Accessibility Evaluation of Automated Vending Machines

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Abstract. Electronic vending machines are a wide-spread system for delivering and accessing goods: the possibility of operating in a completely automated fashion and independently from business hours makes them extremely convenient for serving public and private locations. However, they fail their purpose in serving individuals with special needs: their lack of accessibility prevents users who are blind or have severe visual impairments from autonomously purchasing products. In this paper, we focus on the ergonomics of electronic vending machines and their automatic payment systems: we discuss their human factors and, specifically, usability to individuals who have severe low vision. Furthermore, we present a user experience analysis of their components and we detail the results of a study that evaluated the performance of different common types of commercially-available vending machines in the three steps of a purchase, that is, product selection, payment, and collection. Our results demonstrate that poor design, lack of tactile information, and absence of non-visual feedback have a significant impact on accessibility and prevent most customers who are blind from being able to independently select, pay, and collect a product.

Keywords: Accessibility · Blindness · eVending · Automated payment systems · Americans with Disability Act

1 Introduction

Electronic Vending machines (eVending) are a convenient method for delivering and accessing different types of goods in public locations as well as in private facilities that cannot be served otherwise, and outside office hours. Modern eVending features a variety of categories of products, such as, tickets for public transportation, electronic gadgets, books, and food and beverage. With specific regard to the latter, other than comforting customers, vending machines provide them with additional choices that include more affordable options. The success of the eVending industry is demonstrated by recent market reports, which estimate that currently there are 4.6 million automated devices in operation, in the United States alone, with an annual spending of 7 billion US dollars in food and beverage, alone [1]. Also, industry reports show a growing trend in all the diverse sectors. Moreover, the increasing adoption of eVending benefits from and facilitates the introduction of cashless technology:

according to recent statistics, vending machines that offer an electronic payment system represent 30 percent of the existing market [1].

Primarily, studies about eVending devices focused on the type and quality of food offered, on the habits of consumers, and on how to improve interaction by connecting vending machines to Internet-based services. However, human factors received less attention, and there are very few studies that investigate the usability of eVending systems. Specifically, there is a lack of understanding of the accessibility principles that enable people with disabilities to independently buy food and drinks from vending machines. Despite the numerous challenges in supporting interaction for people who are blind [2] [3], addressing and supporting accessibility is an often-overlooked aspect. The Americans with Disabilities Act (ADA) established in 2012, outlines design guidelines and details federal regulations for rendering eVending devices usable and accessible, as well as defining penalties for violations [4]. Nevertheless, ADA rules primarily address physical accessibility for people with limited mobility (e.g., wheelchair users), only, and do not consider sensory conditions, such as, blindness or severe low vision. Unfortunately, a recent article [5] reports that the Supreme Court and the U.S. Department of Justice declared that vending machines are not public accommodations under the Americans with Disabilities Act.

In this paper, we introduce a study that investigated accessibility in the most common types of automated vending machines, with specific regard to people who are blind or have significant visual impairments. We discuss the results of an accessibility assessment of the individual components of eVending devices. Moreover, we detail an experiment in which we studied the usability performance of two different types of automated vending machines in serving a group of people who experienced them as if they were blind.

2 Related Work

In the last decade, the topic of accessibility, with specific regard to individuals who are blind, received increasing attention and has been introduced as a major theme in the design of public and private spaces [6], products and appliances [7], and software [8]. Recently, the lack of accessibility in kiosks [9], eVending, and other types of self-service devices, has been considered by the research community, though there is an ongoing legal debate on whether accessibility of automated vending machines should be regulated [10]. The authors of [11] question Title III of the Americans with Disabilities Act and describes the legal pitfalls that can lead to non-compliance in the design of websites as well as self-service vending machines.

Previous studies discussed methods for supporting individuals who are blind or visually-impaired in several tasks [12], using wearable devices [13], touch- or sign-based communication [14], or implementing Braille [15]. Nevertheless, most of research resulted in new technology. Conversely, others focused on analyzing and improving accessibility of existing devices: the work of [16] investigated the use of touchscreens and other types of input devices that utilize capacitive sensors, demonstrating the impact of systems that do not provide any tactile feedback on the usability of self-service kiosks. Indeed, lack of accessibility in devices for enabling equitable use of public transportation has the largest impact on the blind community [17] [18]

[19]. Therefore, many are addressing support to mobility from different perspectives, such as, leveraging smartphones or increasing the presence of auditory and tactile feedback. Nevertheless, their applicability still requires further investigation. In this paper, we present the result of an experimental study that aimed at increasing awareness on the impact of poor accessibility in eVending. Moreover, we demonstrate the problem and describe simple and resource-effective fixes that, despite negligible investments, might lead to significant social return.

