

STANDARDS RESEARCH

New Technologies for Self-Service Devices and Their Impacts on Usability for Persons with Disabilities

September 2023

Authors

Plinio Pelegrini Morita, **P.Eng., M.Sc., Ph.D.**, University of Waterloo

Gaya Bin Noon, **B.Sc.,** University of Waterloo

Larissa Ugaya Mazza, **B.A., M.Sc,** University of Waterloo

Gillian Morgan, **B.A.,** University of Waterloo

Project Advisory Panel

Dimo Jovanov, RBC

Hilton Schwartz, Canadian Advocacy Representative

John Apgar, Diebold Nixdorf

Laura Miller, Vispero

Leslie Yee, Board Member of The Canadian Council of the Blind

Monica Ackermann, Scotiabank

Rylan Vroom, Scotia Digital

Steven Winters, Transport Canada

Dragica Jeremic Nikolic, CSA Group

Stephanie Singh, CSA Group (Project Manager)

Financial Support

This work was supported in part by Accessibility Standards Canada.

Accessibility Standards Canada | Normes d'accessibilité Canada

Disclaimer:
This work has been produced by University of Waterloo and is owned by Canadian Standards Association. It is designed to provide general information in regards to the subject matter covered. The views expressed in this publication are those of the authors and interviewees. University of Waterloo and Canadian Standards Association are not responsible for any loss or damage which might occur as a result of your reliance or use of the content in this publication.

Table of Contents

Executive Summary 5

1 Introduction 6

1.1 Impact of Disabilities 6

1.2 Types of Technological Needs and Definitions 6

1.3 Objectives 7

2 Methods 8

2.1 Technology Review 8

2.1.1 Usability 8

2.1.2 Privacy and Security 8

2.1.3 Potential for Integration 9

2.1.4 Technology Readiness Level 9

2.1.5 Availability of Relevant Standards 9

2.2 Stakeholder Consultations 10

3 Results and Discussion 11

3.1 Security and Privacy 11

3.2 Technologies for Accessible Self-Service Devices 11

3.2.1 Input Technologies for Accessible Self-Service Devices 11

3.2.2 Output Technologies for Accessible Self-Service Devices 21

3.3 Consultation with Stakeholders 24

3.3.1 Participant Characteristics 24

3.3.2 Major Themes 25

3.3.3 Solutions Proposed by Interview Participants 28

3.4 Recommendations for Inclusion of Technologies 30

3.4.1 Technologies Recommended for Consideration or Inclusion in CSA/ASC B651.2 28

3.5 Recommendations for Future Research 34

3.5.1 Usability Testing of Accessible Technologies 34

3.5.2 Training in Using Accessible Technologies 35

3.5.3 International Comparison of Accessible Technologies and Policies 35

3.5.4 Wayfinding for Self-Service Devices 35

4 Conclusions 35

References 36

Appendix A: Interview Questions 46

A.1 People With Lived Experience of Disability and Advocates 46

A.2 Industry and Regulation 47

Executive Summary

Self-service interactive devices, or kiosks, refer to devices that require user input to provide physical or electronic output to access information or services without interacting with service personnel. Self-service devices are used in retail, banking, travel, and health care. While practical benefits to self-service devices for both service providers and users are unequivocal, the requirement for increased accessibility is growing as a result of national and international efforts to develop inclusive societies.

CSA/ASC B651.2, Accessible Design for Self-service Interactive Devices, specifies the requirements for electronic and mechanical self-service interactive devices to be accessible and usable by people with blindness or low vision, hearing, physical, cognitive, or intellectual disabilities and impairments. Here, accessibility refers to the extent to which products, systems, services, environments, and facilities can be used by people from a population with the widest range of user needs, characteristics, and capabilities to achieve identified goals in identified contexts of use.

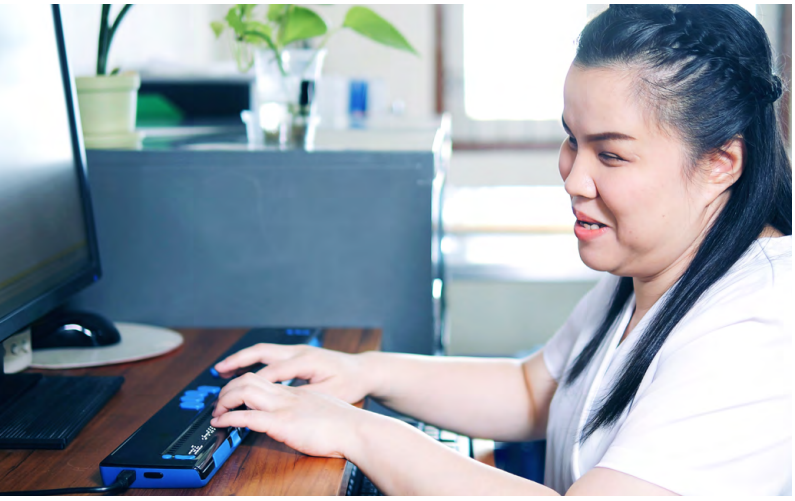
The main goal of this research project is to review new and existing input and output technologies that could be incorporated into self-service interactive devices to enhance accessibility and usability of self-service interactive devices. Each technology was evaluated to determine its purpose, readiness for use and implementation, direct or indirect applicability, applicable standards, and the evidence for its usability by people with disabilities.

The usability of a technology was determined based on the quality of the experience that people have when interacting with the technology or a product or system with which that technology is integrated. Applicability to CSA/ASC B651.2 was based on the technology's ubiquity for both personal and commercial uses as well as the quality of available literature on the usability of the technology.

Exploration of the objectives was done through two successive research approaches:

1. Literature search and technology review on existing and emerging input and output technologies potentially applicable for self-service interactive devices; and
2. Stakeholder consultations with people with lived experience of disability and industry and regulation experts to validate and explore the applicability of the research findings.

Overall, of the approximately 20 technologies assessed, 14 are recommended for consideration for review in the preparation of the updated standard: facial detection, facial recognition, sign language avatars, gesture recognition, personal device integration, word completion and prediction, screen readers, antiglare screens, text-to-speech capability, fingerprint recognition, iris recognition, voice command and dictation, text enlargement, and refreshable braille displays. These technologies were re-examined in order to take into account relevant guidance. However, the recommendations discussed in this report are not universal for all self-service devices, as various technologies recommended for inclusion may have different impacts, utility, and legal implications in varying contexts. Finally, recommendations for future research are provided.



"Adaptive technologies are objects or systems specifically designed to adapt or modify existing technologies to increase or maintain the accessibility of devices for persons with disabilities."

1 Introduction

1.1 Impact of Disabilities

The *Accessible Canada Act* was passed in 2019 with the goal of making Canada barrier-free by 2040. The Act defines a barrier as "anything physical, architectural, technological or attitudinal, anything that is based on information or communications or anything that is the result of a policy or a practice – that hinders the full and equal participation in society" of people with a disability [1]. A disability is defined as a functional limitation or restriction of an individual's ability to perform an activity [2]. According to the 2017 Canadian Survey on Disability, 6.2 million Canadians aged 15 years and older, or around 22% of the overall population, reported having a disability [3]. Among those surveyed, 23% reported having recurrent disabilities, 25% had fluctuating disabilities, and 13% had progressive fluctuating disabilities [4]. These proportions are expected to increase as the Canadian population ages [2].

Nearly 45% of people surveyed reported difficulties using information and communication technology [3]. Of these, 27% were impeded when trying to use self-service technologies [3]. To mitigate the barriers, 48.1% of youth (15 to 24 years old) reported using at least one kind of aid, assistive device, or accommodation [5]. Assistive technology describes any product, software, or equipment purchased commercially, modified, or customized to maintain or improve the functional capabilities of people with disabilities [4], [6]. These devices are not designed exclusively for people with disabilities and are commonly utilized as functional aids for hearing, vision, mobility, walking, memory, dexterity, and learning. Assistive technologies include reading glasses, closed-captioning, and switch-adapted appliances [4].

