A Study into Accessibility and Usability of Automated Teller Machines for Inclusiveness

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Abstract. At first glance, interaction with an Automated Teller Machine (ATM) tends to look limiting and prescriptive. Both hardware and interface do not seem to provide adaptability layers for vulnerable groups of users, particularly those with disabilities. This study considers users who have different requirements because of temporary or permanent disabilities and needs. After an overview of ATMs' functionality and principles of user interactions, we introduce the main topics of this study: accessibility and usability for inclusiveness. We then describe a heuristic evaluation exercise as well as the methods and criteria used in order to assess how ATM systems, even if sharing the same functionalities, differ substantially in providing a usable and accessible experience to users. Finally, we reflect on the emerging issues that affect the user experience with ATM and highlight how even for such a simple everyday use tool, we are still far from real inclusion. Therefore, with the support of the literature, we propose some recommendations for further studies.

Keywords: Accessibility · People with Disabilities · ATM · Inclusiveness · Usability

1 Introduction

In recent years, substantial research and development efforts have been made to enhance Automated Teller Machines (ATM) functionality and usefulness, offering a remarkable body of expertise, demonstrations, and models of best practice [5]. ATMs are a particular category of devices that we need to study concerning accessibility and usability: the physical access to its hardware and the interaction with the graphical user interface (GUI), as both contribute to the overall user experience (UX). In general, ATMs are supporting a straightforward task that could be classified as of low complexity. Users need them to be simple, easy to learn and remember, resistant to errors, fast recovery from mistakes, efficient, and time-saving while providing an adequate safety level as expected when dealing with money. When it comes to users with temporary or permanent disabilities, it is essential to understand what kind of cognitive effort is required during the interaction and what abilities are necessary to have an effective interaction with ATM, which ends with achieving the supported tasks. Given that users interact with a GUI, identifying, recognizing, and making sense of labels

and icons is essential for successful interaction, as the only available alternative is the audio option. Besides, a limited number of ATM stations are made available where height is adapted to serve customers on a wheelchair. Thus, for instance, as a case study, we have Mary. During her evening walk with her dog Nero, she stops by an ATM to quickly withdraw some money and discovers to have left her glasses at home as well as her earphone. There is no way to accomplish her task, and she gets frustrated by the lack of available alternatives has to go back home to try again next time. Equally unsatisfied is John, who has never been able to read and has to guess the meaning of labels on the screen while hoping to remember his identification number (PIN) in order to get the sum he needs to pay for his daily expenses. These simple case scenarios show how while ATMs may bring substantial benefits in terms of 24/7 access to money deposits and withdrawing, accessibility is far from being attained. More needs to be done if such devices have to provide a genuinely inclusive UX. In the following sections of this paper, we will report on relevant literature covering the peculiarities of ATMs and describe the different needs these systems should serve to provide usability and accessibility to users with temporary or permanent disabilities. We will then discuss the approach and method used to assess the kind of UX currently provided when interacting with available ATMs and the findings of our analysis. Finally, we will show their implications on future study and design of more inclusive systems to support a broader range of different needs.