3 Experimental study

We designed a preliminary experimental study to evaluate the accessibility of vending machines to people who are blind. The objective was to discover if currently available systems can be effectively used by blind people in each of the steps of a purchase, that is, product selection, payment, and product collection. Additionally, by doing this, we also aimed at evaluating the accessibility of automatic payment systems to individuals who are blind. The experimental study was realized in the library of a state university. We chose a public space because our goal was to evaluate the use of eVending in a real-life scenario that an individual with visual impairments might encounter.

3.1 Protocol

The experimental task consisted in completing the purchase of a product. The task was repeated twice with each of the vending machines: first, they realized it while being blindfolded to simulate the circumstances of being blind; then, they were asked to repeat it without any impairment, to simulate acquisition from a control group. The order of eVending was selected at random. The experimental task was divided into three sub-tasks, that is, product selection, payment, and collection. They were recorded, timed, and analyzed separately. Subjects had a 60-second time limit to complete each sub-task, which was considered as unsuccessful after 1 minute.

Sub-task 1: selection. Subjects were verbally instructed to select a specific product: for machine A, they were asked to purchase the drink at the very bottom left; for device B, they had to select product having code 609. In addition to standardizing the protocol and removing confounding variables, this was to simulate the situation in which they already used the eVending and knew which product to select.

Sub-task 2: payment. Participants were verbally asked to complete a payment for the selected item. Regardless of the type of vending machine and product selection, product price was set at 1.75 US dollars to standardize the protocol and avoid confounding variables. This sub-task was further divided in two pieces: payment with credit card and with cash. The objective of this task was to realize which automated payment method and system might prove to be easier for a visually impaired person to operate. Before the beginning of each activity in this sub-task, participants were provided with a credit card or with 2 dollars in notes and 1 dollar in coins.

Sub-task 3: collection. In this activity, participants were verbally asked to collect the product from the dispenser. A sample item was placed in the collection container before the beginning of the sub-task. This was to provide subjects with the same type of auditory feedback they would receive if the product was released after they actually purchased it.

Before the experiment, participants were provided with informed consent form and instructions. Subjects were not allowed to touch the vending machine until the timer started. Experimental data were recorded using a camera and a paper-based experiment worksheet. After completing all the experimental tasks, participants were asked to fill out a questionnaire that collected their accessibility evaluation of each of the vending machines.

3.2 Equipment

For this study, we utilized two types of eVending: one serving drinks (A) and one snacks (B). They are shown in Figure 1. They were chosen because their components had very different design, with regard to product selection and payment. Specifically, machine A, which offered 12 products, featured a large, embossed press-button for each drink. On the contrary, machine B utilized a flat, touch-sensitive keypad to enable users to access a greater choice of products (approximately 50) by entering their code.

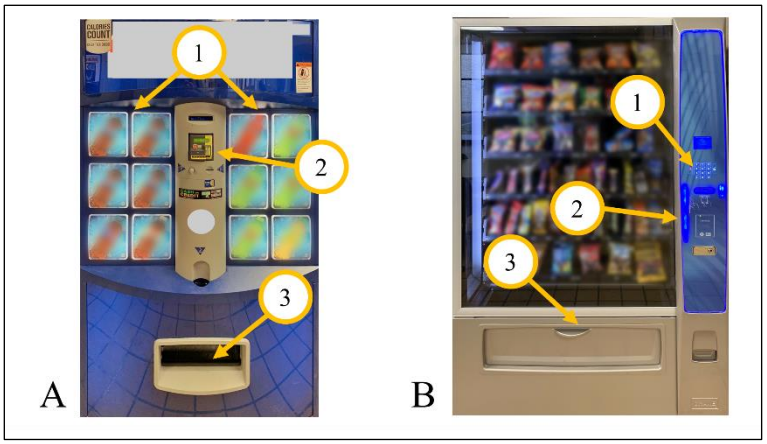

Fig. 1. The eVending utilized for the experimental study. We utilized two standard vending machines for beverages (A) and snacks (B) offering payment with both cash and credit card. Also, machine B implemented contactless payment. The numbers illustrate the different configuration of the devices in regard to: (1) product selection, (2) payment, and (3) product collection.

