Challenges in Mobile Text Entry using Virtual Keyboards for Low-Vision Users

Vassilios Stefanis, Andreas Komninos, John Garofalakis
[stefanis,akomninos,garofala]@ceid.upatras.gr
University of Patras
Rio, Greece

Figure 1: Visualisation of low-vision conditions during virtual keyboard use, produced using the Novartis ViaOpta AR simulator. From left to right: Wet macular degeneration, users lose most of their field of vision, the keyboard needs to be really close for use; Dry macular degeneration, users can achieve partial view of the keyboard and entry area; Glaucoma, users lose all peripheral vision, only a small portion of the keyboard is visible.

ABSTRACT

Mobile text entry for sighted and blind persons has received much research attention. However, much less is known about meeting the text entry needs of persons with low vision, whose ability to use the visual channel alongside audio, speech and haptic modalities, may open unexplored opportunities for efficient and privacy-preserving mobile text entry. We present findings from a qualitative study with 9 low vision users, revealing current text entry challenges for this user group, and providing future directions for text entry research.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Interaction techniques**; **Empirical studies in ubiquitous and mobile computing**; **Accessibility technologies**; **Touch screens**; *Smartphones.*

KEYWORDS

mobile text entry, low-vision users, accessibility, virtual keyboards

ACM Reference Format:
Vassilios Stefanis, Andreas Komninos, John Garofalakis. 2020. Challenges in Mobile Text Entry using Virtual Keyboards for Low-Vision Users. In *19th International Conference on Mobile and Ubiquitous Multimedia (MUM 2020), November 22–25, 2020, Essen, Germany.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3428361.3428391

1 INTRODUCTION

The ability to quickly and accurately input text on smartphones is a key aspect of mobile usability. Work in mobile text entry has been prolific in past literature, focusing on the needs of sighted persons. However, there exists a significant proportion of people with varying degrees of vision loss. Low vision is experienced by 1 in 30 Europeans and is often a precursor condition to total vision loss. There exists significant work in eyes-free mobile text entry for blind persons. To date, research and commercial mobile text entry methods for persons with visual impairments, rely heavily on providing audio feedback during text entry, or employing voice-to-text entry methods, while also exploring other modalities such as haptic feedback. Therefore, while mobile text entry is a predominantly unimodal (visual) experience for sighted users, persons with low vision experience mobile text entry as a multimodal service.

Speech-feedback and voice input for mobile text entry can have significant drawbacks, including reduced privacy in public contexts, and during use in noisy environments. Persons with low vision are able to use on-screen keyboards, even if with some difficulty. However, little work has been carried out in the design space of mobile virtual keyboards (*VKs*) for low vision (but *not* blind) users.

In the context of an ongoing research project, we are interested in understanding how persons with low vision interact with their mobile VKs, and to develop novel VKs that enable faster and/or more accurate text entry for low vision. This paper presents an overview of the challenges and opportunities for users, based on focus groups with nine persons with various low vision conditions.

2 RELATED WORK

Interaction design research for blind users is prolific, but less has been done for low vision users [10, 28]. Szpiro et al. [28] found that low vision users prefer visual compared to text-to-speech interfaces, but face difficulty during screen content changes, manipulation of assistive tools (e.g. screen magnifiers), and feel uncomfortable disclosing their disability to others during use of technology tools. More recent work highlighted that there remain significant gaps in our knowledge on the effects of technology mediation in the professional (work/task efficiency) and personal (creative expression) life aspects of low vision users [8]. Poor text entry performance with VKs is a significant concern amongst users with low vision [5]. A recent survey by Watanabe et al. [29] with 50 low-vision Japanese smartphone users, found that 90% of them use VKs, in both the QWERTY and numeric-key layouts. Despite difficulties with VK use, voice input was less preferred (only 36% of respondents use this). Input rate has not been found to be prohibitively slow, but text editing and error correction have been identified as the hardest operations during text entry for blind users [21, 25].