A subset of assistive technologies is adaptive technologies. Adaptive technologies are objects or systems specifically designed to adapt or modify existing technologies to increase or maintain the accessibility of devices for persons with disabilities [4], [6]. Examples of adaptive technologies include screen readers, braille, braille embossers, and tactile or haptic devices. The most frequently used adaptive technologies are specialized software or laptops and tablets (43.6%) [2]. Almost half (41.7%) of people with hearing disabilities use at least one type of assistive technology, while about one in ten (10.8%) people with vision disabilities reported using assistive devices [5].

According to the Canadian Survey on Disability, 14.0% of people with a vision disability reported having unmet needs for aids or assistive devices, while 29.6% of individuals with a hearing disability and 54.4% of individuals with learning or developmental disabilities reported that their needs for assistive technology were not being met [5].

1.2 Types of Technological Needs and Definitions

A self-service interactive device, or kiosk, is an electronic or mechanical device that requires user input to provide physical or electronic output [7]. Such devices, typically interactive tablets or touchscreen

computers, allow a person to access information or services without directly interacting with service personnel. Self-service devices are used in retail, banking, travel, and health care, and include (but are not limited to) check-in tablets at medical offices, check-in kiosks at airports, self-ordering kiosks in restaurants, and point-of-sales systems at retail stores [8]. For retailers and service providers, the benefits of using self-service devices include cost reduction, increased customer satisfaction, and extended market reach [8]–[10]. On the other hand, the accessibility of self-service devices must take into account their usability by people with disabilities and the security of these technologies.

The ISO 9241 series outlines ergonomic requirements for human–computer interactions, providing guidance on the accessibility and usability of interactive systems [11]. ISO 9241-112 [12] defines accessibility as "the extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use," and the term accounts for "direct use or use supported by assistive technologies". ISO 9241-11 [13] defines usability as "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."

A major limitation in the accessibility of self-service devices is beyond the technical characteristics of the self-service devices themselves. Users, particularly those with vision disabilities, may not be aware of the presence of adaptive technologies in a self-service device when encountering it for the first time. Furthermore, the available accessibility features may not meet a person's specific needs. In those instances, the user may have to request assistance from staff, which undermines the fundamental purpose of a self-service device, or resort to asking a stranger for help, risking revealing their personal information [14].

CSA/ASC B651.2 [7] specifies the requirements for accessible electronic and electromechanical self-service interactive devices usable by people with vision, hearing, and physical disabilities. CSA/ASC B651.2 is referenced in the *Accessible Transportation for Persons with Disabilities Regulations* [15]. CSA/ASC B651.2 [7] includes requirements for accessible design for automated teller machines (ATMs).

CSA/ASC B651.2 [7] defines a self-service interactive device as "any machine where the user may need to enter data, read presented information, respond to prompts, or select from a number of choices for a service to be performed." Moreover, it defines accessible as the way "the design or adaptation, or both, of self-service interactive devices, sites, and exterior spaces possess the necessary characteristics for them to be as usable as practicable."

1.3 Objectives

The goal of this research project was to review new technologies and provide recommendations for consideration of applicable technologies to update the CSA/ASC B651.2 Standard, and to enhance the accessibility and relevancy of self-service interactive devices. The main objectives were to identify and review novel input and output technologies and determine the feasibility of including them in self-service interactive devices to enhance the accessibility and relevancy of these devices, as well as to determine the feasibility of including novel input and output technologies by people with disabilities. Other objectives of this work were to:

- Exemplify the use of the identified emerging technologies to enhance the accessibility of input technologies (which prompt the device to perform some action) or output technologies (which present information to the user) for self-service devices; and
- Understand users' experiences in order to identify gaps and provide recommendations for improvement of self-service devices.
- The research into the identified technologies considered the barriers experienced by people with disabilities that, for the purpose of this report, have been grouped into the following types: physical, vision, cognitive, and hearing.

2 Methods

Qualitative research methods [16]–[18] were used in two phases:

1. Literature review of scientific journals, standards, and other documents, and an environmental scan of applicable emerging technologies; and
2. Analysis of data obtained through interviews with people with lived experience of disability and experience with the use of adaptive technologies in a real-world setting, advocacy groups or organizations, industry experts, and regulators.

2.1 Technology Review

The research team undertook a literature review and environmental scan to identify and examine novel technologies currently on the market. The reviewed documents included academic peer-reviewed literature and grey literature published between 2012 and 2023 and retrieved via the databases Scopus, PubMed, EconLit, and GreyNet International and via the search engines Google Scholar and Google Search. Search terms included "kiosks," "self-service," "disability," "accessibility," and "usability," the disability types, and technologies discovered through the preliminary literature review and interviews, and advisory panel. This multifaceted search protocol was necessary because of the number of technologies covered by the research objectives and the technologies' different levels of maturity [19, 20].

A list of 22 existing technologies (refer to Recommendations section for the summary of technologies) was retrieved based on a literature search of the available evidence [3], [21], [22]. Each technology was evaluated to determine its purpose, readiness for use and implementation, direct or indirect applicability, applicable standards, and the evidence for its usability by people with disabilities.

Each of these technologies was reviewed in terms of their applicability to CSA/ASC B651.2 based on the following criteria: usability; privacy and security; potential for integration into self-service devices, or usefulness; and technology readiness level (TRL). These criteria are detailed further in sections 2.1.1 through 2.1.4.

Findings are discussed in detail in the Results and Discussion sections and summarized in Tables 1 and 2. The evaluation based on these criteria describes the broad application of these technologies in self-service devices. However, the recommendations that are based on these criteria are not universal and the context of use must be taken into account, that is, some technologies (e.g., facial recognition) may be limited by legal or practical considerations in one setting, but advantageous and widely acceptable in others.

2.1.1 Usability

Usability refers to the extent to which specified users can use a system, product, or service to achieve specified goals effectively, efficiently, and to their satisfaction in a given context of use [13]. The usability of a technology was determined based on the quality of the experience that people with and without disabilities have when interacting with the technology or a product or system with which that technology is integrated. Applicability to CSA/ASC B651.2 was based on the technology's ubiquity for both personal and commercial uses as well as the quality of available literature on the usability of the technology.

Published empirical usability data were considered complete if the technologies were tested by people with disabilities and people without disabilities. Published literature on usability testing of technologies by people without disabilities was considered to be "partial," having potential, but with limitations. The literature that did not include empirical tests to assess usability of technologies was considered inadequate.

The insights of people with lived experience of disability and experience with the use of these technologies in real-world settings were also taken into account in the recommendations. Interviewees' descriptions of the technology as functional and easy to access was considered more useful than their comments on how hard or useless the feature was.

2.1.2 Privacy and Security

Data privacy refers to the rights and obligations of individuals and organizations with regard to the collection, use, retention, disclosure, and disposal of personal information [23]. Security refers to the



"Data privacy refers to the rights and obligations of individuals and organizations with regard to the collection, use, retention, disclosure, and disposal of personal information."

protection of data from intentional or unintentional destruction, modification, or disclosure [24]. For example, dictation functions could pose a privacy concern if people nearby can overhear someone dictating their personal information; however, dictation is not a security concern unless the voice data are stored to serve as a form of identification and could be stolen.

The governance of privacy and security issues are outlined under the *Personal Information Protection and Electronic Documents Act* (PIPEDA), Canada's federal privacy statute [25]. PIPEDA regulates identifiable data collection and information storage to ensure the safety and privacy of the people whose data were collected [25]. Further information about PIPEDA and its implications on the technologies are outlined in section 3.1.

2.1.3 Potential for Integration

The potential for integration, or usefulness, of a technology was defined as the extent to which it can be integrated into self-service devices. Two forms of integration were considered: either the technology could be built into, or integrated into, the self-service device; or a user's personal device, with the technology, could be connected to and synchronize with the self-service device, to fully or partially interact with the system. Personal device integration was only considered for the technologies brought by the user, such as headphones or braille notetakers.

2.1.4 Technology Readiness Level

The technology readiness level (TRL) refers to a technology's level of maturity, or degree of development and readiness for use, described on a nine-point scale [26]. There are four broad technology development stages in TRL: fundamental research; research and development; pilot and demonstration; and adoption and commercial availability [26]. Each TRL score is associated with a checklist of activities that must be met before a technology is considered at a particular level [26]. To be considered in this feasibility assessment, a technology had to be commercially available or have a TRL of 9, meaning that it was in the early adoption stage, had been successfully deployed and proven in a variety of operational settings, and operational tests and reports have been completed for the prototype. TRLs were assigned based on a technology's readiness and level of adoption as reported in economic articles, press releases, or other product-related communications.