Furthermore, the payment system of eVending A consisted of an external unit that incorporated a vertical slot for swiping credit cards and a horizontal opening for cash; the opening for coins was located separately, on the bottom of the payment unit. Con-

versely, machine B featured 3 adjacent openings: a large vertical inset for credit cards, a horizontal slot for cash and a small vertical opening for coins. Both machines implemented released the product in a container located at the bottom: machine A had a simple opening whereas the compartment of machine B was protected by a sliding door. They are shown in Figure 2.

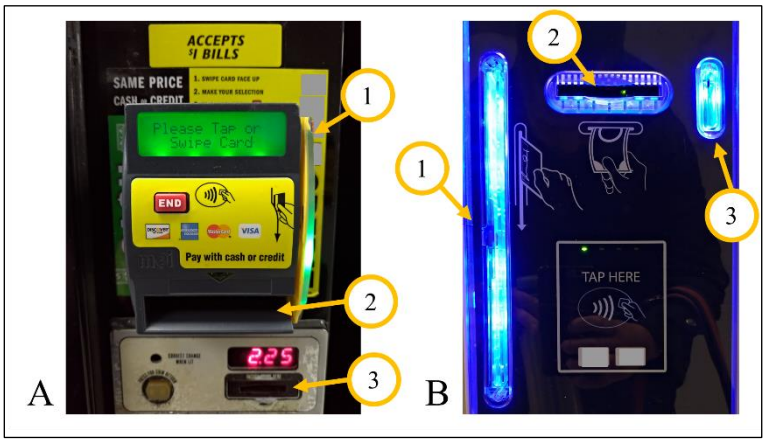

Fig. 2. The automated payment systems for eVending A (left) and B (right). The devices had different configurations. The numbers indicate the different design of the components for (1) swiping credit cards and inserting notes (2) and coins (3).

3.3 Participants

A total of 15 participants were recruited in this experimental study (12 females and 3 males); 12 (80%) aged 18-24, 2 (13.33%) were in the 25-34 bracket, and 1 (6.66%) aged 35-44. As this was a preliminary study, we did not specifically involve individuals with blindness: subjects did not have any visual impairment and their vision was generally good, though it was not assessed with any optometry test.
Participants' familiarity with vending machines was evaluated before the experiment using a self-assessment tool in which respondents described the frequency of use of eVending and their preferred method of payment.

4 Results and discussion

Our results show that very few subjects were able to complete the experimental tasks when they were blindfolded, despite the presence of the experimental staff, who suggested which product to buy, told participants the price of the item, and prevented actions that could impact the task, such as, inserting the credit card in the slot for notes. Furthermore, subjects would fail every sub-task without this type of guidance. Regardless of the simplified and supervised setting, participants were not successful in finalizing product selection using the touch-sensitive keypad incorporated in machine B, due to accidental input, lack of auditory or tactile feedback, and to the im-

possibility of recognizing individual buttons. As a result, in a real-life scenario, they would not be able to move the purchase forward. Table 1 summarizes the experimental result, with specific regard to the success rate (SR) in each task: very few subjects succeeded in paying with credit card, leading to an aggregate success ratio of 17%, on average. In this regard, the design of the payment device is key: the slots for credit card and cash are similar in shape and structure, there are very few details that help distinguishing them, and no measures prevent users from inserting the payment method in the wrong slot. On the contrary, participants were relatively successful in product collection.

Table 1. Timing (T) and success rate (SR) in the experimental sub-tasks using machine A and B. The table shows results for subjects when they were blindfolded (BF) and without any impairment (NBF). Success rate is not shown for the latter as all subjects were able to complete the task.