The most common commercially available approach is the combination of screen readers (Talk-Back on Android, VoiceOver on iOS) with the standard OEM keyboard (GBoard, Apple Keyboard). However this combination is not ideal. Khan and Khusro [15] argued that the multiple function mappings of keyboard keys are designed for sighted users and do not work well with screen-reading software. Touch delays and mis-interpretations can also cause considerable frustration during use. Finally, bad synchronization between touch input and speech output also is reported as a cause of several usability issues during text entry [21].

From a research perspective, a systematic review of prototypes to support text entry for blind and low vision users is offered in [26]. Some characteristic works are presented next, to put our paper in context. There are three main categories of these keyboards: *Stroke/gesture-based*, *braille-based* and *split* keyboards.

Several stroke/gesture based keyboards can be found in past research (e.g [7, 11]). A recent example is ThumbStroke [17]. Selecting desired characters is achieved using thumb strokes anywhere on the screen instead of specifically on the keyboard. The letters are organized circularly, with an aim to make it easy for users to remember the location of each letter. One main limitation of that keyboard is that if the user wants to confirm the selection of the desired character, she has to enable the read out functionality, an option that has many privacy and accessibility issues [30]. Researchers have also examined Braille-based keyboards (e.g. [13, 18, 20]). A recent example is the SingleTapBraille keyboard [2], based on single-finger tapping on any part of the screen, according to braille patterns. The main limitation of these keyboards is that Braille literacy is low and declining globally [3]. Some researchers propose split keyboards that enable users to use both thumbs, but keeping all parts of the keyboard visible at the same time (thus requiring a small key size) [9, 22]. Focusing on the problem of increasing key size while maintaining the familiarity of the QWERTY layout, in [12] only half of the keyboard is shown on screen, with a "shake" gesture replacing it with the other half. Split keyboards also include *chorded* VKs, with one recent example presented in [23]. More recently, touch modelling and language models have improved the accuracy of touches by low vision users during text entry, minimising the need for corrections at a character level [27].

Overall, most previous research focuses on eyes-free text entry. Braille entry for smartphones is mature but low-vision and blind populations have low Braille literacy. Eyes-free entry is necessary for blind users, but low-vision users do not necessarily need it, and even impaired vision can afford distinct opportunities for assistive design for this population group.

3 METHODS

We conducted a qualitative study based on focus groups. To identify suitable persons with low-vision conditions, we partnered with the Pan-Hellenic Association for the Blind (Western Greece Regional Chapter). The chapter attempted to recruit participants on our behalf. We organised focus groups to take place at the chapter's offices, a location which is known to members and can be travelled to in relative ease, since it is in the city center and thus easily accessible by public transport. Nine volunteers turned up for the focus groups. The number of participants is in line with other related qualitative research (e.g. 11 in [28]; 10 in [8]; 5 in [24]).

We arranged three separate focus group sessions (G1-G3), involving three participants in each (G1: [P1-P3]; G2: [P4-P6]; G3: [P5-P9]). Five participants were female. Participant ages ranged from 22-50 years old. Four participants were unemployed and on welfare. Two were under early retirement due to their low-vision condition. The remaining three were active students at our university. The participants represented a range of conditions, including *Retinitis Pigmentosa* (3), *Retinal Detachment* (2), *Macular Degeneration* (1), *Cone-Rod Dystrophy (Alström Syndrome)* (1), *Optic nerve Glioma* (1) and a type of *burn damage* (1), which the participant likened to *Cataracts*. All participants reported significant experience in living with their condition (10+ years). An illustrative representation of use of a smartphone with visual impairment is shown in Figure 1.

The focus groups were semi-structured, starting off with an ethics form, which was read out to the participants, and signed by them. Inline with legislative and ethical constraints, a sighted person (chapter secretary) acted as a witness to the signing, and also signed on behalf of two persons whose condition prevented them from legally doing so themselves. At the first part of the focus group, we collected basic demographics and inquired about the type, frequency and purpose of mobile text entry. Next, we held a semi-open discussion, in which we raised some pre-determined questions to act as conversation prompts, while allowing participants to elaborate on responses, or to bring up other related topics. The responses were manually coded independently by three researchers, each using deductive coding and a flat coding frame. Related codes were merged as appropriate through consensus, to identify pertinent themes in the responses.