2.1.5 Availability of Relevant Standards

Relevant standards that provide guidance on the design or performance of each technology were identified. Although these standards do not necessarily outline requirements related to the use of the technology in self-service interactive devices, many of the reviewed technologies are commonly used in other contexts.

Most of the relevant standards were developed by International Organization for Standardization/ International Electrotechnical Commission (ISO/ IEC) technical committees and subcommittees. The scope of the ISO/IEC JTC 1 technical committee is standardization in the field of information technology [27]. ISO/IEC JTC 1/SC 35 subcommittee specifically manages standards related to how user interfaces in information and communication technology environments support all users, including those with different accessibility needs [28]. ISO/TC 159/SC 4 subcommittee manages ergonomic guidance for human-system interactions and is responsible for the standardization of hardware ergonomics (e.g., input and output devices, displays, and interactive devices), software ergonomics (e.g., interaction and interface design), ergonomics in the context of use (e.g., task relevance and built environment), and human-centred design processes and methods (e.g., participative design, accessibility, and usability engineering) [29]. ISO/TC 173/ SC 7 subcommittee is responsible for standards related to assistive products designed to assist people with impaired sensory functions in their daily activities and social interactions [30]. ISO/IEC JTC 1/SC 37 covers the standardization of generic biometric technologies involving human beings to support interoperability and safe and secure data exchange [31].

2.2 Stakeholder Consultations

Results of the literature review and environmental scan led to identifying major areas of technological accessibility for further investigation to better inform the semistructured interviews. The semistructured interviews were conducted according to established qualitative methods [16]–[18], [22], [32], in consultation with the project advisory panel, which was made up of individuals with lived experience of disability, industry members, and disability advocates. A semi structured interview allows questions to be modified during the interview based on the backgrounds and expertise of the interviewees [33]. Interviewees included experts from three domains:

- Users with lived experience of disability;
- Disability advocates; and
- Manufacturers and regulators of self-service devices and accessible technology.

The project advisory panel suggested relevant groups and individuals who might be interested in participating in the interviews. Potential participants were sent an informed consent letter outlining the purpose of the interview and the intended outcomes of this report and were asked to confirm their participation. Interviews were conducted via Microsoft Teams or Zoom, according to each participant's preference. Interviews were recorded and transcribed, and the content of the transcripts analyzed by three researchers using content analysis [16], [34]–[36], with the aim of understanding the participants' perspectives on and concerns related to the use of select technologies, including any complexities not reported in the literature.

The main themes that arose in the interviews are discussed as recommendations for further consideration by the technical committee responsible for maintaining CSA/ASC B651.2, outlined in section 3.3 of this report. The interview guide was slightly modified for experts operating in the industry. For a full list of interview questions, refer to Appendix A.

The interview questions were designed to explore the following:

- Participants' own experiences with accessible technologies, if applicable;
- Users' comprehension of an ideal accessible system for self-service devices;
- Concerns about self-service devices; and
- The current state of industry efforts to make self-service technologies more accessible, including training and usability.

While the needs of the participants were taken into account wherever possible, limited project resources precluded providing sign language interpretation services. As such, we acknowledge a limitation in our ability to represent the perspectives of the Deaf people and sign language users.

3 Results and Discussion

3.1 Security and Privacy

PIPEDA establishes rules for the use and collection of biometric data, including facial, palm, fingerprint, and iris recognition [25]. PIPEDA is Canada's federal privacy statute and regulates the collection, use, and disclosure of personal information by the private sector for all commercial settings in Canada, including federally regulated organizations (e.g., banks, air transportation, telecommunications) [25]. Alberta, British Columbia, and Quebec are exempt, but have enacted similar laws governed at the provincial level [25].

Within the scope of technologies for self-service devices discussed in this report, biometric data may be used to identify or authenticate an individual for several reasons, including confirming their entitlement to services, monitoring or recording certain individual experiences, or authenticating personal identity [37]. Furthermore, as biometric data are unique to each individual, the organizations collecting these data must operate under PIPEDA's fair information principles to ensure the protection of each user's personal information [25].

3.2 Technologies for Accessible Self-Service Devices

This section describes each technology's purpose and the barriers the technology could help overcome. Note that in some cases, the technology was not explicitly designed as an assistive technology, but persons with disabilities may still benefit from its integration into a self-service device. Technologies were grouped into input and output technologies for accessible self-service devices based on whether they prompt the device to perform some action (input) or present information to the user (output).

3.2.1 Input Technologies for Accessible Self-Service Devices

In this section, 15 input technologies are described in terms of their usability, privacy and security, integration (or usefulness), the barriers the technology could help overcome and relevancy to CSA/ASC B651.2. All but one are commercially available.

3.2.1.1 Facial Detection

Facial detection is a technique that allows machines to scan images and videos and determine the presence of human faces via artificial intelligence [38]. This technique generally involves an algorithm that, when paired with a camera, can read images and distinguish between human faces and background images. This technology is often the precursor to facial recognition and facial gesture recognition [38]. To recognize a face, the algorithm first locates and maps human eyes, lips, nose, and ears to construct an image of the face [38]. Once that mapping is done, the algorithm conducts more tests to ensure that what it detected is a human face [38].

Facial recognition algorithms have been upgraded over the last couple of years to take into account the increased use of facemasks during the COVID-19 pandemic [39].

Several commercially available solutions are available, including ones that could be suitable for self-service interactive devices.

Facial detection is an accessible technology that could play an important role in automating self-service devices. On detecting and identifying a user, facial detection technology could trigger planned interactions, such as greetings and appropriate offers of assistance. The technology can also be used to determine the presence of other people, which could affect user privacy. Although a user must show their face, or a part of it, for the technology to identify them, sacrificing some privacy, facial detection does not affect an individual's data security as biometric data are not stored in the self-service device after a face has been detected and identified.

There are no existing standards related to facial detection technologies. Nevertheless, facial detection should be considered for integration with self-service interactive devices because it is a preliminary technology for other facial analysis algorithms, including facial recognition [40]. While facial recognition will authorize certain system functions based on an individual's identity, facial detection can determine whether a human face is in an image and activate general system functions.

Facial detection technology could be useful for people with blindness or low vision, cognitive and other disabilities because the system can begin to operate and automatically provide guidance when a face is detected, without requiring physical input. However, the inclusion of facial detection also requires taking into account output technologies that can support individuals with physical, cognitive, and vision accessibility needs to receive the information a self-service device presents. Difficulties may arise when there are too many faces in the image, poor lighting, low image resolution, complex background, face occlusions (e.g., glasses, scarves, hair), facial expressions, and anthropometric differences [40].

3.2.1.2 Facial Recognition

Facial recognition technologies match the image of a user's face against a reference image for authentication. This process involves using sensors to recognize a human face, analyzing facial geometry and key features, and comparing the unique facial signature against a database of known faces [41].

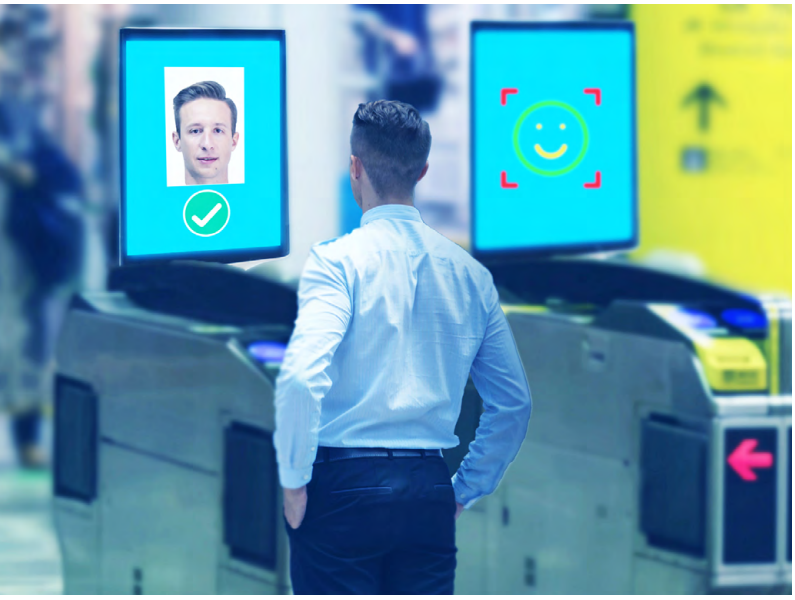
Commercially and operationally deployed facial recognition solutions relevant to self-service interactive devices are available on the market [42-43]. Recent advances have enabled facial recognition tools to accommodate individuals who are wearing glasses [44] or facemasks [39]. However, facial recognition presents a challenge for both privacy and security: an individual's face must first be detected by the self-service device, with the biometric data then analyzed alongside a database of images stored for identification purposes. According to PIPEDA, users must be aware of the collection, use, and disclosure of personal information, and any such collection, use, or disclosure of personal information must only be for purposes that are reasonable and appropriate in the circumstances. The requirement to demonstrate reasonable purpose for collection may be challenged in various contexts, including numerous commercial and retail settings. This is especially prudent where minors use the devices; while PIPEDA does not differentiate between adults and youth and children, the photography and collection of data of youth and children should be treated with sensitivity and may require additional safeguards and security measures [25].