2 Automated Teller Machines (ATMs)

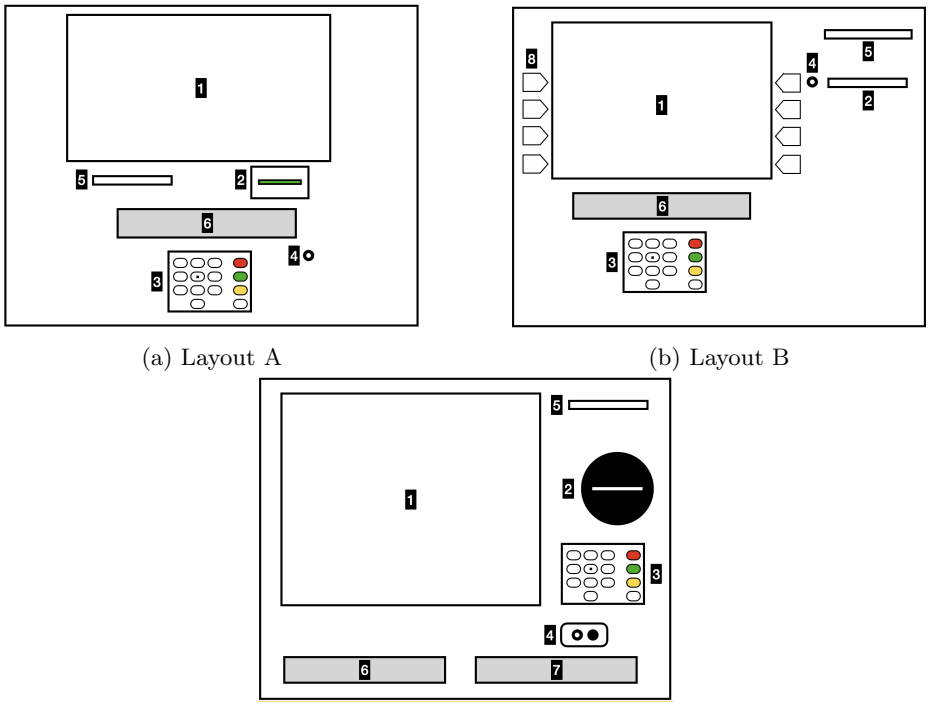
In the early 1970s and after the advent of credit cards, the next major technology was ATM's production, which began to fulfill much of the bank's teller duties. The ATM network has made a significant contribution to the quality of most financial transactions for consumers securely. ATMs give both banks and consumers valuable benefits. The machines encourage customers to withdraw and deposit cash at more convenient times and locations than during banking hours. Around the same time, ATMs reduce the cost of operation for some consumer needs by automating processes that have previously been completed manually. Such gains are compounded as banks exchange their ATMs with others, encouraging other banks' customers to access their accounts via a branch's ATM.

An ATM is an automated computerized telecommunications system that enables clients of financial institutions to enter their bank accounts through a straightforward and secure contact process. The ATM is a self-service banking terminal that collects cash and collects deposits. Most ATMs also allow users to carry out other banking transactions, such as balance checking or purchasing third-party services, link train tickets, or phone credit recharges. The ATM is enabled by inserting a bank card into the card reader slot and entering a valid PIN. For instance, ATM first connects the bank's machines to check the balance when a customer attempts to withdraw cash, then dispenses the money and finally transmits a completed transaction note.

While ATMs provide bank customers with a beneficial tool, they can often be challenging to use, and there is also much space for improvement in the design of the interface. For high usability standards, the successful design of the graphical user interface is, therefore, imperative. There are sometimes difficulties or inconveniences faced while using an ATM; some of the issues include: the inability to see well the ATM screen due to the sun reflection or other external factors, the incorrect insertion of the ATM card, especially for new users who are not familiar with their new card and the ATM, or the menu options on some ATMs may not be aligned with their corresponding menu key. Some more addressable usability-related issues of cash dispensers are understanding operations and the instructions on how to perform actions, which are pretty challenging to understand for some ATM users. Also, the banking jargon may be too complicated for inexpert users or specific users such as illiterates, semi-literates, or older people. Moreover, the ATM card is often returned to the user while further operations are required (e.g., once the user requests a sum of cash, the card is returned, and no additional operations are allowed). This will result in a very inefficient procedure, and time-consuming process since the client has to reinsert the card, increasing their time spent at the ATM further. Another inefficiency often happens while getting the necessary amount of money. Most ATM displays on the initial screen the available banknotes available to be withdrawn. Still, none will show the amounts after the customer has inserted the card and selected a custom amount to withdraw, leading the user to mistakes.

Different banks offer diverse ATM hardware architectures, depending on the machine's hardware producer, which results in distinct dispositions of the elements composing an ATM system. We can see some layout examples in Figure 1. Although each ATM's architecture is different, they all contain the same essential components; a card reader who reads the information stored in the magnetic stripe on the back of an ATM card and relays the information to an internal device, connecting to the cardholder's register. A display screen that provides the interface between the internal device of the ATM and the cardholder, newer machines use touchscreen technologies while older ones still rely on buttons. The keypad allows choices and input details to be made by the cardholder, and all modern ATMs should have braille keyboards for the visually impaired. The number keys are used to input the PIN of the card or the amount to be withdrawn. Other external parts such as a cash dispenser, a receipt printer, seldom a deposit slot for banknotes or checks, cash dispensers, and speakers make it easier for the keys to beep. Sound feedback allows the user to recognize whether the button has been pressing hard enough to register with the machine, which is fundamental for older or visually impaired users. Different hardware architectures can cause usability issues for some users. Just imagine visually impaired or blind users reaching an ATM. They have to figure out where to plug in their headphones. This first step could result in a challenge since the hardware differs much from bank to bank. Moreover, the spot to plug in the headphones jack is very tiny, and there is no rule of thumb for the placement; usually, it is some-

where on the left side of the screen. In the pictures below are displayed three different architectures and dispositions of the hardware components.



