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## Touchscreen Accessibility in Self-Service Terminals

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### Abstract

Touchscreens are becoming a ubiquitous method for interacting with technology, including self-service terminals (SSTs). However, they can pose significant accessibility issues for people with disabilities. The lack of tactile features can be particularly problematic for people with visual impairment. Furthermore, there are additional technical requirements aimed at ensuring the security and privacy of the information processed by SSTs, especially on automated teller machines (ATMs) when entering the Personal Identification Number (PIN). These technical requirements mean that very limited feedback can be given to the user about the options available or the input entered. To explore ways of making touchscreen-based ATMs accessible for everyone, a research project was initiated. After an iterative development process in collaboration with a multidisciplinary team of interaction designers, industrial designers, accessibility and usability specialists, expert evaluators from the Royal National Institute of Blind People (RNIB) in the UK and two rounds of usability testing with people with visual impairment, a solution was found. This paper reports the results of this research project: an input method that allows people with visual impairment to use the touchscreen to interact with an ATM independently, including entering their PIN in complete privacy.

### Keywords

Self-service technology, ATM, touchscreen, visual impairment, privacy.

## Introduction

Self-service technology is becoming more widespread and increasing in importance (Castro et al). One of the biggest benefits of self-service is the convenience and availability of services to anyone, anywhere, anytime (Barnes et al). On the other hand, this is also one of the main challenges of making self-service accessible. Self-service terminals (SSTs), such as ATMs (automated teller machines), supermarket self-checkouts and airport check-ins, must be accessible to anyone, without training or assistive technologies.

More and more often, the primary method of interacting with an SST is via a touchscreen. This trend has been evident for the last decade, and shows no sign of diminishing (Couts). For example, a survey in 2004 of 18-34 year olds in the US found that 82% had used a touchscreen at a self-checkout system, and 70% had used a touchscreen at an ATM. The majority of respondents (89%) reported that they expected touchscreens to become the standard way of interacting with SSTs. (Penn & Berland) However, touchscreens can pose significant accessibility challenges, particularly for people with visual impairments. Although great progress has been made to improve touchscreen accessibility on personal mobile devices, there are additional challenges in the self-service context (Jokisuu et al). There are also strict legal and regulatory requirements to ensure both the accessibility and security of the self-service transaction (e.g. Department of Justice; PCI).

In this paper, we present our research into making touchscreen interaction on SSTs accessible to people with visual impairment, particularly when entering private information, such as a Personal Identification Number (PIN).

## Usability Tests

### *Exploring Gestures Test*

To investigate the possibilities of using touchscreen gestures on SSTs, three early concepts were created by a team of usability specialists and interaction designers (reported in Jokisuu et al). These three concepts were developed to test the experience of entering a PIN using gestures only. The concepts were evaluated in an expert review by assistive technology evaluators from RNIB (Royal National Institute of Blind People) and two visually impaired users. Based on the expert review, two of these concepts were developed further and two additional concepts created to be tested in more detail with users with visual impairment.

The four PIN entry concepts included in the test were:

- A) Visual tallies: swiping up and down anywhere on the screen the number of times corresponding to the number you want entered.