Three relevant standards for facial recognition technology were identified. CSA ISO/IEC 19794-5 [45] specifies the data format and the scene, photographic, and digitization properties required for images of faces to be used in the context of both human verification and computer-automated recognition. It presents specifications for the storage, recording, and transmission of facial images and data. Using technologies that comply with CSA ISO/IEC 19795-5 [46] would facilitate scalability and interoperability across different self-service interactive devices and technologies. However, CSA ISO/IEC 19795-5 [46] specifies that these guidelines are not tailored to users with disabilities, lacking provisions for irises that are not visible or faces that are incorrectly positioned in front of the camera. It specifies that specialized applications will warrant specialized testing processes.

IEEE P2884 [47] defines requirements and testing methods for a facial recognition testing system for end-user devices. Key metrics for this standard include false acceptance rates, false rejection rates, attack presentation false acceptance, and bona fide presentation false rejection rate.

Alongside IEEE P2884 [47], CSA ISO/IEC 30137-1 [48] sets a precedent for facial recognition devices, including cameras and software, to produce high-quality, consistent, and accurate images, minimizing the number of system errors and improving device usability. Improving system functions and the capabilities of facial recognition technologies will allow an individual with anthropometric differences or with disabilities to direct their eyes at the self-service device, to be recognized by the self-service device, and to be authorized to complete tasks [48]. Reducing the number of system errors allows individuals with and without disabilities to operate self-service devices independently, without assistance from service personnel.

Facial recognition requires the self-service device to obtain and store biometric data and subsequently access the data from within the device. The organizations operating the devices must adhere to PIPEDA's fair information principles [25], and request consent from the individuals whose data are being collected. Based on the sophistication of this



"The adoption of facial recognition technologies will need to take into account the legal limitations of integrating them and the hesitancy towards their widespread adoption, particularly in terms of the personal data of minors."

technology, facial recognition technology may be of greater use in some self-service devices, for example, an ATM or health kiosk versus a point-of-sale or food-ordering kiosk.

The adoption of facial recognition technologies will need to take into account the legal limitations of integrating them and the hesitancy towards their widespread adoption, particularly in terms of the personal data of minors. However, facial recognition technology offers individuals, including those with physical, vision, and cognitive disabilities, another input method when accessing services and completing tasks that require a high level of personal authentication. As such, facial recognition technology should be considered for integration with self-service interactive devices and is recommended to be considered for inclusion in CSA/ASC B651.2.

3.2.1.3 Facial Gesture Recognition

Facial gesture recognition can be applied to self-service devices to provide users with an input option that does not rely on the use of arms or hands. Instead, the systems read the facial gestures of users and convert them into actions. For example, a person can use their tongue or head to point at something on a screen and the interface will read that movement and respond accordingly [49]. Specific commands could be associated with gestures such as nods, smiles, and winks [50]. Aspects of this technology were originally developed with the intent of supporting people with limited mobility or balance and posture impairments [51]. Facial gesture technology may improve accessibility for people with physical, and intellectual disabilities [52], [53].

The TRL score for facial gesture recognition is 6 (TRL 6) as prototypes have been demonstrated and tested in a simulated environment [26]. However, the prototypes are generally being tested for usability under limited conditions by, for example, research groups and manufacturers. There are no perceived privacy or security concerns associated with this technology.

Although there are no standards specific to facial gestures, standards related to gesture technologies for the control of interfaces could serve as basis for their development. As an example, ISO 9241-960 [54] provides guidance on determining and selecting body gestures and the factors to consider when defining gestures, although not specifically facial gestures. ISO/TS 9241-430 [55] informs the selection of the most effective arm and hand gestures for human–computer interaction, specifically recommending usability and ergonomics in gesture selection to prevent fatigue and discomfort while gesturing. ISO 9241-960 [54] and ISO/TS 9241-430 [55] could be used as guidelines when evaluating and assessing facial gesture technologies to support accessibility and usability of self-service devices by people with varying mobility functions.

ISO 9241-910 [56] defines common terms and describes various concepts that are relevant when

designing devices with tactile and haptic interactions. ISO 9241-940 [57] describes ways of evaluating tactile and haptic interaction based on interaction quality, haptic device attributes, and logical space and design usability. ISO 9241-910 and ISO 9241-940 could include people with disabilities when evaluating tactile and haptic interactions to determine how individuals who use wheelchairs and mobility aids may benefit from different physical configurations of the space around self-service devices.

No facial gesture devices are currently commercially available or operational. Therefore, facial gesture technology should not be considered for integration with self-service interactive devices and is not recommended for consideration for CSA/ASC B651.2. However, as facial gesture recognition is an adaptive technology for individuals who may not benefit from full-body gesture recognition, for example, people with physical disabilities, this technology could be reconsidered in the future after further development.

3.2.1.4 Head-Mounted Pointers

Head-mounted pointers are a group of devices that allow objects to be manipulated or mouse pointers to be controlled via voluntary head movements [58]. Variations include a simple mechanical pointer, which acts like a finger, and a laser pointer that often requires an embedded sensor in the screen. Commercially and operationally deployed head-mounted pointers are available, but have typically been developed for people's personal use, rather than being part of a communal commercial device.

There are no security or privacy concerns associated with using head-mounted pointers. In the case of simple mechanical pointers, no additional modification is needed to allow the user to interact with the self-service device. In the case of laser pointers, self-service devices would require embedded laser sensors.

ISO 9241-410 [59] provides guidance on the design of physical input devices for interactive systems. These devices include keyboards, mice, pucks, joysticks, trackballs, trackpads, tablets and overlays, touch-sensitive screens or touchscreens, styli and light pens, and voice- and gesture-controlled devices. Although ISO 9241-410 does not specifically cover head-mounted pointers, the guidance could apply as it provides generic design criteria based on user abilities. In turn, ISO/TS 9241-411 [60] specifies ways to evaluate the design of these physical input devices.

Although head-mounted pointers may be beneficial to individuals with physical disabilities, there is insufficient evidence on their usability and practicality when integrated with self-service interactive devices. This technology is not recommended for consideration in CSA/ASC B651.2.

3.2.1.5 Voice Command and Dictation

Voice command and dictation allow the user to interact with a device solely through speech. The device has a built-in microphone and uses artificial intelligence and natural language processing to analyze a user's speech and accommodate variations in speech quality and phrasing [61]. Voice command allows the user to direct the device to perform certain actions. Dictation, or speech-to-text, transcribes a user's speech, providing an alternative to typing. Any voice command technology should theoretically have dictation capability, but a dictation technology will not necessarily have voice command and invoke specific actions. Either voice command or dictation can be combined with voice recognition for additional security or a more personalized user experience.

Several commercially and operationally deployed solutions are on the market, including for self-service interactive devices. This technology could apply to a wide range of accessibility needs [62], [63].

While there are no security concerns associated with voice command technologies, there are significant privacy concerns if individuals audibly input personal information and passwords in the presence of bystanders.

