysis or even to get an overview of the content without acting on the data.

Scanning for Specific Information

Websites, documents, or books with a lot of text may hinder the search for specific content when the user struggles to find a particular word or phrase to search for. Participants suggested the use of concurrent speech when scanning for a particular subject while studying or searching for something specific in a book. This may be especially useful in longer texts, where users may divide the content of different paragraphs, sections, chapters or even different websites into different concurrent voices. To cite a few examples, one could be searching for a particular detail on a Wikipedia page or an audio book, or open two websites from a Google search and start reading them to understand which one has the relevant information.

Notifications using a Secondary Audio Channel

The aforementioned scenarios focus on scanning tasks that occur occasionally. The use of concurrent speech as the main mode to consume auditory information would be highly cognitively demanding and therefore somehow unrealistic. While the main exploration mode may still rely on a unique speech source, notifications do not need to be confined to uninformative alert sounds. While listening to a document, blog post or the daily news, chat or e-mail notifications could include the subject or the sender's name, instead of a beep sound that may induce the user to interrupt his current task. Moreover, when this information is provided, it should not interrupt what the user is doing (as stated by one participant when referring to Skype Talking). Instead, it could use a secondary channel to provide such notifications. Another example is the one of SNS, where a user may be listening to the news feed and simultaneously be informed about new notifications or chat alerts. Moreover, a proper use of Accessible Rich Internet Applications specification (WAI-ARIA) could leverage a secondary speech channel to help deal with dynamic content, website refreshes, and advanced interface functions developed with Ajax, HTML5, or JavaScript.

Although the use of a secondary channel to deal with notifications may benefit from the use of concurrent speech, it is important not to overload the user and distract (at least, too much) the user from the task at hand. That being said, there may be situations where users want to receive all notifications as they arrive. However, when performing tasks that require greater attention, notification management could gather and present a summary less frequently. On other occasions, notifications can be completely turned off. Another important aspect, as mentioned by one participant, is the type of notifications, since some may be so important that they should be read with full attention (e.g. system notifications).

TV Navigation and Subtitles

The advances in digital television are excluding blind users from an equal access to the features they now provide to sighted users. While watching a particular channel, sighted users may navigate through the other channels, seeing what is playing on a particular channel without actually changing the channel. However, this information is visual. Even after changing the channel, the information about the current (and following) program is still visual. The use of one Text-to-Speech channel would enable blind users to have the same feedback that sighted users have visually, while simultaneously presenting the regular audio of the current channel. Another scenario suggested was the one of subtitles. In this scenario, blind users could use headphones to hear both the regular sound of a movie/program and the subtitles when watching something in a language they do not understand.

Apart from these scenarios, participants also referred to the navigation on the TV and Video listings in the same way as in the Relevance Scanning scenarios previously described.

Assisted Navigation

Participants referred to the GPS navigation while walking on the street as a good scenario for concurrent speech. In this case, the spatial location of the speech sources could be used to reflect the location of the items reported. However, it is important to notice that walking on the street may be a cognitively demanding task by itself. It would be interesting to understand how concurrent speech could be presented in this context without overloading the user. Actually, it would be interesting to understand how one (or two) voice could be combined with the environment sound, so that blind users may have a comprehensive auditory aid, without compromising the understanding of their surroundings. This may be achieved, for example, with bone-conducting headphones, which do not cover the ears and are also able to provide some auditory spatial cues [20] (although not as accurate).

Text-Entry Correction and Feedback

Text entry in touchscreens is a highly demanding task. Besides being slow when inputting text in soft QWERTY keyboards (the defacto method), it is also error prone [18]. Alternative methods, such as braille-based keyboards (e.g. [19]) were able to improve input speed, but the typing accuracy remains a major problem. A common solution to deal with text entry inaccuracy is the use of spellcheckers, which flag words that may be spelled in an incorrect way and suggest alternatives. These correction systems are often based on features such keyboard layout and word frequencies. For example, B# is a correction system for multitouch Braille input that uses chords as the atomic unit of information rather than characters [17]. Although these correction systems already provide accurate suggestions that reduce the number of errors, research has not focused on how to present such suggestions to the user, including in mainstream solutions and methods. We are currently exploring [16] how to present suggestions in secondary auditory channels, while the main channel reads aloud the characters inserted.