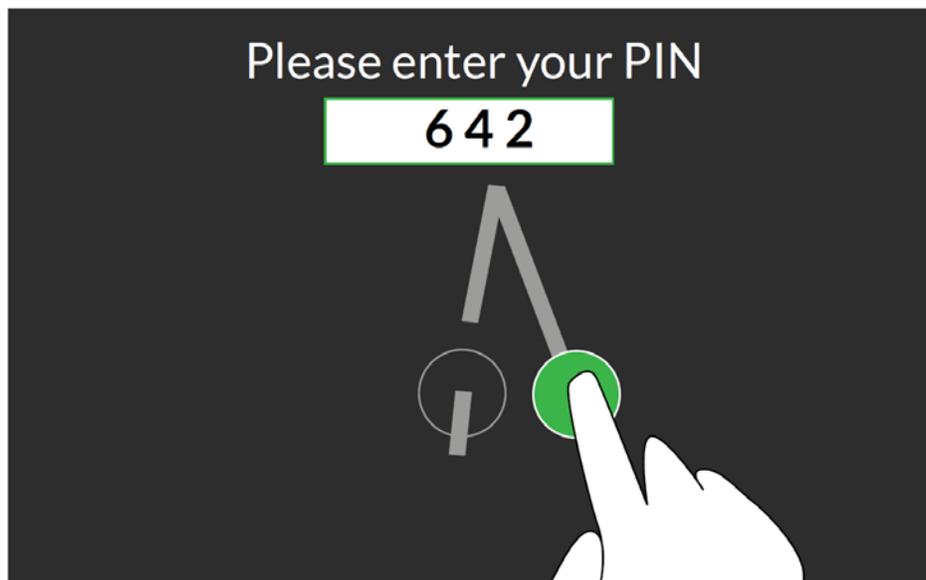


Fig. 1. Concept A for PIN entry: Visual tallies.

- B) 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.

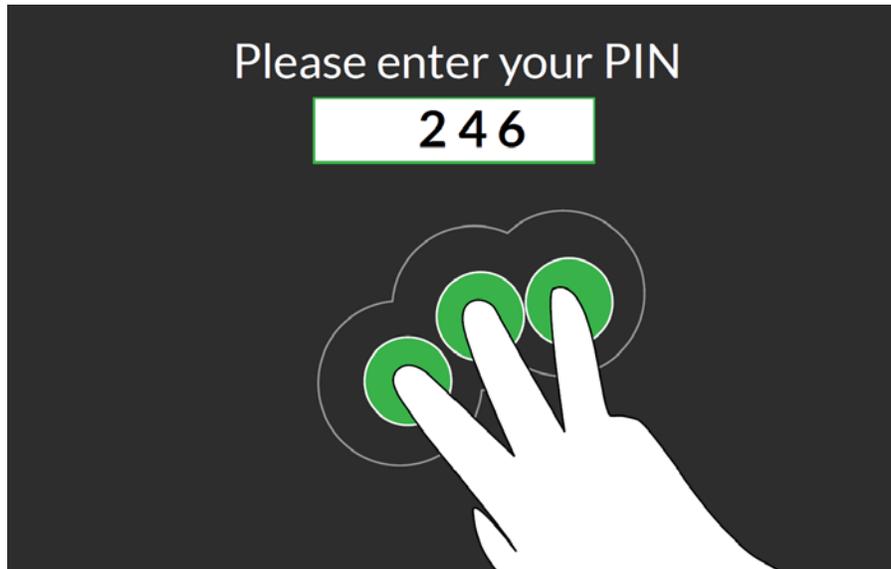


Fig. 2. Concept B for PIN entry: Multi-finger multi-tap.

- C) 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.