Two standards apply to voice command and dictation, and both have been adopted in Canada. CAN/CSA ISO/IEC 30122-1 [64] provides a framework and general guidance for essential voice commands and outlines

a limited number of commands that the user could memorize to facilitate the use of devices, but it does not provide guidance for natural language processing. CAN/CSA ISO/IEC 30122-2 [65] provides test methods for voice commands and speech recognition, including phonetic requirements for spoken words or phrases. Applying both standards to self-service devices would result in a relatively consistent user experience at different self-service devices, improving overall accessibility and usability.

In addition, ISO 9241-154 [66] and ISO/IEC 13714 [67] describe interactive voice response and voice messaging applications in telephone-based services. ISO 9241-154 [66] provides general guidance for user interface design in interactive voice and automated speech systems and contains requirements developed to accommodate callers with special needs. ISO/IEC 13714 [67] provides guidance on maintaining a consistent mode of interaction, independent of the underlying operating system. While these standards are not directly related to the development of self-service devices, they are useful for understanding the requirements of interactive voice systems across different operating systems. Although incorporating call answering into self-service devices is not recommended, these standards demonstrate ways of improving voice controls and dictation that may be relevant to how users interact with self-service devices. Lastly, ISO 9241-410 [59] provides guidance on interaction design for voice commands and dictation systems, while considering the capabilities and limitations of different users.

ISO 9241 could specify use conditions for user populations with different disabilities, including physical, vision, hearing, and cognitive disabilities. Further consideration should also be given to the environment where the device will be used, and how noise levels may affect voice command features. Voice command is a widely adopted and practical technology that individuals, including those with vision, physical, and cognitive disabilities, can use to input information and complete tasks. While individual security needs to be taken into account, voice command that can be applied to many self-service devices, including food-ordering kiosks, check-in stations, and point-of-sale terminals. As such, voice command and dictation are recommended for integration with self-service interactive devices and for consideration for inclusion in CSA/ASC B651.2.

3.2.1.6 Palm Recognition

Palm recognition technology scans the user's palm and authenticates them based on specific characteristics such as lines, ridges, vein patterns, palm prints, and hand geometry [68], [69]. Typically, the user hovers their palm over a scanner, without having to touch the palm reader, which makes the process more hygienic than fingerprint recognition techniques [69].

A number of commercially and operationally deployed solutions are on the market. Palm recognition has been adopted on a global scale in a variety of settings including federal institutions (e.g., banks) and retail stores [68], [70]. While there are no associated privacy concerns, there are several security concerns because palm recognition requires the collection, use, and possible disclosure of biometric data to identify the user and enable functions on self-service devices.

ISO/IEC 19794-15 [71] specifies requirements for interchangeable record formats for palm creases for the purpose of identification and verification, which falls under PIPEDA's regulation of the use of personal information [25].

Palm recognition may enhance the user experience by reducing additional input for personal authentication. However, the technology requires that users locate the palm recognition sensors and then hold their hand steadily in a precise position over the scanner [[72], which may present difficulties for people with vision or physical disabilities [58], [72].

Given these accessibility challenges, palm recognition technology is not recommended to be considered for integration with self-service interactive devices or inclusion in CSA/ASC B652.2.

3.2.1.7 Fingerprint Recognition

Fingerprint recognition compares a person's fingerprint with existing verified fingerprint scans to authenticate the person's identity. This technology: (1) captures



fingerprint data through a sensor; (2) pre-processes the data to remove impurities or incomplete data; (3) processes the image to extract data about the fingerprint that can be used for recognition; and (4) matches the fingerprint data with an existing database to confirm the user's identity [73]. Fingerprint data can be collected in several ways, including through two-dimensional imaging, three-dimensional mapping of finger ridges, or comparing the minute details inherent in each fingertip [74], [75].

The technology is commonly applied in cellphones, and various fingerprint recognition systems are commercially available. Still, fingerprint recognition requires individuals to correctly place and hold their finger over a scanner, which can be challenging [76], [77].

Fingerprint recognition in a self-service device presents a security concern as it involves the collection, use, and possible disclosure of a user's biometric data. In these instances, the organization responsible for the self-service device must adhere to PIPEDA's ten fair information principles [25].

ISO/IEC 19794-8:2011 [78] provides guidance on how a fingerprint can be recorded, thus defining parameters for algorithmic and computational procedures [60]. ISO/IEC 19794-2:2011 [79] focuses on the concept of minutiae, which is the matching of two fingerprints based on the number of minute details shared. IEEE P2891 [80] specifies a fingerprint test system for smart devices, to evaluate performance metrics such as false acceptance rates and false rejection rates [80].

Overall, fingerprint recognition is recommended to be considered for integration with self-service interactive devices and inclusion in CSA/ASC B651.2, as this technology provides an alternative input method for individuals with cognitive or physical disabilities, while minimizing the amount of personally identifiable information necessary to authorize certain system functions. Although there are some accessibility concerns related to the fine motor functions required to scan a fingerprint, ergonomic considerations can be given to the size and design of finger scanners. Fingerprint recognition may not be necessary on self-service devices that do not require personally identifying information, such as food-ordering kiosks and self-checkout machines.

3.2.1.8 Iris Recognition

Iris recognition is widely regarded as one of the most effective ways to collect biometric information [81]. After an invisible infrared light is shone into the eye to reveal the unique and otherwise invisible patterns of an iris [82] , the technology compares these patterns with existing verified iris scans. Iris recognition can be used in dark or poorly lit environments [81]. Moreover, it is contactless and unaffected by face accessories such as glasses or face masks [81], although false rejection

rates vary with different types of contacts and artificial lenses [82]. There are no privacy concerns, although there are security concerns as this technology involves the collection, use, and possible disclosure of biometric data. Under PIPEDA, organizations must comply with the rules and regulations for data collection, use, and disclosure, and must obtain informed consent from the users [25].

A number of commercially and operationally deployed iris recognition solutions are on the market.

ISO/IEC 19794-6 [83] details iris image interchange formats for enrolling (i.e., collecting and storing data for later comparison), identifying, and verifying systems. ISO/IEC 29794-6 [84] establishes standards and methods to quantify the quality of iris images, including normative requirements on the software and hardware that produce the iris images and measure the image's usability. Lastly, IEC 62471 [85] provides requirements such as exposure limits for lamps and lamp systems used in iris cameras and reference measurement techniques for the control of the photobiological hazard.

Overall, iris recognition is recommended to be considered for integration with self-service interactive devices and inclusion in CSA/ASC B651.2, as this technology may be useful as a way of confirming identity without requiring additional user input. However, iris recognition may be inaccessible or not useful for people who are blind or with a visual impairment. Additional consideration must be given to the ergonomic design of iris recognition technologies in self-service devices, taking into account people's different heights or if users have to approach the device at an angle.

3.2.1.9 Braille Keyboard

Braille keyboards are built-in or portable assistive technologies intended for inputting information into, rather than receiving information from, a digital system [86]. Braille keyboards include standard braille-embossed QWERTY keyboards, which require the user to memorize the sequences of keys to select the correct character. These are less popular than braille notetakers, which typically have unique custom-designed hardware and software that includes a refreshable braille display for reading braille output and either a braille keyboard or touchscreen-based emulation for braille input.

A number of commercially and operationally deployed solutions are on the market. There are no security or privacy concerns associated with using braille keyboards.

ISO 17049 [87] details the requirements for braille users around the world as well as guidelines for implementation of braille on equipment, appliances, and signage. There are two distinct forms of Unified English Braille (UEB), the official braille language of North America: contracted and uncontracted. Uncontracted UEB uses the complete form of words, whereas contracted UEB uses shorthand, special symbols, or abbreviated words. French diacritics can be added to UEB braille tiles to denote accents and pronunciation, but Code Braille Français Uniformisé (Unified French braille, or CBFU) is commonly used by people who know French braille [88].

Although alternatives to braille input exist (e.g., voice commands and dictation), they may not be preferred by or appropriate for everyone. In addition, consideration must be given to individuals who use braille systems from before the adoption of UEB in 2010 and are familiar with Nemeth code for mathematics and scientific notations in braille [89]. While braille keyboards are equipped to produce both forms of UEB, it is necessary to consider whether a self-service device can understand input in all braille forms.

