Evaluating touchscreen PIN entry with visually impaired users

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Abstract. Touchscreens on self-service terminals such as ATMs (automated teller machines) can be difficult to use for people with visual impairment. In this paper we present a study developing gestural interaction methods to be used for entering the Personal Identification Number (PIN), which is a particularly challenging task as there are additional security requirements prohibiting most auditory feedback. After initial concept development, four PIN entry concepts were evaluated with visually impaired users. The concept with tactile features was found to provide significant benefits: a fixed tactile reference point for orientation as well as added support for people unfamiliar with touchscreen interaction.

Keywords. Visual impairment, touchscreen accessibility, self-service terminals, privacy

1. Introduction

Making self-service terminals such as automated teller machines (ATMs) accessible to blind people has traditionally involved the use of a physical keypad, private audio and some means of mapping all on-screen options to a number (Day et al., 2013). However, with the growing ubiquity of touchscreen-equipped personal devices such as smartphones and tablets, and the provision of accessibility features in mainstream products that both Apple (iOS) and Google (Android) have offered, there has been a growing adoption by some blind and partially sighted people of accessibility features that utilize touchscreens and audio.

For this reason, and because we are also seeing a trend to touchscreen usage in self-service (Digital Trends, 2011), a research project was begun to investigate how a large touchscreen-only ATM could be made usable for people with visual impairment, without the need for prior training or experience. Some existing accessibility solutions are particularly well suited to a small (smartphone-sized) touchscreen; namely techniques that require moving a finger around to find each option. This quickly becomes a tedious exercise on a larger (15+") display.

In addition, ATMs have stringent security standards. One such standard (PCI, 2013) means that the system cannot vocalize either during selection or when entering a PIN, and in fact the software is not allowed to know the PIN (as it is encrypted and transmitted as a block). This means that alternative solutions are required that provide accessibility while meeting the security rules.

2. Initial concepts and testing

2.1 Initial concepts

Three functional concepts responding to touch input were created in Flash. In the horizontal strip concept (
Figure 1), the user slides a finger along the bottom of the screen exploring options. They then slide their finger up on the option to enter it. In the grid concept (
Figure 2), the user swipes to select an option (left/right/up/down), then taps anywhere onscreen to enter. In the rotary selection concept (

Figure 3), the user slides their finger in an arc to select, and then taps anywhere onscreen to enter. The concepts were tested on a 19" touchscreen with a 5:4 aspect ratio. An off-the-shelf 19" touchscreen was used for this initial assessment as the real ATM touchscreen was not available at that time.

Figure 1. Horizontal strip

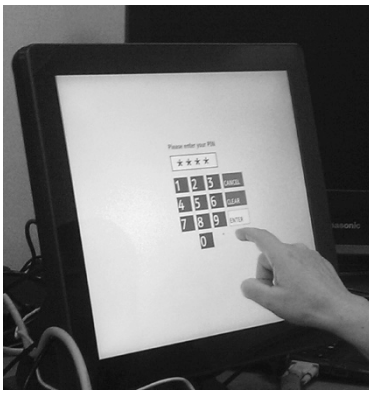


Figure 2. PIN pad grid

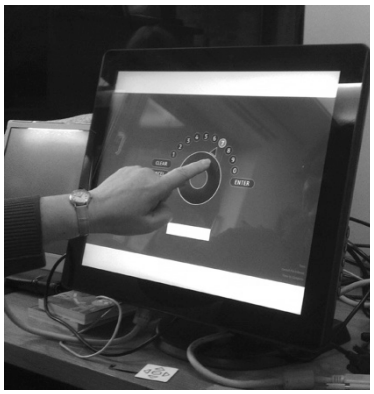


Figure 3. Rotary selection

2.2 Evaluation of early concepts

A formative, informal assessment was conducted in two parts. Firstly three accessibility specialists from RNIB conducted expert reviews. Once these were complete, two participants were recruited from among RNIB staff. One was blind with no useful residual vision; the other was blind with some residual vision. A repeated measures experimental design was used, with all participants and reviewers using all three concepts. Participants were asked to comment on each concept in turn after using it, and then to compare at the end by ranking in order of preference.