4 FINDINGS

4.1 Text entry type, purpose and frequency

All participants use a mobile phone daily in their lives, in the form of a smartphone (seven Android and two iPhone users), using both Greek and English keyboard layouts. Except one user, all use enlarged fonts and high-contrast themes. All participants use messaging apps, either SMS or IM-type. One participant (P8) uses both a smartphone and a feature phone, as the physical keypad and fixed menu structure on the latter make it easier for him to perform certain functions without relying too much on vision. This is accomplished by memorizing a sequence of keypresses that enable access to certain functions (e.g. to search for a contact).

Next, we asked them to indicate how frequently they use the VK to enter text for any purpose. To assist the discussion, and informed by the common activities described in [24], we asked specifically about the tasks of composing SMS, Instant Messages (IM), Emails, performing information searches (either for on-device content such as a contact's name, searching for an app, or querying a web search engine), and filling in text on the web (including replying to comments on social media, or on-line shopping). From the responses (see Figure 2), it appears that predominant use is for short communications (SMS, IM) and information searching (i.e. short queries). We asked participants to name any other use-cases they could think of; using the "Notes" app on their device and saving a new contact were mentioned. One other related case is to enter a PIN to unlock their device - although this is not done through the VK per-se, it can be considered a valid use case as numbers are entered through a 10-key keypad.

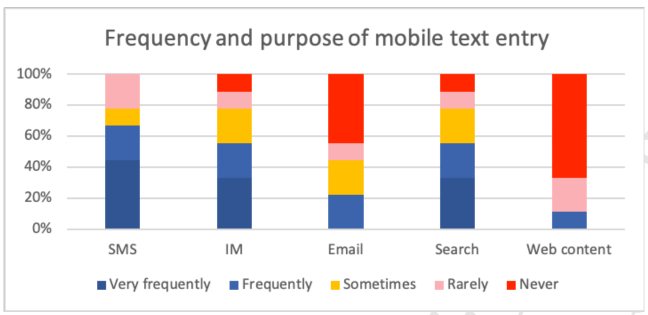

Figure 2: Use of mobile text entry across participants

We asked what type of smartphone keyboard they use on their device. All participants mentioned use of a virtual QWERTY keyboard layout, except P8 who uses a 12-key physical keypad on their feature phone for almost all text-entry needs, and P1 who has downloaded a third party keyboard for her smartphone device and selected the 12-key layout on this. We asked if participants had used another keyboard layout in the past, with 6 participants mentioning the physical 12-key keypad (P1-P3 & P5-P7), and the remaining three mentioning that the virtual QWERTY keyboard was the only type they had ever encountered. One interesting observation here is that with the exception of one participant (P1), others were not aware that VKs can be downloaded, which allow customisation of the layout (e.g. selecting the 12-key one), key sizes, fonts etc.

4.2 Findings from semi-structured discussions

For this section, participant verbatims were translated to English by the authors. Where multiple participants expressed consistent opinions through similar statements, the presented verbatim is the authors' expression of the shared opinion.