(a) Layout A

(b) Layout B

(c) Layout C

Fig. 1: Different architectural layouts and dispositions of the ATMs' hardware

The same heterogeneity holds for the machines' embedded software, which will produce different user interfaces and user experiences for the customer. Those different interfaces have been grouped into three categories and analyzed with several factors and criteria in the next section, focusing on usability concepts for users with temporary or permanent disabilities.

This paper aims to point out the most evident differences in user interfaces, design choices, hardware disposition and analyze each factor from an accessibility and usability point of view, focusing on particular need users.

3 Usability, Accessibility, and ATM Users

When interacting with ATMs, we consider all sorts of users, disabled and non-disabled users, with permanent or temporary conditions. To have software and hardware integrated with users' needs, we should consider Usability and Accessibility as key areas to enhance their experience. The term usability refers to the

utility of a product or service and the simplicity with which individuals can use it. Unfortunately, in software development, it still remains a secondary concern [9]. Accessibility defines the degree to which as many individuals as possible can access a solution, particularly those with impairments. Designing a product or device such that all future customers are able to use it is often a challenge. In other words, not ignoring large consumer classes, such as persons with disabilities, is of considerable importance. Sauer [10] states that usability and safety studies are exceedingly limited.

Accessible and usable ATMs are essential for every user and can be frustrating when they cannot achieve their goal. According to the World Health Organization, there are more than one billion people in the world living with some form of disability. People with disabilities have significantly lower rates of information and communication technology use than non-disabled people [6].

The involvement of people with a disability or impairment has a direct positive effect on accessibility development, and way more work is needed to make accessibility indeed a core topic of our curriculum and industry development [12]. The users can have a variety of needs, being temporary or permanent disabilities and needs, such as:

- Physically impaired
- Visually impaired, colorblind and blind
- Illiterate and semi-literate
- Cognitive impaired
- Older adults

Many of the new ATM tech products are focused mainly on text communication and can thus cause severe challenges for consumers with disabilities [15]. The banking performance of these devices continues to be limited, and, sadly, assistive technologies are not necessarily adequate to enhance the accessibility of applications. Consequently, this ATM program provides low usability for most users, particularly for those with contrast sensitivity and visual acuity issues. Some of their challenges include: the height of the ATM screen and hardware for wheelchair users; button colors and not clear charts for visually impaired, colorblind, and blind users; illegible texts and numbers for illiterate and semi-literate users; hard-to-read textual information for cognitive impaired users; complex interfaces, be afraid to make mistakes, and the lack of feedback for older users [11]. In the next section, we are going to discuss our study and methodology.

4 Analysis and Discussion

We want to focus on new casual users as well as on expert users who interact with the same system or a different one. Users with temporary or permanent disabilities such as the visually impaired, color blind, and physically impaired are part of the user analysis, and older people who often can have physical and mental marks. We set realistic but straightforward tasks: withdrawing a standard and a non-standard amount of money, with or without a receipt, and interacted with

locally available ATMs. Due to the COVID-19 pandemic situation, we could not involve directly vulnerable users in indoor spaces, such as ATM locations or evaluation labs. Therefore, we run an expert evaluation focusing on the interaction dimension of the UX. A standard user experience target table as proposed by Harton and Pyla [8] was adapted to this purpose. In order to proceed with feedback collection, we took photos and recorded videos from the main actions that can be performed in ATMs. In total, third-one videos were recorded from eleven different systems, with an average content length of three minutes per session. The number of videos varied because when one researcher was alone, there was a need to use both hands to interact with the ATM, and in other cases, the need to show extra explorations of the interface. The videos were analyzed and scored in a second moment by the authors, that are researchers and experts in the User Experience and User Interaction research area.