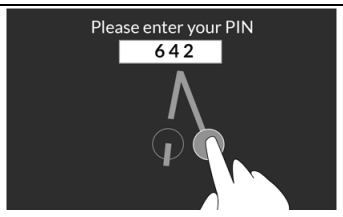
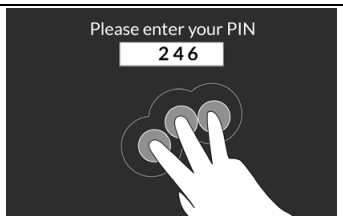
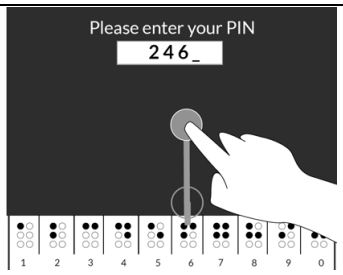
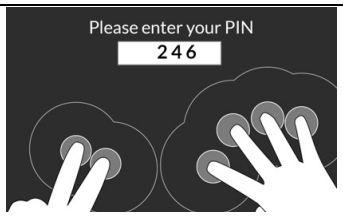
The preferred concept was the horizontal strip, although changes were suggested as to how to select and give feedback (and to make it more secure). The rotary selection concept was least liked, and was therefore abandoned as a concept. The grid concept appeared to have some merit, but not for PIN entry where security is important.

3. User evaluation with blind and partially sighted consumers

Expanding the initial evaluation, a user evaluation with 49 blind and partially sighted consumers was conducted, and two more tasks were added to the evaluation: selecting a menu option and entering alphanumeric characters. This paper discusses the PIN entry task only; the other two tasks will be reported in later publications.

Based on the results of the initial evaluation, the horizontal strip concept was developed into a concept called Tactile markers: a plastic strip with tactile features was affixed to the bottom edge of the display to aid the user in locating the correct target on the screen. Three new concepts were also created to explore different ways to enter numbers on a touchscreen without any feedback to locate, identify or confirm the desired input. All four concepts are described in Table 1.

Table 1. The four concepts for entering the PIN

Concept		Gesture to enter number
Visual tallies		Swiping up and down anywhere on the screen the number of times corresponding to the number you want entered, e.g. swipe up and down to enter 2.
Multi-finger multi-tap		Either touching and holding on the screen the number of fingers you want entered, or tap repeatedly with one or multiple fingers the number of times you want entered, e.g. two taps with two fingers to enter 4.
Tactile markers		A plastic strip with tactile features affixed to the bottom of the screen to guide the finger onto the correct target area on the screen.
Multi-finger tap + hold		Touching and holding on the screen the number of fingers you want entered.

A total of 49 people (27 women, 22 men) participated in the evaluation. They were recruited through RNIB, and the test took place at the RNIB offices in London and Peterborough. All participants had some level of visual impairment: 18 were blind without any useful residual vision, 22 blind with some useful residual vision and 9 were partially sighted. Their ages ranged from 25 to 75+. There were 33 participants who did not use an ATM independently and 16 participants who had never used an ATM at all. 22 of the participants had never used a smartphone or tablet.

In the PIN entry task the participants were asked to enter the PIN 4608. The evaluation was a repeated measures design, with participants completing the task using each of the concepts in Table 1 (the order was counterbalanced to reduce any learning effect). The test equipment consisted of a 10” touchscreen attached to a pedestal to simulate the screen size, height and angle of a finished ATM. The touchscreen used was the actual 10” touchscreen from the ATM that was intended to first use this accessibility method, giving a high level of ecological validity to the evaluation. Before starting the test, the participants were given an introductory tour and time to explore the test equipment to help orientate themselves. Each concept was accompanied by a pre-recorded audio guidance describing how to enter a PIN, which the participants were able to listen multiple times if needed. During the test, no practice was allowed, but if a participant seemed to struggle with a concept, the facilitator intervened and gave additional instructions. After using each concept, the participants were asked for their subjective ratings on a 5-point Likert scale. The number of attempts required to enter the PIN correctly was also recorded.

4. Results of the user evaluation

Overall, entering the PIN correctly, without any auditory feedback, was extremely difficult. The majority of the participants seemed to understand the concepts but failed to enter the PIN correctly. As the scale of this problem became evident in the early stages of the evaluation, a new metric was introduced to record the number of attempts it took to enter the PIN correctly. The data for this metric is therefore available for only 31 of the participants. For all four concepts, fewer than half of the participants (10 – 12 of them) were able to enter the PIN correctly on the first attempt. After a second attempt, another 10 – 11 participants were able to complete the task. With each concept, there were 5 – 7 participants who failed to enter the correct PIN.