Braille keyboards are not currently recommended for consideration in CSA/ASC B651.2 as both braille-embossed QWERTY keyboards and braille notetakers are difficult to integrate with self-service devices and will not benefit braille users, including people with vision loss or visual impairment, to the extent that other input methods may. Braille-embossed QWERTY keyboards are outdated and require the user to have memorized the sequences of keys to select the correct character. On the other hand, braille notetakers are highly customized devices that are unique to each braille user. Other

considerations are the space and configuration required to embed a braille keyboard on a self-service device and the hardware necessary to incorporate a personal device into the self-service device.

3.2.1.10 Gesture Recognition Devices

Gesture recognition devices (e.g., mice, styli, joysticks, touchscreens) allow the user to interact with a device through hand movements. These movements are captured by sensors and interpreted by the device as commands. Tactile gestures that are specific to the screen readers are described in Section 3.2.2.1.

A number of commercially and operationally deployed solutions for gesture recognition are on the market, mostly for use in or with personal devices such as computers and cellphones [90]. Although these gesture recognition devices are designed for the convenience of all users, they may be useful alternative input methods for those with fine motor control disabilities or difficulties with manual dexterity. Gesture recognition may not be useful for individuals who have quadriplegia or whose ability to gesture or maintain control of their hands or arms is affected.

The usability of this technology has been tested with people with spinal cord injuries and with hearing impairments and people experiencing the physical and mental effects from a stroke. Users have found gesture recognition technology a positive addition when learning to use a new system, increasing their motivation to use a device [91], [92].

There are no security or privacy concerns associated with gesture recognition devices.

ISO 9241-971 [93] provides guidance for increasing the accessibility of interactive systems that make use of tactile and haptic input and output modalities, including gestures, vibration, and force feedback. ISO 9241-971 [93] also describes the application of haptic and tactile interactive systems to inaccessible devices, which CSA/ASC B651.2 could reference as guidance on the implementation of haptic interactions in self-service devices. An important consideration is the placement of the sensors on the devices; they should be able to capture the movements of people with different statures or those who position themselves in a different way in front of the device. For example, if someone in a wheelchair cannot face the self-service device, they may have to approach it from the side.

Similarly, ISO 9241-410 [59] provides recommendations for ergonomic design. These recommendations are given for a context-free environment; CSA/ASC B651.2 could therefore take into account cases that are specific to individuals with disabilities, in environments with varying degrees of distraction, space requirements, and lighting. In addition, ISO 9241-960 [54] provides guidance on the selection or determination of the gestures to be used in a gesture interface. Using devices that comply with ISO 9241-960 would ensure that all self-service interactive devices using this technology provide a relatively consistent user experience, improving accessibility. ISO 9241-960 does not dictate system response and, therefore, may be adapted for the needs of the device [54].

ISO/IEC 30113-11 [94] defines common single- and multi-point gestures for gesture interfaces. Single-point gestures, such as single taps and clicks, swipes, and drags, are common system actions in information and communication technologies, performed with an input device (e.g., mouse and stylus) or a body part (e.g., fingertip and hand). ISO/IEC 30113-12 [95] specifies common multi-gesture movements or inputs, such as two-point taps or two-finger swipes.

Overall, it is recommended that the broad application and feasibility of single-point gestures in self-service devices be determined, and that gesture recognition devices be considered for inclusion in CSA/ASC B651.2.

3.2.1.11 Single-Switch Entry Devices

A single-switch entry device refers to an assistive technology that is typically used with on-screen or virtual keyboards to eliminate physical interaction with these devices. A cursor moves automatically across the keys of the on-screen keyboard or menu, and when the desired item is in focus, the user presses, flips, or clicks the switch [96].



A number of commercially and operationally deployed solutions are available. However, these are most commonly embedded in or used with personal devices such as personal computers. Still, single-switch entry devices can provide an alternative input method for people with physical disabilities. Furthermore, single-switch devices do not present security or privacy concerns for users.

No relevant standards apply to this technology.

Single-switch entry devices are not recommended for integration with self-service interactive devices or CSA/ASC B651.2 consideration as there is not a large enough commercial interest to necessitate their inclusion in a meaningful way.

3.2.1.12 Foot Switches

A foot switch is an adaptive foot-operated switch, pad, or pedal. By tapping or pressing the foot switch, the user prompts the compatible software to enact a specific action or command in a computer [96]. A number of commercially and operationally deployed solutions are available, but these are most commonly embedded in or used with personal devices such as computers or home appliances and fixtures.

Although similar to single-switch entry devices, foot switches offer individuals an input method that does not require hand and finger dexterity, potentially providing support for users with physical disabilities. However, these devices are likely to only benefit a small portion of people with mobility issues.

No relevant standards apply to this technology. There are no security or privacy risks associated with using foot switches in self-service devices. While the interest in and ubiquity of these devices is still growing, there is not a large commercial demand for foot switches as assistive accessibility technologies. As such, foot switches are not currently recommended for integration with self-service interactive devices or CSA/ASC B651.2 consideration.

3.2.1.13 Eye Tracking

Eye tracking allows users to interact with a device by controlling a cursor or a keyboard on a screen or surface through voluntary eye movements. This technology typically involves using a low-power, infrared light-emitting diode (LED) and a camera. The LED may be mounted on a personal device, a self-service device, or on a pair of glasses worn by the user. The emitted light is pointed toward the user's eye and is reflected toward the camera, which tracks the eye movements and allows the user to perform specific actions [97].

A number of commercially and operationally deployed solutions are on the market. While these are most

commonly used in or with personal devices such as computers, there are some commercially available solutions for self-service interactive devices [98].

There are no relevant standards specific to this technology. ISO 9241-400 [99] and ISO/TS 9241-411 [60] include ergonomic design and testing requirements for physical tracking input devices (including trackballs and trackpads), but do not apply to eye tracking. Similarly, WCAG2.1 addresses input modalities, specifically the capacity for motion actuation and the ability to disable this feature intermittently to prevent accidental actuation [100]. EN301-549 [101] emulates this by recommending that specific accessibility features should be accessible for both software and hardware with closed functionality.

Eye-tracking software does not present any significant security or privacy concern for users.

Eye-tracking technology has the potential to assist individuals with physical or mobility disabilities when inputting information and navigating a self-service device. Although eye-tracking devices are commercially available, they are highly personalized and require a large amount of precision. User testing of eye-tracking and gaze-interaction devices found that these devices can be difficult to calibrate and recalibrate when a system or user error occurs, limiting their practicality in a self-service device [102]. For that reason, eye-tracking devices are not currently recommended for integration with self-service interactive devices or CSA/ASC B651.2 consideration.

3.2.1.14 Adaptive Keyboards, Word Prediction, and Word Completion

Adaptive keyboards describe commercial keyboards that have undergone modifications to better suit a person with disabilities. Adaptations include keyguards, larger keys, compact size, and on-screen keyboards [103]. A keyboard can be combined with other assistive technologies, such as word prediction and word completion, to suggest words as the user is typing or automatically complete phrases without the user having to finish typing [104].

Some types of adaptive keyboards (e.g., keyguards and keyboards with larger keys [103]) are commercially available. Word prediction and completion technologies are also commercialized and widely adopted across multiple software. This type of technology is useful for people with physical, vision, and cognitive disabilities, as it serves as assistive technology for writing and manual input.

No relevant standards were identified for these technologies. No security or privacy concerns have been associated with word prediction technologies or adaptive keyboards.

Word prediction and completion are recommended to be considered for integration with self-service interactive devices and inclusion in CSA/ASC B651.2.

3.2.1.15 Personal Devices

Personal devices are often loaded with accessibility software and tools to which users are accustomed [105], [106], with the software settings tailored to people's specific preferences and needs [107]. One way to support people with disabilities may be to accommodate the use of their personal devices with self-service devices, rather than attempting to integrate a technology into the self-service device. Personal device integration refers to an option for users to connect their own input or output devices with the self-service device through a wired or wireless connection. Examples include a smartphone or tablet, relevant mobile applications, and any other device used for augmentative and alternative communication.

Personal device integration presents several significant concerns for individuals' security and privacy because the self-service devices will require access to users' data to coordinate accessibility features. PIPEDA requires disclosure of the use, collection, and storage of data, and user consent before enabling device integration [25]. Other common threats and hacking schemes may occur, primarily via wireless and Bluetooth connections.