The adapted user experience target table is related to the most common services of an Automated Teller Machine. We list the actions to be performed chronologically, assuming that the user follows a standard sequence and no system error occurs. We measure the following usability aspects [14]:

- **Effectiveness:** Effectiveness is about whether users can complete their goals with a high degree of accuracy.
- **Efficiency:** Users can perform tasks quickly through the most straightforward process.
- **Engagement:** The users find it pleasant to use and suitable for its industry.
- **Error tolerance:** It supports a range of user operations and only exhibits an error in real erroneous conditions. Error tolerance is achieved by finding out the type, number, and severity of typical errors users perform and how easily users can recover from those errors.

After the analysis of the interactions with the different ATMs when performing the set tasks, we grouped ATMs by similarity, as presented in Figure 1. Group A is composed of four Swiss banks, Group B by three and Group C by one. The experts analyzed the four usability aspects of each task. Table 1 reports the results ranging from 1 (very unsatisfied) to 10 (very satisfied). Likewise, the discussion about the findings are presented as follow:

1. Insertion of the card: The three groups, A, B, and C, are getting the same scores across the four usability aspects. In terms of Effectiveness, all of them could do slightly better if adopting more innovative solutions in the banking industry, such as card-less withdrawals. They are all faring very well under Efficiency since users can complete their goals with a high degree of accuracy. Engagement is just above sufficient as users may not engage with the system as they could be concerned about security, have to wait in long queues, and therefore feel time pressure, or simply have forgotten the correct card. Finally, across the three groups, all ATMs are highly error-tolerant; if the user inserts a wrong card or the correct card in the wrong way, the machine ejects the card immediately.

2. Enter PIN: The three groups have similar scores on all factors but Engagement. Effectiveness and Efficiency across all groups get very high scores

User Task	Effectiveness			Efficiency			Engagement			Error Tollerance		
	Group A	Group B	Group C	Group A	Group B	Group C	Group A	Group B	Group C	Group A	Group B	Group C
1. Insertion of the card	9	9	9	10	10	10	7	7	7	10	10	10
2. Enter PIN	9	9	9	9	9	9	6	8	8	5	5	5
3. Homepage / Menu	9	9	10	10	10	10	7	9	7	10	10	10
4. Select withdrawal from menu	10	10	10	9	9	10	8	8	8	5	5	10
5.1. Select amount	10	10	10	5	5	5	6	6	6	5	5	10
5.2. Select other amount	10	10	10	5	5	5	6	8	8	5	5	5
6. Receipt? (yes / no)	10	10	10	9	9	5	8	6	5	5	5	5
7. Withdraw card	10	10	10	5	5	5	10	7	10	10	10	10
8. Withdraw cash and receipt	10	10	10	10	10	10	10	8	10	10	10	10

Table 1: Adapted User Experience target tables for different ATM tasks and groups

since the process is straightforward and can be completed with a high degree of accuracy (as long as the users remember their PIN). Engagement for group A is rated just sufficient because nowadays, technology proposes much more attractive and secure ways to authenticate users using bio-metrics. Engagement for group B has a good grade because of the interactive PIN-input fields, the same score for group C thanks to the immersive PIN-input areas. Still, there is a margin of improvement for both by looking at innovative technology to provide far more enticing and safer forms to authenticate users. All three groups get a low score for the system's error tolerance because if a customer types in the wrong PIN, the machine keeps the card after the third attempt. In order to get back the banking card, the user has to face a time-consuming procedure with the bank.

3. Homepage / Menu: The three groups have the same Efficiency and Error Tolerance scores, with different Engagement results and very similar for Effectiveness. In Group A and C, the lack of icons in the menu makes the GUI less engaging for the user, while in Group B, the presence of icons makes the GUI more engaging. If a user clicks the wrong button in the group A and B, it is no longer possible to go back to the main menu. The banking jargon may be hard to understand for some novice users of the industry. In group C, it is tough to understand which buttons or keys have to be used to input a command; the system provides no touchscreen but lateral buttons and keypad buttons.