After using each concept, participants were asked to give a rating on a 5-point scale, where 1 was very negative, 3 was neutral and 5 was very positive. They were asked to rate how easy or difficult it was to understand the audio instructions. Multi-finger tap+hold was rated the easiest, with a mean of 4.08. The mean rating for Tactile markers was 3.49, and for Visual tallies 3.44, with the Multi-finger, multi-tap rated with a mean of 3.29. (Figure 4)

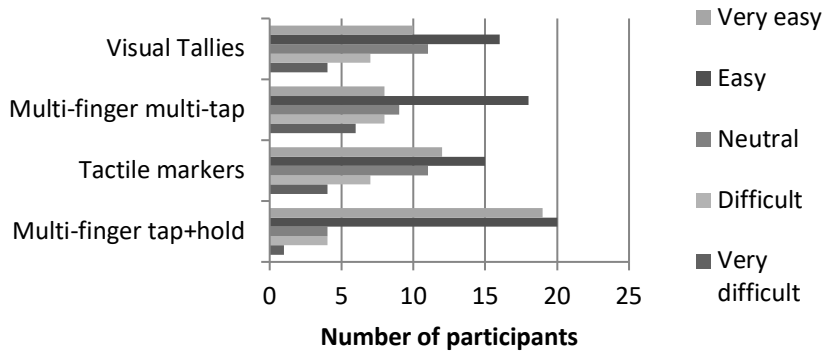


Figure 4. Ratings for the ease of understanding the audio instructions

The participants were then asked to rate the ease of performing the gestures. This time Multi-finger, multi-tap was rated the easiest, with a mean rating of 4. The second easiest was the Tactile markers (a mean of 3.75), followed by Visual tallies (3.4) and Multi-finger tap+hold (3.35). (Figure 5)

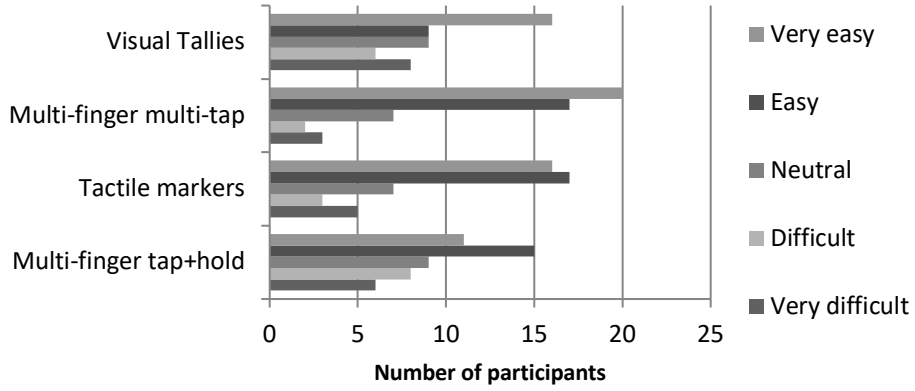


Figure 5. Rating for the ease of performing the gestures

We also asked the participants how confident they would be to use the PIN entry method on an ATM, on a scale of 1 (Not confident at all) to 5 (Very confident). The

participants felt most confident with the Tactile markers (the mean rating was 3.88), followed by Multi-finger, multi-tap (3.76) and Multi-finger tap+hold (3.61). The lowest confidence rating was given to Visual tallies (3.32). (Figure 6)

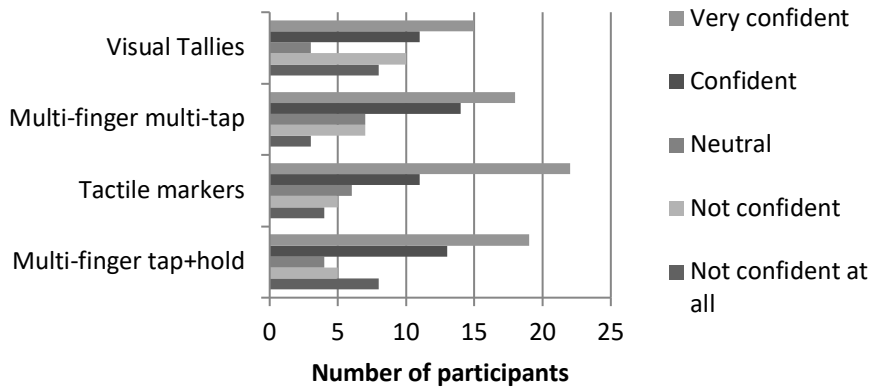


Figure 6. Confidence to use each PIN entry method independently

Finally, we asked the participants how private they felt when entering the PIN, compared to using a traditional physical ATM PIN pad, on a scale of 1 (a lot less private) to 5 (a lot more private), with 3 denoting an experience comparable to the current ATM PIN pad. It was notable that the mean rating for all concepts was under 3, meaning all of them were considered to be less private than the current experience on a physical PIN pad. (Figure 7)