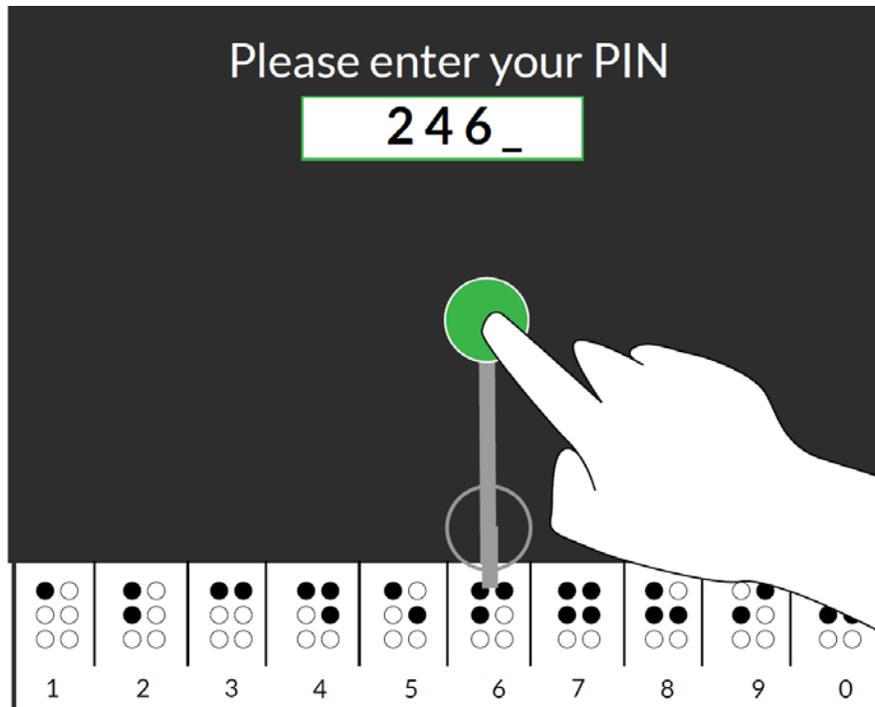


Fig. 3. Concept C for PIN entry: Tactile markers.

- D) Multi-finger tap & hold: touching and holding on the screen the number of fingers you want entered.

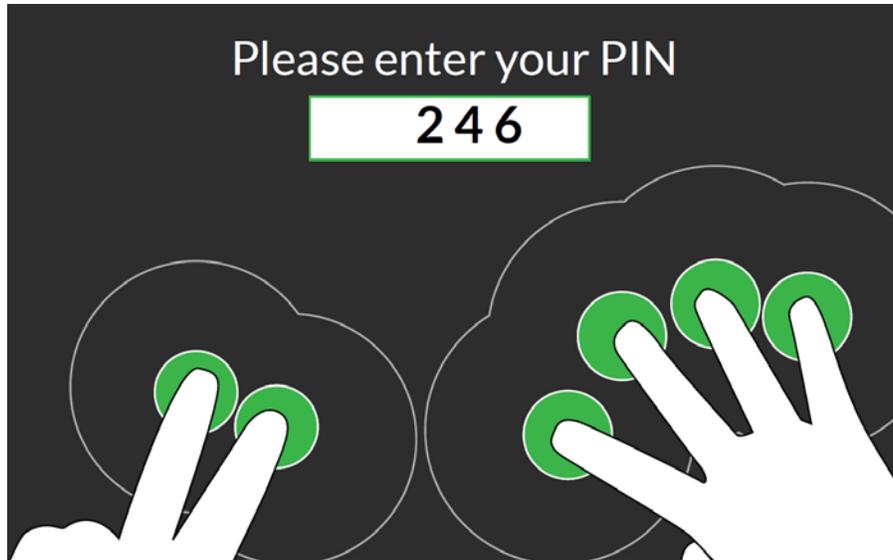


Fig. 4. Concept D for PIN entry: Multi-finger tap & hold.

Concept D for PIN entry: Multi-finger tap & hold. There are specific technical requirements for PIN entry to ensure the PIN remains private and secure (see PCI for details). These requirements mean that no individual numbers or user input can be vocalized.

In addition to the PIN entry task, two other tasks were included in the test: task 2 was to select a specific option in an on-screen menu, and task 3 was to enter the word "SAVE" using an on-screen keyboard. To test these tasks, three concepts were developed:

- A) Talking fingers: moving the finger on the screen to hear the menu option/alphabetic character in focus vocalized, then double-tap to select. Options were arranged in a fixed grid in the center of the screen.