4.2.1 Importance and issues with VKs for mobile text entry. Our analysis begins with participants' perception on the importance of mobile text entry through VKs. Although most participants typically use the speech-to-text function to enter text, all felt strongly about having the ability to use a VK as well. Two participants (P3, P5) mentioned that the QWERTY layout is familiar to them from using a personal computer, so they appreciated having the same layout on their mobile keyboard. All but two participants (P1, P8) often rely on the talk-back function to use the VK and they all felt that it is not always appropriate or convenient. The reasons for the strong desirability to use a VK without talk-back relate mostly to sentiments over privacy, e.g. (*P1: "I don't want others to be able to hear what I'm typing or reading", P2: "Even when I'm at home [with my husband], some things are my own business", P6: "When I'm at a public space I feel embarrassed to use talk-back"*). An additional privacy problem is that talk-back also reads out loud the numbers entered to unlock the screen. Some participants (P7,P9) mentioned using the fingerprint reader to secure their device as a more practical alternative. However, at least on Android, the device often asks users to enter their PIN as an additional security measure at random times, or when the fingerprint reader is unable to read the user's finger (e.g. sweaty hands), so this doesn't always solve the problem. Additionally, two participants (P1, P6) raised concerns about not being annoying to others in their vicinity and also practical advantages (e.g. *P4: "My ability [to enter text] changes throughout the day depending on my surroundings and how tired I am, so I'd like to have options", P9: "Writing without talk-back is harder but it lets you reflect more on what you want to write, instead of the practicalities of actually writing"*. In discussing their satisfaction with talk-back keyboards, five participants mentioned a range of issues, e.g. (*P3: "I'm ok with letters but I often can't easily find symbols", P1, P3, P4: "Key letters are too small even on maximum font size", P3: "The same talk-back speed settings for screen-reading and keyboard use is not convenient", P1, P9: "While you can magnify the screen contents on Android, the magnification cannot be applied to the keyboard"*. These sentiments verify that the challenge of enabling mobile text entry without speech-based feedback is valid and worth addressing.

4.2.2 Attitudes towards mobile text entry with VKs. We asked participants how they felt when placed in a situation of using the VK to enter text for a purpose that doesn't involve others (e.g. look up some information). Three participants mentioned experiencing stress and discomfort, e.g. *P3: "Most things nowadays [i.a. paying bills, managing finances, applying for services etc.] need to be done over the internet, so I feel helpless", P4: "It makes me more aware of my disability when I can't write back to reply to messages", P8: "I feel anxious because I often need help to finish entering some text"*. The rest adopted a more relaxed stance, the general attitude being towards taking their time towards the task at hand, and not stressing over completing a task quickly (e.g. *P1: "If I can't do it quickly, it's not the end of the world", P6: "I'm used to it, it just needs time", P9: "I use a magnifying glass to help, it takes more time now [compared to when my eyesight had not deteriorated as much] but that's OK"*.

We asked if these sentiments remained when the task involves replying to another person's message. P5 mentioned deferring replying until they are at a more comfortable context (*"When I'm calm and without pressure of time"* and feeling more stressed if participating in a group chat flowed too quickly. P9 felt more worried about grammatical mistakes, especially when replying to strangers (e.g. comments on Facebook).

We inquired further about the perceived expectation from participants' close and wider social circles regarding their ability to reply in writing. The participants perceptions varied. P3, P4 and P6 felt that people who don't know them (e.g. other social network users) would have expectations to receive quick replies and without mistakes. In relation to communications with new personal encounters, P1, P2 and P3 mentioned that others can be very surprised to find out that they can reply by text, despite their low-vision (e.g. *P2: "They might ask me, do you want me to call you or send you a text? And I will say, send me a text. And then they will be like: Are you sure? And then they might say something like: But how do you know how to spell?*) This raises positive feelings towards using VKs for text entry and persevering with them. However, as P9 mentioned, once this ability becomes known, then there is an increasing expectation that communication can take place in this way (*"Once they see that I can reply, they expect me to be able to do so"*). P1, P3, P6 and P8 agreed that others are generally patient with the speed of reply, and tolerant of grammatical mistakes. But for others, this expectation can become stressful (e.g. *P4: "Even people who know my problem well expect me to reply to their texts quickly now, and my doctor often asks me to send him things by email, which is even harder"*). P4 and P8 mention dealing with this pressure by reverting to replying via phonecall or voice messages, rather than texting.