Sub-task	A/BF T	A/BF SR	A/NBF T	B/BF T	B/BF SR	B/NBF T
Selection	30.32 ±17.57	92.86%	2.36 ±1.88	60 ±0	0%	5.95 ±3.7
Payment - card	59.19 ±3.03	7.14%	13.04 ±12.58	51.87 ±16.7	28.57%	12.31 ±9.07
Payment - cash	51.01 ±13.22	33.33%	11.85 ±4.86	44.97 ±13.97	64.28%	17.27 ±12.8
Collection	16.5 ±16.07	92.86%	2.91 ±0.66	22.68 ±17.94	85.71%	6.79 ±8.5

The total time for accomplishing the experimental task is described in Figure 3. On average, subjects experienced a 4-fold increase in purchase time when they were blindfolded. However, as none of the experimental subjects could complete product selection with machine B, the time associated with this sub-task was 60 seconds.

Nevertheless, in a real-life scenario, individuals who are blind would not be able to select a product and, consequently, move the purchase process forward. Also, the lack of any type of non-visual feedback prevented participants from understanding if the machine was working, if they selected the right product, the cost of the selected item, if they inserted the cash or card correctly, and if there was any issue with the purchase.

In addition to quantitative data acquired during the experiment, we asked participants to complete a survey that featured items on a 5-point Likert scale. Figure 4 shows the overall usability of machine A and B, indicated as perceived frustration and accessibility. Several subjects ranked eVending as accessible, despite their frustration and even if they were not able to complete some of the experimental tasks. This might be due to a lack of familiarity with the concept of accessibility: our future work will address this aspect.

Moreover, users were asked to report the accessibility of machine A and B in each sub-task, considering the experience they had while being blindfolded (see Figure 5).

Overall the accessibility of both devices was considered less than acceptable. Despite product collection had a good outcome, respondents identified selection and payment as inaccessible. This is supported by other experimental data, which showed high failure rate in these tasks.

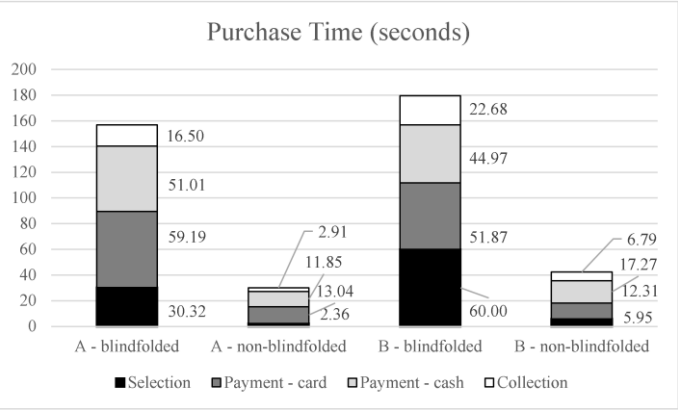

Fig. 3. Time (in seconds) for completing the different steps of a purchase, that is, selection, payment with cash or credit card, and collection. Although customers use only payment method, data are shown in an aggregated form as they describe how design affects each phase.

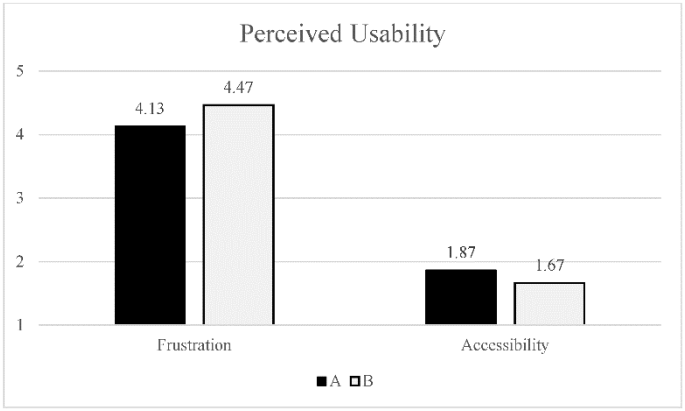

Fig. 4. Overall usability experienced by experimental subjects and displayed as frustration and perceived accessibility. Most of the users felt very frustrated with both machines, and they scored the devices as not being accessible. Unsuccessful product selection was the main reason why eVending B ranked the worst, though both devices scored very low in usability.