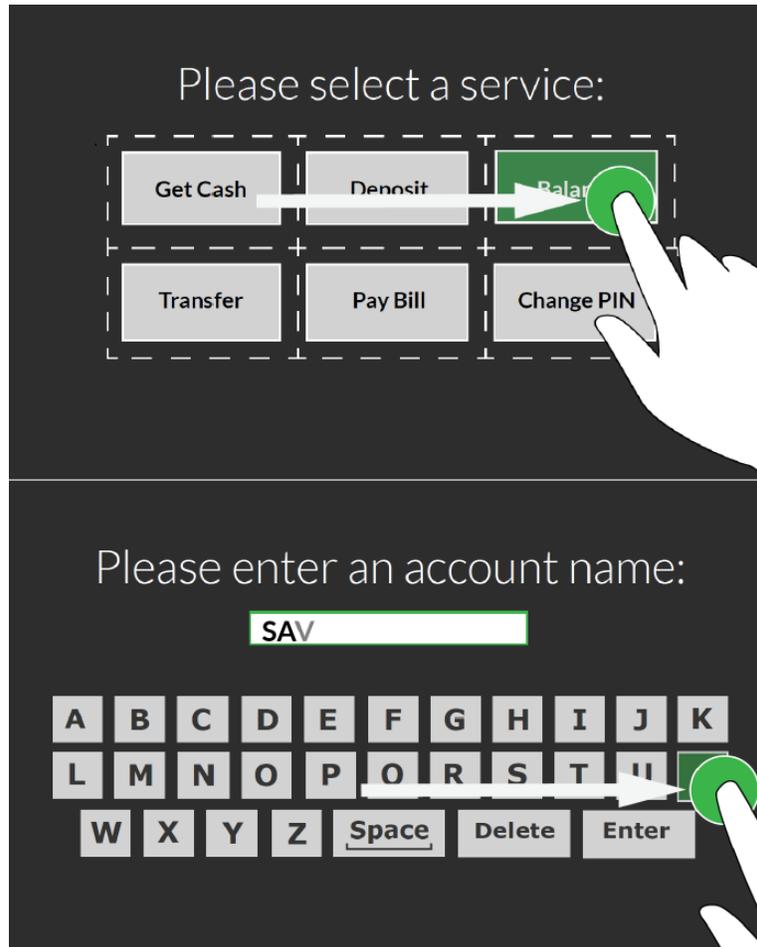


Fig. 5. Concept A for menu selection and text entry: Talking fingers.

- B) Virtual grid: swiping left or right, up or down anywhere on the screen to cycle through the menu options/alphabetic characters, double-tap to select.