Collaborative Work

Tools such as Google Docs enable users to collaborate by editing the same documents either at different time periods or simultaneously. In these tools, sighted users are able to edit while seeing other users' activity, but this information is inaccessible to blind users. Although it seems unlikely that blind users would like to listen to everything as their co-workers write, concurrent speech could be used to provide more knowledge to the user about who's writing, when, and where in the document.

Open Challenges

The findings of our research point towards the use of concurrent speech to speed up the auditory consumption of digital information. Herein, we present possible directions of future research that may extend this work or address topics that were elevated by our research.

Study Interaction Mechanisms. Our last user study enabled users to interact with concurrent speech in three different scenarios. However, users were only able to select and mark the items they were interested in analyzing with further care. Besides a deeper study of which commands are of most importance to deal with concurrent speech, there is the need to study how users can apply those commands in real world scenarios. The most prominent options are the ones of keyboard shortcuts and touchscreen gestures. However, within a multitude of commands that already exist, both in personal computers and mobile devices, the inclusion of new commands should be carefully studied to ease the navigation and interaction with multiple audio sources.

Integration with Mainstream Screen Readers. Participants' comments strengthened our stance that concurrent speech should be integrated in mainstream screen readers. Although focused, applicational solutions may benefit scanning in their particular scenarios, the impact of concurrent speech approaches can only be maximized if they are made available in the solutions that are transverse to their digital navigation.

Study In-the-Wild Usage. The integration with mainstream screen readers would ease studies that try to understand how people deal with concurrent speech approaches in real scenarios and when performing their typical interaction and navigation. In-the-Wild studies enable to capture usage and behaviors that are not possible to capture with laboratory-based evaluations [15]. Such studies can help understanding how and when concurrent speech is used and improve the users' experience based on their needs and interaction patterns.

Explore Different Usage Scenarios. In this research, we explored mostly *Relevance Scanning* scenarios, followed by two-handed interaction in touchscreen devices. In the previous section, we discuss several other scenarios that may benefit from the use of concurrent speech. Further research and solutions would help understanding which scenarios may also benefit from concurrent speech approaches.

Study the Combination with Other Techniques. This research showed that concurrent speech can be combined with faster speech rates and also with navigation through Headings. Such combinations can accelerate information scanning even more than each technique alone. Another research direction would be merging concurrent speech techniques with other promising solutions, such as summarization [1,14].

Study the Effect of Practice and Learning. There is evidence that speech segregation can benefit from practice [2]. In line with this evidence, our user study with faster concurrent speech suggested that participants were able to improve very slightly (non-significant) even with small speech rate increments. Since our user studies took approximately 45 minutes (on average), we were not able to assess the effect of practice on users' performance. However, such analysis would help determining the *Information Bandwidth* that experienced users could reach and still maintain the basic understanding of the content.

Study the Effect on Cognitive Load. Participants' comments have suggested an increase in cognitive load when the number of voices (and speech rate) increases. Although some participants claimed they were a little tired at the end of the last trials, these experiments comprised very demanding conditions (particularly the last ones). Further research is needed, as their comments alone do not show the effect of concurrent speech over time in settings they find comfortable.

Acknowledgments

The research presented above was performed during my PhD, always advised by Daniel Gonçalves. The user studies concerning two-handed exploration in multitouch scenarios were done in collaboration with Tiago Guerreiro, Hugo Nicolau, Kyle Montague, André Rodrigues and Rafael Nunes. This work was supported by the Portuguese Foundation for Science and Technology, under grants SFRH/BD/66550/2009 and INCENTIVO/EEI/LA0021/2014.