4. Select withdrawal from menu: The three groups have the same Effectiveness and Engagement scores, with different Error Tolerance results and very similar for Efficiency. In the group A and B, if the users press the wrong button in the menu (e.g., withdraw Euro), they can not go back and correct the selection. Also, the banking jargon may be too complicated for some inexpert users (e.g., sometimes called PIN, sometimes NIP), which will face problems in understanding the various options. Likewise, icons and any graphical support are missing.

5.1 Select amount: Effectiveness is very high for all groups as all machines support the task across all groups. Efficiency is insufficient as the system does not smoothly support the withdrawal of amounts that do not match those preset.

Moreover, the last withdrawn amount is only saved by the used machine; if the customer changes ATM within the same bank, the amount will not be displayed. Lastly, the user cannot save a favorite amount from being held. Engagement is just sufficient in all three groups. In group B also, unfortunately, the default amount list is very short in this ATM. The error rate for groups A and B is rated relatively low because of the impossibility of going back to the main menu. In group B, the inclusion of an "Other amount" button icon is an exciting improvement. Nevertheless, the buttons and text size are tiny and, therefore, offer very poor legibility. For group C, Error-tolerance has a very high score because of the possibility of going back to the main menu if the current session has been initiated by mistake.

5.2 Select other amount: If the users cannot find the desired amount in the standard list referred to above, they have to insert the amount manually. Across the three groups, scores for Effectiveness and Efficiency are the same as for the "Select amount" with the same rationale. For group A, Engagement is barely sufficient; other systems offer a keypad's visual support to make the action more straightforward. Moreover, the system does not show the user the possible amounts and banknote sizes available to be withdrawn (it is only offered on the very first screen of the ATM - before inserting the card). Users also have to know their daily or monthly limits on their own since the bank gives no information at all. Instead, Engagement gets a higher score for groups B and C as they provide tactile support for a keyboard to make the operation more transparent. The error tolerance score is insufficient for all three groups as the customer cannot go back to the previous interface.

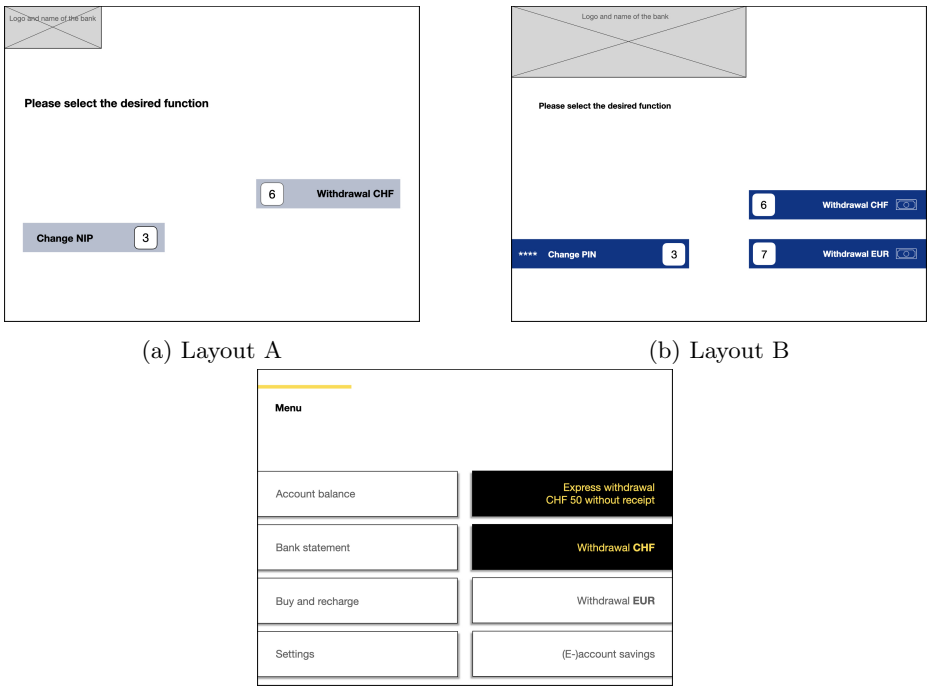
6. Receipt? (yes / no): For all three groups, once the users have inserted the desired amount, they have to confirm it and select if they would like to have a receipt or not. Unfortunately, if the users approved a wrong amount in the previous action, they cannot correct it; instead, they have to abort the entire procedure and start over. This is why they all get a very high score for Effectiveness and a low one for Error rate. Group A has good Efficiency, while Engagement could be improved for this particular task; the whole screen is left entirely blank. Group B has a high grade for Efficiency, but Engagement should be enhanced; even if icons are applied to the action buttons, the color elements are absent. The text, in comparison, is incredibly tiny and difficult to read. For group C, both Efficiency and Engagement are low as users cannot see the amount as a confirmation of the withdrawal. The system only gives the possibility to choose whether or not they would like to have a receipt.