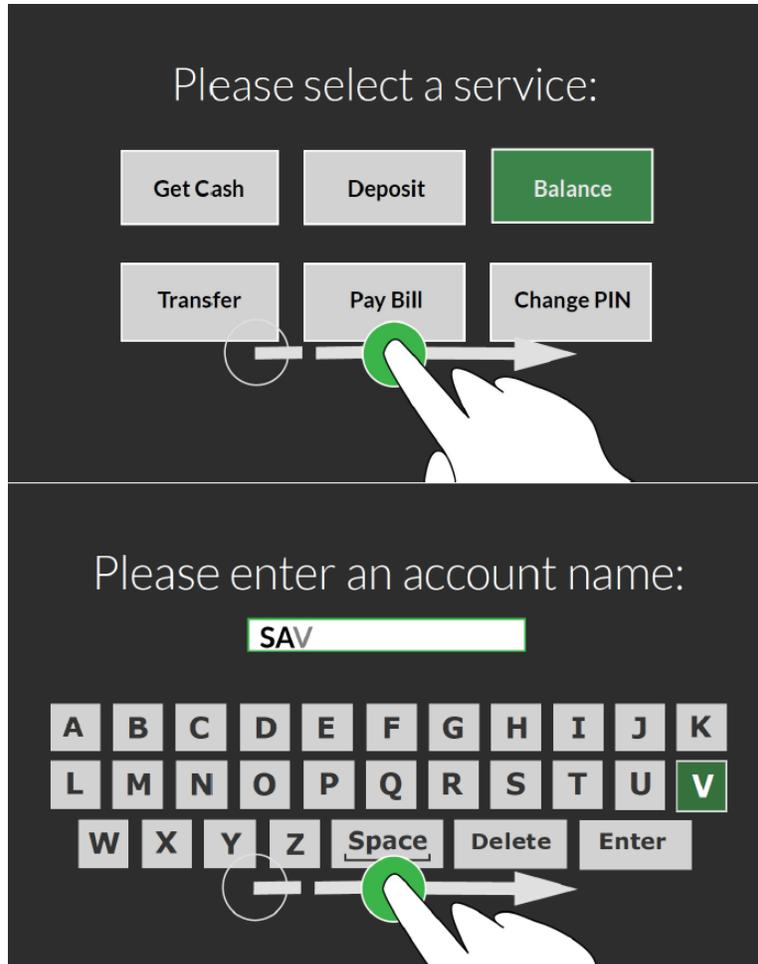


Fig. 6. Concept B for menu selection and text entry: Virtual grid.

- C) Slider: sliding a finger horizontally along the bottom of the screen to hear each menu option/alphabetic character in turn, double-tap to select.

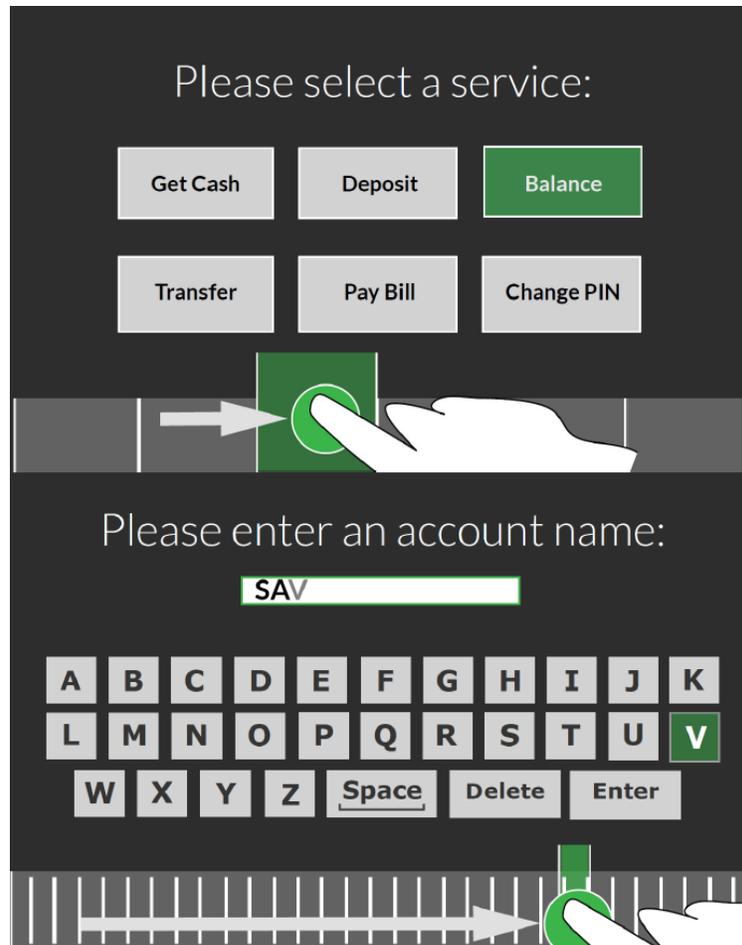


Fig. 7. Concept C for menu selection and text entry: Slider.

A total of 49 people (27 women and 22 men) with varying levels of visual impairment (9 were partially sighted, 22 were blind with some useful residual vision and 18 were blind without any useful residual vision) took part in the usability test. They were recruited through RNIB. The evaluation was a repeated measures design, and the order in which the concepts were used 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 to rate on a 5-point Likert scale: 1) how easy it was to understand the audio instructions; 2) how easy it was to perform the touchscreen gestures required to complete the task; 3) how confident they would be to use an ATM with that interaction method; and 4) specifically about the PIN entry concepts, how private it felt.