References

1. Ahmed, F., Borodin, Y., Puzis, Y., & Ramakrishnan, I. V. (2012, April). Why read if you can skim: towards enabling faster screen reading. In Proceedings of the International Cross-Disciplinary Conference on Web Accessibility (p. 39). ACM.
2. Alain, C., Snyder, J. S., He, Y., & Reinke, K. S. (2007). Changes in auditory cortex parallel rapid perceptual learning. Cerebral Cortex, 17(5), 1074-1084.
3. Borodin, Y., Bigham, J. P., Dausch, G., & Ramakrishnan, I. V. (2010, April). More than meets the eye: a survey of screen-reader browsing strategies. In Proceedings of the 2010 International Cross Disciplinary Conference on Web Accessibility (W4A) (p. 13). ACM.
4. Bronkhorst, A. W. (2000). The cocktail party phenomenon: A review of research on speech intelligibility in multiple-talker conditions. Acta Acustica united with Acustica, 86(1), 117-128.
5. Brungart, D. S., & Simpson, B. D. (2005). Optimizing the spatial configuration of a seven-talker speech display. ACM Transactions on Applied Perception (TAP), 2(4), 430-436.
6. Cherry, E. C. (1953). Some experiments on the recognition of speech, with one and with two ears. The Journal of the acoustical society of America, 25(5), 975-979.
7. Darwin, C. J., Brungart, D. S., & Simpson, B. D. (2003). Effects of fundamental frequency and vocal-tract length changes on attention to one of two simultaneous talkers. The Journal of the Acoustical Society of America,114(5), 2913-2922.
8. Ericson, M. A., Brungart, D. S., & Simpson, B. D. (2004). Factors that influence intelligibility in multitalker speech displays. The International Journal of Aviation Psychology, 14(3), 313-334.
9. Guerreiro, J., & Gonçalves, D. (2014, October). Text-to-speeches: evaluating the perception of concurrent speech by blind people. In Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility (pp. 169-176). ACM.
10. Guerreiro, J., Rodrigues, A., Montague, K., Guerreiro, T., Nicolau, H., & Gonçalves, D. (2015, April). TabLETS Get Physical: Non-Visual Text Entry on Tablet Devices. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (pp. 39-42). ACM.

11. Guerreiro, J., & Gonçalves, D. (2015, October). Faster Text-to-Speeches: Enhancing Blind People's Information Scanning with Faster Concurrent Speech. In Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility (pp. 3-11). ACM.

12. Guerreiro, T., Montague, K., Guerreiro, J., Nunes, R., Nicolau, H., & Gonçalves, D. J. (2015, November). Blind People Interacting with Large Touch Surfaces: Strategies for One-handed and Two-handed Exploration. In Proceedings of the 2015 International Conference on Interactive Tabletops & Surfaces (pp. 25-34). ACM.

13. Guerreiro, J., & Gonçalves, D. (2016). Scanning for Digital Content: How Blind and Sighted People Perceive Concurrent Speech. ACM Transactions on Accessible Computing (TACCESS), 8(1), 2.

14. Harper, S., & Patel, N. (2005, October). Gist summaries for visually impaired surfers. In Proceedings of the 7th international ACM SIGACCESS conference on Computers and accessibility (pp. 90-97). ACM.

15. Montague, K., Nicolau, H., & Hanson, V. L. (2014, October). Motor-impaired touchscreen interactions in the wild. In Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility (pp. 123-130). ACM.

16. Montague, K., Guerreiro, J., Nicolau, H., Guerreiro, T., Rodrigues, A., & Gonçalves, D. (2016). Towards Inviscid Text-Entry for Blind People through Non-Visual Word Prediction Interfaces. CHI Workshop on Inviscid Text-Entry and Beyond.

17. Nicolau, H., Montague, K., Guerreiro, T., Guerreiro, J., & Hanson, V. L. (2014, April). B#: chord-based correction for multitouch braille input. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 1705-1708). ACM.

18. Oliveira, J., Guerreiro, T., Nicolau, H., Jorge, J., & Gonçalves, D. (2011, October). Blind people and mobile touch-based text-entry: acknowledging the need for different flavors. In The proceedings of the 13th international ACM SIGACCESS conference on Computers and accessibility (pp. 179-186). ACM.

19. Southern, C., Clawson, J., Frey, B., Abowd, G., & Romero, M. (2012, September). An evaluation of BrailleTouch: mobile touchscreen text entry for the visually impaired. In Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services (pp. 317-326). ACM.

20. Walker, B. N., Stanley, R. M., Iyer, N., Simpson, B. D., & Brungart, D. S. (2005, September). Evaluation of bone-conduction headsets for use in multitalker communication environments. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 49, No. 17, pp. 1615-1619). SAGE Publications.

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