Cash was considered a more accessible payment system than credit card. This is mainly due to the lack of tactile indications that help locate and distinguish where to and in which side and direction to insert the card. Also, the design of the slots for inserting cash and credit cards is ambiguous, and in several instances the experiment required the intervention of the assistants, who prevented subjects from inserting the

payment system in the wrong slot. We found no significant correlation between previous experience with vending machines and perceived or calculated accessibility; moreover, participants' preferred method of payment had no impact on their ability to complete a purchase using cash or credit card.

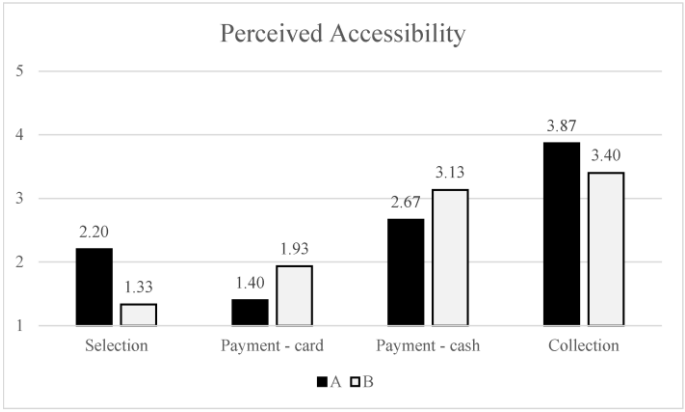

Fig. 5. Detail of perceived accessibility in each of the experimental tasks. Product selection with machine B was the lowest ranked because it was impossible for blindfolded subjects to operate the touch-sensitive keypad due to lack of tactile features and spurious input. Payment with credit card was perceived as the hardest, whereas subjects were able to use cash and coins to complete the purchase. Nevertheless, using either method was indicated as hard. Conversely, product collection was perceived as the most accessible sub-task, though the presence of the sliding door on machine B impacted the user experience.

At the end of the experiment, most of the subjects spontaneously shared their feedback about aspects that could be improved to render the eVending systems more accessible. Specifically, the majority indicated lack of auditory feedback and absence of tactile information as the main issues. Interestingly, addressing the items reported by participants would result in a negligible cost for manufacturers.

5 Conclusion

Automated vending machines are an established technology that experienced a significant growth in the last decades and its diffusion is capillary in public and private spaces. Nevertheless, their accessibility has been addressed only partially: although the sighted use this technology without major limitations and ADA defined implementation criteria for enabling people with limited mobility (i.e., using a wheelchair) to operate them, they are still not accessible to individuals who are blind; also, as regulations do not enforce any accessibility guidelines in regard to blindness, their needs are not taken into consideration. Moreover, there are very few studies on the accessibility of vending machines, kiosks, automated dispensing systems, and devices that serve more fundamental needs (i.e., mobility and personal care).

In this paper, we focused on the accessibility of eVending. Specifically, we were interested in evaluating if people who are blind can independently operate them and

successfully complete a purchase. To this end, we realized a study that involved two of the most common types of eVending offering snacks and beverage. Specifically, we realized a quantitative analysis of each task involved in the use of eVending systems, that is, selection, payment with cash- and card-based systems, and collection. Our preliminary study involved 15 participants only. Despite the small sample might limit the applicability of our results, this paper is one of the first attempts to investigate accessibility of vending machines for people who are blind. From our findings, we can conclude that the majority of eVending systems lack features that are crucial for enabling individuals who are blind to independently select, pay for, and collect a product. Current automated vending machines do not support people who are blind at all: although our data show only a 4-fold increase in the time required to blindfolded subjects to complete a purchase, this result was obtained in a setting where participants were guided in every step of the process, that is, which product to select, and the amount to be paid. However, subjects would not be able to even select a product without indications from an assistant. Moreover, our study demonstrates that the adoption of novel technology, such as, touchscreens, which might improve the look and feel of a device, involves the overlooked risk of rendering them less accessible.

Although this study focused on eVending that dispense food and beverage the results are applicable to almost all other types of vending machines as well as to kiosks providing information. In our future work, we will expand our sample and we will involve individuals who are blind, so that we can achieve more accurate results. Furthermore, based on the outcome of our study and on feedback from participants, we will work with appropriate populations on developing design guidelines that allow vendors to incorporate inclusion in their design strategy, or at least to improve the accessibility of their current devices by introducing minimal, low-cost refactoring.

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