### *Exploring Gestures Results*

Entering the PIN was extremely challenging. Due to the security rules around PIN entry, no feedback identifying individual numbers could be vocalized. Participants tended to understand the concepts, but made errors in entering the numbers, and were unaware of these errors until informed. Of the four concepts tested, Concept B “Multi-finger multi-tap” and Concept C “Tactile markers” were rated the easiest to use, and the participants felt the most confident using them. All four concepts were thought to be less private than a traditional ATM PIN pad. The average ratings for each concept are shown in Table 1.

**Table 1. Participants’ subjective ratings for each of the four PIN entry concepts in the first usability test (average rating on a scale of 1 = very negative to 5 = very positive).**

	<b>A. Visual tallies</b>	<b>B. Multi-finger Multi-tap</b>	<b>C. Tactile markers</b>	<b>D. Multi-finger Tap+Hold</b>
Ease of understanding the audio instructions	3.44	3.29	3.49	4.08
Ease of performing the gestures	3.4	4	3.75	3.35
Confident to use independently	3.32	3.76	3.88	3.61
Privacy compared with traditional ATM	2.59	2.7	2.74	2.48

**Table 2. Participants' subjective ratings for each of three concepts in the menu selection task (average rating on a scale of 1 = very negative to 5 = very positive).**

	<b>A. Talking fingers</b>	<b>B. Virtual grid</b>	<b>C. Slider</b>
Ease of understanding the audio instructions	4.15	4.08	4.19
Ease of performing the gestures	4.02	4.27	4.4
Confident to use independently	4.47	4.25	4.47

Due to the significant difficulties in entering the PIN, it was evident that the PIN entry concepts needed to be improved. Concept C with the tactile markers was selected for further development. An added benefit of this solution was that it also provided a fixed tactile reference point to help users maintain their spatial orientation on the touchscreen, whereas all the other PIN entry concepts relied on gestures only.

Participants found tasks 2 and 3, i.e. the menu selection and text entry tasks, easier than the PIN entry task, primarily because they were able to hear the options and their input vocalized. There was no clear preference for any one concept but Concept C "Slider" was rated highly for the menu selection task, and Concept A "Talking fingers" and Concept C "Slider" for the text entry task. Average ratings for the menu selection task are shown in Table 2 and for the text entry task in Table 3.

**Table 3. Participants' subjective ratings for each of the three concepts in the text entry task (average rating on a scale of 1 = very negative to 5 = very positive).**

	<b>A. Talking fingers</b>	<b>B. Virtual grid</b>	<b>C. Slider</b>
Ease of understanding the audio instructions	4.11	3.57	4.06
Ease of performing the gestures	3.41	2.85	3.4
Confident to use independently	3.82	3.24	3.72

### *Improving PIN Entry Test*

Several variations of the “Tactile markers” concept were created to refine the tactile features that would help identify the numbers and the Cancel and Enter functions. Different raised and recessed features were investigated to help differentiate between the numbers, along with different shapes to guide the finger to the correct target area on the screen. These concepts were again reviewed with RNIB evaluators. Based on their feedback, two variants were selected to be tested with users in the next usability test.

1. Tactile strip with grooves to guide the finger to the correct target area on the screen. There were 12 grooves: one for each number, a shorter groove for Cancel and Clear and another shorter groove for Enter.