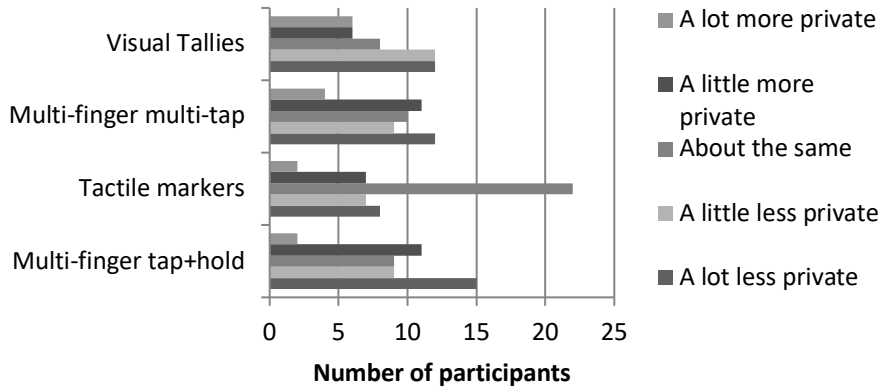


Figure 7. Perception of privacy compared to a traditional ATM PIN pad

5. Discussion and Conclusion

When the participants were asked to rank the concepts in order of preference, the Multi-finger, multi-tap was ranked the first, Tactile markers second, Visual tallies third and Multi-finger tap+hold fourth. The benefit of the Multi-finger, multi-tap concept is that it gives consumers the freedom to choose their own way of entering the PIN: they can either use one finger only or multiples of two or more fingers, which enables them to personalize their PIN entry technique (and spend time at their leisure learning different ways to tap their particular combination of numbers), which provides an extra layer of security and privacy.

However, there were significant difficulties observed with touchscreen interaction more generally (reported in Jokisuu et al 2015). These included the continuous challenge of maintaining orientation due to the lack of fixed tactile reference points, as well as the unfamiliarity with touchscreen gestures, such as swipes and taps. Some of these

difficulties could be alleviated by providing the tactile features of the Tactile markers concept. After careful consideration of all aspects, including security and manufacturability, the Tactile markers concept was selected for further development (Figure 8). To refine the features of the tactile strip, new concepts were developed and evaluated in another round of user evaluations, which will be reported in a future publication. Further research is also indicated to assess whether this type of input method can be transferred onto different touchscreen sizes.

Figure 8. The tactile markers concept was selected for further development

Acknowledgements

The authors would like to thank Sabine Croxford, Lori Di Bon-Conyers and Cathy Rundle from RNIB for their invaluable feedback in the development of the concepts and their help in conducting the user evaluation.

References

Day, P.N., Chandler, E., Carlisle, M. & Rohan, C. (2013). Making self-service accessible: talking ATMs. In: M. Anderson (Ed.), Contemporary Ergonomics and Human Factors 2013: Proceedings of the international conference on Ergonomics & Human Factors 2013, Cambridge, UK, 15-18 April 2013 (pp. 339-342). CRC Press, Taylor & Francis Group.

Digital Trends (2011) European McDonald's to replace human cashiers with touch screen computers. Retrieved on 1 October 2015 from http://www.digitaltrends.com/computing/european-mcdonalds-to-replace-human-cashiers-with-touch-screen-computers.

Jokisuu, E., McKenna, M., Smith, A.W.D., Day, P. (2015) Improving Touchscreen Accessibility in Self-Service Technology. In M. Antona and C. Stephanidis (Eds.): UAHCI 2015, Part II, LNCS 9176, pp. 103–113, 2015.

PCI Security Standards Council (2013) Payment Card Industry PIN Transaction Security Point of Interaction Security Requirements v4.0. PCI Security Standards Council LLC, June 2013.