In general, self-service devices may be vulnerable to a variety of network assaults, even without connecting to personal devices, via a wired or wireless mode.

Attackers can use various techniques to bypass security, access controls, and intercept users' personal information. Specifically, apps with integrated Visual Basic (VB) editors and web browsers pose a threat to self-service devices [108] [109]. Most health terminals, for example, use VB editors so that programmers can alter system applications [108]. Attackers can enable these editors and use them to create short coding scripts that open security vulnerabilities and give attackers unrestricted access to the system [108]. Alternatively, an attacker can reach protected file systems through a browser. Although many browser features are blocked on most terminals and the URL bar is usually turned off, clicking a hyperlink while holding down the shift key will launch the link in a new browser tab, typically with the address field activated. This will launch the online browser and give access to additional file system locations [109].

Bluetooth is a widely used technology that enables mobile devices to connect and share information wirelessly within a close range [110]. Despite its reasonable reliability, Bluetooth has some shortcomings in its protocol and is susceptible to attacks and malware [110]. Hackers may attempt to gain unauthorized access to a person's devices, either actively (e.g., by manipulating the owner into providing access) or passively (e.g., via hacking schemes to gain control of the device). Malware, or malicious software (e.g., trojans and worms), is covertly embedded in a system with the intent of compromising the device's integrity [110]. Both attacks and malware can be classified as high, medium, or low severity based on the extent of the effects on the victims. High-severity attacks may result in the loss of personal information, data theft, location tracking, and financial losses, whereas low-severity attacks include temporarily impairing a device or interfering with Bluetooth connection [110].

Given the common Bluetooth vulnerabilities, there is a need to evaluate current security leaks, conduct security updates to protect Bluetooth operations, and increase user and manufacturer knowledge of risk mitigation [111]. Implementing risk mitigation measures at both individual and organizational levels can aim to address vulnerabilities and uphold the user's security and privacy. Users should be conscious of potential security threats and exercise care to prevent security breaches. Some risk mitigation strategies include personalizing default Bluetooth settings on a personal device, using strong passcodes, monitoring device activity, and updating Bluetooth security software on personal devices [109].

Alternatively, developers and businesses can implement more advanced risk mitigation strategies to protect their users. Advanced programming techniques can be applied to block surveillance devices from accessing the information on the user's personal devices. Specifically, user-space script on the Bluetooth control system can be easily implemented on all self-service device terminals without modifying the hardware of the device [112]. This user-script changes the state of subchannels, making it is more difficult for a hacker to learn the adaptive bouncing method [112].

3.2.2 Output Technologies for Accessible Self-Service Devices

All of the technologies described in this section are output devices that facilitate the transmission and presentation of information from the self-service device to the user. Six technologies were reviewed and assessed for their usability, privacy and security, potential for integration into self-service devices, and relevancy to CSA/ASC B651.2.

3.2.2.1 Screen Readers

Screen readers can read aloud the content of files, texts, dialogue boxes, images, and menu options on a screen or send the output to a refreshable braille display device [113]. Using keyboards, touchscreen gestures, or voice commands, users with visual impairments or difficulty reading commonly operate screen readers on personal devices, at work, and in community settings to perform everyday tasks as well as complex operations [113].

A number of commercially and operationally deployed screen readers are on the market. Commercially



"As an adaptive technology that facilitates reading, text-to-speech can assist people with blindness or low vision, or cognitive disabilities."

available screen-reading systems are compatible with most common computer operating systems. The most well-known of these is a lean version of JAWS [Job Access With Speech] screen-reader software used in the Microsoft environment that was specifically developed for use at self-checkouts, check-in counters, bill-paying counters, and other self-service devices for applications [114]. These systems can also be adapted for individuals with cognitive disabilities to ease identification and comprehension of information on a screen [113]. Screen readers are typically personalized and customized for the individual, and as such, the versions of the software on self-service devices are more limited in their functionality [114]. Furthermore, although screen readers do not affect the individual's security, privacy may be compromised if the on-screen personal information is audible to people other than the user.

ISO/IEC 30113-60 [115] provides guidance for common touchscreen gestures and functions specifically for screen readers operating on various information and communication technology devices. The goal is to overcome the issues with information and communication technology device feedback for people with visual impairment. Standardizing navigation controls of screen readers enhances user learnability and accessibility, ensuring that various screen-reading software have common system functions. Further, ISO/IEC 30113-61 [116] defines movements for single-point gestures recognized by the screen readers in a consistent manner regardless of the operating system.

3.2.2.2 Text-to-speech Technologies

Text-to-speech software contains individual phonemes, pronunciation dictionaries, and other synthetic speech components that enable a computer to speak [117]. Text-to-speech technology is implicit in screen-reading technology. Text-to-speech software reads aloud the text on a screen but lacks the navigational tools of screen-reading technology. While screen readers are designed for use by people with visual impairments, text-to-speech synthesizers are generally built into most devices, including smartphones, computers, laptops, tablets, and self-service devices. Text-to-speech programs can also be retrofitted to web browsers and digital applications to enhance accessibility, serving as a less comprehensive screen reader. Some devices and programs allow users to change the language, speech rate, and pitch to suit their preferences and needs. However, these control functions often vary with the computer operating system, search engine, and applications.

Several commercially and operationally deployed text-to-speech technology solutions are on the market. As an adaptive technology that facilitates reading, text-to-speech can assist people with blindness or low vision, or cognitive disabilities. Text-to-speech capability does not jeopardize an individual's security, although privacy may be compromised if personal information is read aloud to confirm correct input.

CSA/ASC B651.2 [7] specifies requirements for voice output technologies:

- There are two distinguishable voices, one for instructions and the other one for dynamic content.
- Any abbreviated text is spoken in the unabbreviated form.
- Numbers are spoken as single digits (e.g., "12" is spoken as "one" and "two").
- Users can control the speed of speech.
- Users can choose between voices in different pitches to accommodate their frequency tolerance and preference.

In addition, ISO 24551 [118] recommends that devices provide instructional feedback on the status of the product or system operation or both. In doing so, a user with blindness or low vision or with a cognitive disability can use devices mostly independently [118].

3.2.2.3 Refreshable Braille Display Devices

Refreshable braille display devices convert on-screen text to braille. This technology is either embedded in a computer or is a stand-alone device compatible with existing computer hardware. Braille displays typically contain a single row of keys to represent individual braille cells. Each key has six or eight tiny pins that are lowered and raised in groups that correspond to braille characters [119]. To use a braille display device, the user runs their fingers along the keys to read text outputs reflecting what is displayed on the computer screen.

Braille display devices come in various forms, including larger units comparable to the size of a computer keyboard and smaller units intended for use with laptops and tablets. There are also several apps for smartphones and tablets that connect to a Bluetooth braille display device and operate wirelessly. However, the apps on mobile devices or computers are typically screen readers, with only Nix operating systems running a braille translation program independently.

Still, there are several commercially and operationally deployed solutions on the market. There may be no easily identifiable security or privacy concerns associated with wired braille display devices, but there may be concerns with wirelessly connected models. More information on these concerns is presented in section 3.2.1.15.

Although other available output technologies, including text-to-speech capability and screen readers, may not be appropriate for or universally preferred by individuals with a visual impairment, and braille display devices are tailored to a smaller number of individuals who can read braille or who have both vision and hearing loss, this technology may be the most appropriate for some users. ISO/IEC 24751-1 [120] highlights that everyone's experience with disability is different and each person's needs and preferences should be taken into consideration, especially in the case of educational digital technology.

3.2.2.4 Antiglare Screens

An antiglare screen has a protective overlay or a coating that limits the reflection of light from light sources, including the sun and artificial lights. Glare can prevent seeing what is on the screen and cause discomfort, reducing operability [121].

Several commercially and operationally deployed solutions are available on the market.

3.2.2.5 Text Enlargement Software

Text enlargement software is an assistive technology that allows users to magnify the screen content and increase visual clarity. There are three main ways to adjust sizing on a screen: by adjusting the size within the operating system; by adjusting the zoom level within the program; and by using screen magnification software. Users should be able to manipulate the size of what they see without distorting what is on the screen.