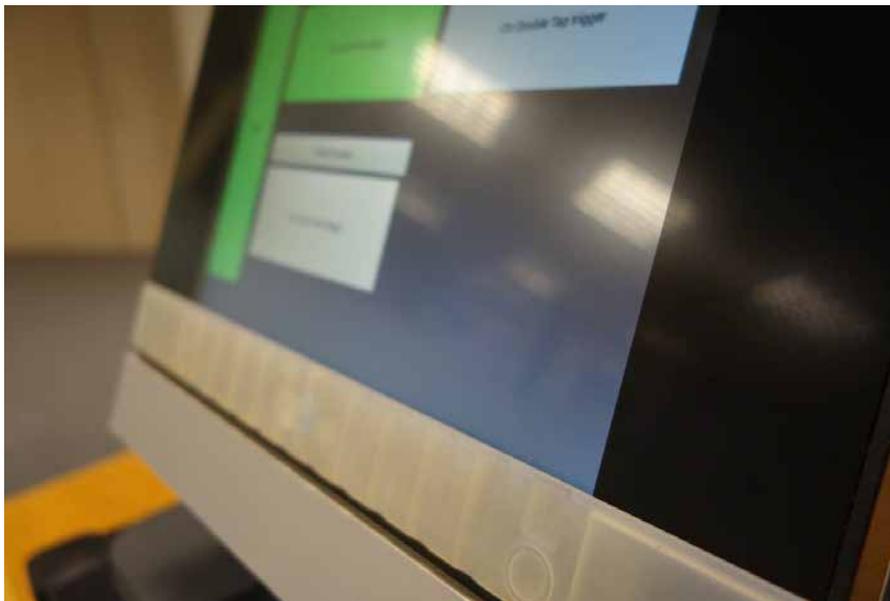


Fig. 8. Concept 1 for PIN entry: Tactile strip with grooves.

2. Tactile strip with holes, similar to the previous concept but each groove also had a hole overlapping the touchscreen to tactilely indicate the target area on the screen.



Fig. 9. Concept 2 for PIN entry: Tactile strip with holes.

An alternative to this interaction method would be for the touchscreen itself to provide tactile feedback in response to touches and gestures. In order to investigate the suitability of this type of haptic feedback in SSTs, a prototype of a haptic touchscreen was included in the test as a third concept:

3. Haptic touchscreen: The layout was similar to a traditional ATM PIN pad, with a subtle pulse when a finger was on a number key, a stronger pulse on the 5 key and the function keys “Cancel”, “Clear” and “Enter” vocalized when the finger was on them. To select a key, the user was expected to press down without lifting their finger.



Fig. 10. Concept 3 for PIN entry: Haptic touchscreen.

4. A traditional ATM PIN pad with physical keys was included in the test to enable comparison with the tactile strip concepts and the haptic touchscreen.



Fig. 11. Concept 4 for PIN entry: Traditional ATM PIN pad.

In the second usability test, all participants were asked to enter a PIN using all four concepts (in counterbalanced order to minimize any learning effect). We had 40 participants (23 men and 17 women) with varying levels of visual impairment: 3 were partially sighted, 15 were blind with some useful residual vision, and 21 were blind without any useful residual vision. When asked about their experience of using ATMs, 17 said they used an ATM independently. There were 3 participants who had never used an ATM and a further 8 who said they did not regularly use an ATM but had tried in the past. When asked about their experience of using personal mobile devices with touchscreens, 18 used a smartphone, 10 used both a smartphone and a tablet, and 12 did not use touchscreen-based mobile devices.

### *Improving PIN Entry Results*

Both of the tactile strips (Concepts 1 and 2) worked well: only nine participants failed to enter their PIN using them. With Concept 1 (the tactile strip with grooves) 28 of the participants managed to enter the PIN correctly on the first attempt and a further 3 on the second attempt. With Concept 2, 17 managed to enter the PIN correctly on the first attempt, and 14 on the second

attempt. On the other hand, the haptic touchscreen was found to be very difficult to use: 21 participants failed to enter the correct PIN, 12 managed it on the first attempt and a further 7 on the second attempt. In contrast, with the traditional ATM PIN pad 37 of the participants managed to enter the PIN successfully on first attempt, a further 2 on the second attempt, and one participant failed to enter the PIN correctly.

Similar to the first usability test, the participants were asked to rate on a 5-point scale: 1) how easy it was to understand the audio instructions; 2) how easy it was to enter the PIN; and 3) how confident they would be to use an ATM with that PIN entry method, both without any practice and with practice. The average ratings are shown in Table 4.