7. Withdraw card: For all three groups, once the amount is confirmed, the customer is required to remove the card; this may be rather inefficient since no further operation may be taken (e.g., verifying the balance or making another withdrawal), which decreases the Efficiency score to 5. Effectiveness instead is very high for all. Group A has high Engagement and Error tolerance scores as the activity is supported by an animated icon that alerts the customer to collect their card once removed. Engagement is scored seven for group B instead because the icons are small and the text too, even though the operation is accompanied

by an icon that invites the customer to remove their card. Finally, for group C, Engagement is scored higher than for the previous task because the icon is animated and more understandable.

8. Withdraw cash and receipt: Groups A, B and C get the maximum scores for all factors except for group B where Engagement is lowered due to the small icon compared to those used in the previous task.

We applied the adapted User Experience target tables for the different groups that present similar interface layouts. In Figure 2 we can see the difference between groups. Group A, available in the Figure 2a, has an uncomplicated menu with alternatives for withdrawing money (button 6) or changing the PIN that the interface presents as NIP. In group B, Figure 2b, we have an alternative to withdrawing money in two different currencies and the possibility of changing the PIN. The options have icons, which can help illiterate, semi-literate, and older users. In Figure 2c we can see Group C's interface. The menu has more alternatives for the user, but no icons or numbers are available. Also, the contrast with the yellow color can be challenging for some users.



(a) Layout A

(b) Layout B

(c) Layout C

Fig. 2: Different interfaces of ATMs from different groups

Overall, all considered ATMs performed well in terms of effectiveness while we detected some issues with efficiency, and even more so with engagement and error tolerance. The work by Curran and King [2] specifically addresses efficiency and error tolerance by proposing a "best-of-breed" ATM menu system: the OptiATM. The OptiATM menu design proved to be a more usable and efficient system than existing ATMs, as it solved the problem of users having to reinsert their ATM cards to perform another transaction. An issue we reported across all ATM systems in our study and summarised in Table 3, under "Execute two distinct actions" that is also closely related to another entry in the same table: "Go back to previous screen". Therefore, few years after that work was published, current ATMs are not taking advantage of what back then was innovative research. Moving on to consider ways to improve engagement, we start by focusing on improving security, a problematic issue with all ATMs in our study, as reported in Table 2 under "Additional security". Moncur et al. [4] report how multiple graphical passwords are noticeably more effective than multiple PINs, even more so by using mnemonics to aid their recall. On a related note, De Luca et al. [3] explore how the increased use and popularity of ATM needs new authentication mechanisms to be developed to overcome PINs' security problems. The results from a field study and two smaller follow-up studies on real-world ATM use, show that there is a number of contextual factors having an impact on security and performance in PIN-based ATM use. All to be accounted for when designing alternative ATM authentication systems as means to increase accessibility and engagement while protecting security.

Still looking at ways to increase engagement via innovative, more accessible, and usable approaches to security, Coventry et al. [1] describe how usable are leading-edge biometrics techniques based on iris verification technology when integrated with the Automated Teller Machine (ATM) user interface. The paper also mentions future work in the area.

When considering alternatives to text and graphics based interfaces, audio support is a highly desirable feature for users, such as the visually impaired who struggle in reading small texts, illiterate people who face barriers in reading or cannot read at all, or blind users who have to rely entirely on audio support if they want to use the service autonomously. Most of the systems analyzed in our study had an insufficient audio quality because of different factors (surrounding noise, inability to adjust the volume, unclear sound). In contrast, other machines had no support at all. Moreover, none of the analyzed machines are equipped to offer remote assistance; users who face issues in handling the systems, especially users with physical and/or cognitive impairment, have to find an alternative way to withdraw money, often visiting their local bank branch during opening times. Oswal [7] describes a user study to understand better the impact on accessibility and usability of voice directions for operating ATMs. Their findings confirm there is still much work to be done in order to make such support systems accessible, usable, and useful, as observed in our study and reported in Table 3, under "Audio quality" as well as "Assistance or help button". Therefore, they strongly encourage the active involvement of people with disabilities in the design team.