In text entry research, performance is typically evaluated with entry and error rate metrics [4]. Sighted users have been found to balance speed vs. accuracy during entry [6]. We asked participants which aspect was more important to them. Three participants (P1, P3, P6) mentioned that it depends on the relationship with the person they send a message to. When sending to strangers, they value accuracy over speed. The reverse applies when sending to familiar persons, in line with previous research focusing on other populations that face text entry challenges (e.g. older adults [19]). The rest of the participants were strongly in favour of accuracy over speed in all contexts.

4.2.3 Technological challenges in VK entry. Related to achieving the best text entry accuracy, we asked participants about how they spot and fix entry mistakes. Support for mistake-fixing was seen by all as very important, since all have a really hard time recovering from input errors. As P6, P8 and P9 put it, *"It pains me, but I knowingly leave most mistakes uncorrected (P6)", "It's usually just easier to delete the whole text and start over (P8, P9)".* Spotting mistakes is not easy: P1 prefers to read the whole composed text using screen zoom before sending, while P2 and P3 mention relying on the talk-back of the complete text, to detect any entry mistakes. P6 believes that speech-to-text is less error-prone compared to typing, but there is no verbal feedback on the recognised text, so it's hard to detect system-caused inaccuracies. P4 and P5 rely on autocorrect to spot and fix grammatical mistakes, but often this results in unwanted input changes. To improve accuracy, P2, P3 and P9 often use the word suggestion bar of their keyboard, saving typing effort and ensuring proper spelling. However, maintaining awareness of the keyboard and text entry area display state that is altered by autonomic actions (e.g. autocorrects and display changes in the suggestion bar) is very difficult with low vision, where only small parts of the screen can be viewed. Low vision also challenges the gaze and cognitive transitions between reading typed text and the keyboard area, needed for reviewing and correcting input, as demonstrated in [14]. In P4's own words: *"You only usually spot your mistakes after the text has been sent"*.

5 DISCUSSION AND CONCLUSIONS

Our study focused on the use of VKs by low vision but not entirely blind users. This is a large population whose specific needs, with relation to text entry, have not been yet adequately studied. For these persons, VK use is challenging with current designs, but also highly desirable, especially due to the privacy it can afford (compared to talk-back and speech-based input) and the presence of supportive tools (e.g. autocorrect, word completion). Currently, there is room for much improvement, especially in the latter, since it is clear that a re-think of how some of these tools can work synergetically with the user is needed, keeping the benefit of accuracy over speed in mind. For example, currently when the Google keyboard autocorrects "Hellp" to "Hello", talk-back currently just says *"Changed p to o"* after autocorrect effects the change. If the user intended to write "Help", obviously, this is not useful and demonstrates the effect of favouring speed of entry over accuracy. A design that favoured accuracy over speed could consider to speak out the whole word as the autocorrect believed it should be, and then ask for user confirmation before effecting the change ("Should I change this word to Hello"?). Avoiding speech altogether, the changed word could be highlighted in the text (e.g. white font over black background) so the user can review it later, as per [1, 16].

Our research demonstrates that there is significant scope for better design of both text entry (e.g. key layouts, support for magnification and keyboard section navigation) and features for entry support (error spotting and correction). From a design perspective, we can derive the following research directions for the future:

- Virtual keyboards should focus on assisting the minimization of entry mistakes and recovery from mistakes. Speed of entry is not as important as accuracy. This assistance can be afforded by revisiting text entry methods (e.g. key layout and input sequences) and also supportive functions (e.g. awareness for mistakes, corrective procedures and actions, cooperation with system-induced autonomic actions).
- The audio sensory channel is very important for low-vision users, but speech-based feedback should be judiciously employed, to maintain user privacy. Other channels (e.g. haptic) should be investigated to provide feedback during text entry, e.g. associating audio or tactile feedback with autocorrect or autocompletion events, or detection of spelling mistakes.
- Display state changes for the keyboard and text entry area must be conspicuous to the user, in order to improve awareness of autonomic actions.

ACKNOWLEDGMENTS

This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme "Human Resources Development, Education and Lifelong Learning 2014-2020" in the context of the project "MoTEVIUs - Mobile text entry for vision impaired users" (5047127).

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