**Table 4. Participants' subjective ratings for each of the four concepts in the second usability test (average rating on a scale of 1 = very negative to 5 = very positive).**

	<b>Tactile strip with grooves</b>	<b>Tactile strip with holes</b>	<b>Haptic touchscreen</b>	<b>Traditional ATM PIN pad</b>
Ease of understanding the audio instructions	4.65	4.65	4.52	N/A
Ease of entering the PIN	4.23	4.2	2.15	4.7
Confident to use without practice	4.22	4.28	2.38	4.8
Confident to use with practice	4.68	4.78	3.28	4.95

Comparing the ratings for the two tactile strip concepts with the ratings for the traditional ATM PIN pad (shown in Table 5), the tactile strips were rated equally easy to use and the participants felt confident that they would be able to enter their PIN as easily as with the traditional ATM PIN pad. The haptics concept was rated significantly more difficult than any of the other concepts, and participants were not as confident that they would be able to use it on their own.

**Table 5. Comparing the participants' ratings for the ease of PIN entry (using Friedman's ANOVA).**

	<b>Tactile strip with grooves</b>	<b>Tactile strip with holes</b>	<b>Haptic touchscreen</b>	<b>Traditional ATM PIN pad</b>
Tactile strip with grooves	-			
Tactile strip with holes	$\chi^2_{F(3)}=.1,$ $p=1.000$	-		
Haptic touchscreen	$\chi^2_{F(3)}=1.5,$ $p=.000$	$\chi^2_{F(3)}=1.4,$ $p=.000$	-	
Traditional ATM PIN pad	$\chi^2_{F(3)}=-0.5,$ $p=.5$	$\chi^2_{F(3)}=-0.6,$ $p=.226$	$\chi^2_{F(3)}=-2.0,$ $p=.000$	-

## Discussion

Based on the first usability test, it was clear that entering the PIN using touchscreen gestures only was extremely challenging. The lack of auditory feedback made it difficult to identify the appropriate number to be entered. It was also difficult to know when a mistake had been made and how it could be corrected. Furthermore, the lack of any tactile reference points on the touchscreen added to the challenge. However, it was positive to discover that the other two tasks, in which it was possible to vocalize on-screen content, were easier to complete.

As shown by these results, the audio instructions and all auditory feedback are very important. They need to be carefully implemented, particularly the sequence and amount of information given to the user. Not everyone will know how to use a touchscreen and perform gestures such as double-taps and swipes. This creates additional challenges for providing instructions that accommodate both first-time users and the more experienced ones.

It is encouraging to note that by refining the tactile features of the first Tactile markers concept and then testing it again with users, a clear improvement could be seen in the participants' ratings. The tactile strips of the second test were rated considerably easier to use, and the majority of participants were able to successfully enter their PIN. Based on our research, it is also evident that the haptics-based touchscreen is not suitable for use on SSTs – yet. This may change in the future as the technologies to create different tactile sensations evolve.

## Conclusions

SSTs have certain characteristics which make them unique in terms of their requirements for accessibility. Anyone must be able to walk up to an ATM and be able to use it without training or assistive technologies. As the user could be anyone, we cannot make assumptions about their prior knowledge and experience. Even for those users who have experience of touchscreen interaction, the self-service environment creates challenges. There is very little time to learn a new interface and master a new interaction method when standing at an ATM. Touchscreen gestures familiar from personal mobile devices cannot necessarily be transferred to an ATM. The bigger screen of an ATM will make it difficult to maintain orientation while navigating the interface. There are also often concerns over privacy and security as the user is required to handle personal and sensitive information in a public place.

Future work will continue to address these issues and improve this initial solution. What the results of this study confirm is that it is possible to make a touchscreen-only ATM accessible for users with visual impairment, allowing them to interact with an ATM independently, including entering their PIN in complete privacy.

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