UI and UX elements	Group A	Group B	Group C
Text size and style	8	6	6
Button size	8	7	10
Background vs buttons and text	9	9	9
Amount of text and options to select	9	9	9
Screen space optimization	8	7	8
Special buttons	7	9	1
Icons on screen	1	8	1
User action icons	10	8	10
Screen to keypad matching numbers	10	10	1
Language settings	6	6	6
Assistance or help button	1	1	1
Select amounts to withdraw	6	6	1
Pressing CORR or STOP abort the process	5	5	9
Go back to previous screen	1	1	9
Execute two distinct actions	1	1	1
Additional security	1	1	1
Sound feedback	10	8	10
Audio quality (headphones)	7	5	7

Table 2: Summary table of usability and accessibility for different ATM systems

A similar co-design approach is proposed by Thatcher et al. [13] when describing an attempt to design more inclusive and usable icons for ATM interfaces, to address the problematic issue we reported in Table 3, "Icons on-screen". Their study engaged a group of functionally illiterate bank account holders in developing icons to provide guidance to customers and take them through the various stages of the ATM withdrawal transaction.

Together with our findings, this brief overview confirms that while ATM interfaces are still lagging behind in terms of usability and accessibility, researchers in this area are actively exploring and proposing valid solutions for more inclusive systems. The hope is that banks will take notice of their efforts and rank accessibility and inclusiveness higher in their busy agenda.

5 Conclusions

We set out to explore the accessibility and usability of a very popular system providing an essential service to users. At first glance, ATM systems seem to share

the same structure and a simple, straightforward interaction style. In this exploration, we examined and analyzed eleven different systems in a detailed way by considering tailor-made UX target tables focusing on accessibility and usability for users with temporary or permanent disabilities and needs. Using expert evaluation to compare different ATMs brought to light differences from a hardware perspective and from the user interface point of view, usability problems, and an overall poor user experience in terms of quality of interaction. Especially when considering users with temporary or permanent disabilities and needs when it comes to reading and making sense of icons and text used to provide on-screen instructions to guide them in the withdrawing process. This is a significant concern as it could mean that a substantial share of the population, temporarily or permanently affected by cognitive and/or sight impairment, would be excluded from taking advantage of a modern commodity such as having access to banking services 24/7. Even if our findings have to be tested with real users in order to confirm this assumption, we feel that the issue per se should be further explored as it had profound implications on the quality of life and inclusion of vulnerable users. The main limitation of this study is that, due to the COVID-19 pandemic, it was not possible to conduct a user-based evaluation and collect feedback, assessments, opinions, and suggestions directly from users as much as to run direct observations. Instead, we had to resort to expert evaluation. Nonetheless, we feel we have managed to highlight a number of crucial issues regarding the UX of such a simple system.

The developed target tables have been derived from literature, expanded and adapted to be used with ATMs, and analyze the main steps of the withdrawal process. Therefore, enabling us to assess usability and accessibility for users with temporary or permanent disabilities and needs. These tables can be used in future work to address research involving different users' communities and expanded to address specific needs. It is also important to notice how when designing for users with limited eyesight and/or cognitive abilities, legibility, as well as the availability of graphical and audio support, are important aspects to consider in order to provide inclusion via accessibility and usability. None of the analyzed systems are adaptive; they are all standard and not personalizable. The only customization, if available, is the setting of a "quick withdrawal" amount, which will be displayed in the menu. Offering users the possibility to adjust text and icon sizes to their needs as well as providing the option of automatically detecting if a user is color blind and in that case use the appropriate combination of colors would all together improve legibility and make the system more inclusive.

We believe ATMs are still far from being inclusive and that a joint effort from researchers in academia and industry is necessary if we want to get there. Adopting a solution that suits the majority, like the current one, can be financially and pragmatically the right thing to do. Still, people are not statistics, and it should be a priority for banks to offer basic services more inclusively, as that is the right thing to do.

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