Several commercially and operationally deployed text enlargement software solutions are on the market. Such software is commonly found on personal devices and is suitable for work, social, and commercial environments. Solutions include buttons for scaling text or a screen magnifier that enlarges touch-selected sections of the screen [122, 123]. Many self-service devices in retail and food service environments already have large screens, ostensibly to make marketing displays more attractive, but these screens may also improve accessibility [124].

Text enlargement could benefit people with visual impairment as well as those with physical, learning, and cognitive disabilities. This technology could potentially compromise an individual's privacy if the on-screen personal information could be visible to bystander others in the vicinity.

CSA/ASC B651.2 [7] acknowledges that interactive electronic devices, where the required visual acuity is greater than 20/70, should include at least one other visual or non-visual mode of operation, and exemplifies enlarged print output. While CSA/ASC B651.2 does not require magnification software, it acknowledges that enlargement software is a common assistive technology for individuals with low vision.

3.2.2.6 Sign Language Avatars

Digital sign language avatars convert on-screen text into visual gestures. The on-screen text can include web pages, interactive e-learning platforms, or service announcements [125]. Sign language is a complete set of gestures and symbols organized linguistically. Each gesture, primarily composed of the signer's hand shape, the position of the hands, and the movement of the hands, represents a sign. The clarity of a sign can be enhanced by specific finger movements, facial gestures, and body movements [125]. Digital sign language avatars are digital two- and three-dimensional graphic representations of humans (and hence are also known as digital humans).

Two distinct sign languages are used in Canada: American Sign Language (ASL) and Langue des signes québécoise (LSQ). Both languages use the same alphabet and number systems, but the symbols and phrases differ between the two [126].

The TRL score for this technology is 9 (TRL 9), meaning that fully operational prototypes have been developed and there is some early adoption. However, videos are often prerecorded sign language interpretations and cannot adapt to dynamic user needs. Studies of sign language avatar use indicate that usability and acceptance vary depending on the user's hearing status, their age at sign language acquisition, and the avatar type [127]. Type of avatar refers to the framing of signs (e.g., full body, half body, close up), whether the avatar is based on human or computer-synthesized movements, and the appearance of the avatar [127], [128].

There are no standards specific to digital sign language avatars. Sign language avatar use does not affect a user's security or privacy.

3.3 Consultation with Stakeholders

3.3.1 Participant Characteristics

A total of 22 interviews were conducted during January 2023. The interviews were conducted with 16 people with lived experience of disability, three advocates for people with disabilities, and three members of industry. All the advocates had lived experience of disability and contributed their insights across two of the groups. The same interview guide was used for people with lived experience and for advocates for people with disabilities, and a separate interview guide was used for members of industry. Refer to Appendix A for both interview guides.

All interview transcripts from these two groups were analyzed for content by the research team.

Of the 22 participants, 18 self-identified as having a vision disability, four as having a physical disability, 3 as having a hearing disability, and 1 as having a cognitive disability. Four participants self-identified as having two or more disabilities and acknowledged the ways in which the combination of disabilities leads to unique challenges when using self-service devices.

The findings in this section were grouped by recurring themes throughout the interviews. Where relevant, participants' disabilities were indicated.

3.3.2 Major Themes

3.3.2.1 People with Lived Experience of Disability and Advocates

3.3.2.1.1 Privacy and Security

Privacy and security when using self-service devices was one of the themes study participants mentioned most frequently (15/19). The participants, particularly those with vision disabilities, were concerned about exposing their personal information while using self-service devices. Seven participants (7/19) reported worrying that someone behind them could be watching what they are doing on the screen or PIN pad without them knowing, and obtaining their passwords or other personal information. Some described heightened concerns if they were unsure whether screen blanking was applied or whether the screen was physically protected from the sight of others.

Three participants (3/19) with vision disabilities described being unable to use touchscreens because of the lack of tactile indicators, alternate modes of input, or audio feedback confirming their entries and, as a result, having to ask strangers to input their information for them. The participants explained that this scenario made them uncomfortable and undermined their independence. Their preferred solutions were audio feedback enabled when headphones are detected and tap-based payment methods that do not require manually inputting information.

3.3.2.1.2 Inconsistency

Thirteen participants (13/19) brought up the lack of consistency across self-service devices and the resulting inability to use the devices intuitively rather than having to learn another unique system. The primary concern was a lack of consistency and continuity in the accessibility features across self-service devices, including the types of features and how they are accessed and used. The participants reported having difficulties discerning how to interact with the self-service device, especially in the absence of guidelines for device use. One participant mentioned that even when they were familiar with the technology and aware of the specific accessibility features, service providers may not be familiar with these features and allow their use, creating inconsistent opportunity for their use. A participant with a vision disability gave the example of ordering food using a tablet at a restaurant, but not being able to access the voiceover that they would normally use when operating such a device.

Seven participants (7/19) described how the variety in accessibility features in different self-service devices requires them to memorize several systems, hindering usability. One participant described preferring having a standard format across self-service devices so that they would always know how to operate a device.

Three participants (3/19) reported that the audio jacks that enable screen-reader functionality vary. The location of audio jacks and the style of compatible earphones can vary from machine to machine. One participant suggested that audio jacks should not be the only technology designed for use with self-service devices, as headphones may not be available to the user at all times.

Six participants (6/19) expressed the need for greater consistency across the specific types of accessibility features available in self-service devices. The lack of information on the location of accessible devices or their specific features were separate but related issues. Four participants (4/19) mentioned that they typically avoid self-service devices because they did not know which accessibility features were offered or how to use them.

3.3.2.1.3 Staff Support

Eight of the interviewees (8/19) mentioned a lack of support from on-site staff when using self-service devices. In general, concerns were about a lack of staff available to ask for assistance or the staff not knowing enough to support individuals' accessibility needs rather than being unwilling to help. Three of these participants (3/19, 16%) described their experiences using self-service devices as isolating and frustrating, explaining how few people are available to help navigate the self-service device, resolve errors, and intervene when devices become inaccessible. One participant noted that the ability to ask for help or draw attention differs for a person with disabilities; they may not be able to make eye contact or wave someone over or know that a staff member was nearby. The participant

suggested incorporating a call button on self-service devices to alert staff that someone required assistance. Although mainstream devices have basic accessibility features, they are commonly disabled in social and commercial settings, and the staff is either unaware that these functions exist or unable to activate them.

The participants noted that enabling accessibility features allows people with disabilities to maintain their independence when performing everyday tasks. Two participants (2/19) described situations where staff actions contradicted their independence goals. In one case, a participant asked a staff member to enable the text-to-speech function on a device, but the staff member insisted on completing the task for the participant. Another participant described being overlooked by staff members who interacted exclusively with the participant's companions when they were asked for help.

3.3.2.1.4 Lack of Accessible Instructions and Feedback

A common topic was a lack of instructions and feedback in accessible self-service devices (15/19). Five interviewees (5/19) described the instructions for use of devices and the subsequent feedback as crucial for user experience. Nevertheless, guided audio feedback, navigational instructions, braille markings, or other methods of giving instructions and feedback were often missing in self-service devices. One participant suggested adding an optional guided tour of the device's features to allow users to learn to operate the device independently. Another participant explained that accessible feedback from self-service devices provides assurance that a task has been correctly completed and enables independent interactions with the device. Two participants described situations where the price and item information was not being read aloud in a self-service store checkout, making it difficult to know that they are using the device as intended. Both participants emphasized the importance of ensuring that the same display options are offered to people with and without visual impairments.

Four participants (4/19) discussed the need for feedback that was not merely operational and instructions for accessible self-service devices. Specifically, users who are blind or with a visual impairment require descriptions of the layout of the self-service devices and the physical environment to be able to follow the device's operational instructions and feedback. One participant described retail self-service checkout devices directing users to place a scanned item in a bagging area without audibly explaining where this bagging area was located.

Two participants (2/19) explained that instructions are necessary because the built-in features and physical configurations of self-service devices. The ability to navigate one self-service device may not translate into successful navigation of another self-service device. One participant described being unable to locate self-service devices in the physical environment and having difficulty determining the function of each. Similarly, another participant discussed being unable to tell when and which device was available for use without a system or staff member to direct users to the next available station. In this case, the participants proposed using sound beacons to identify the self-service device's availability, location, and purpose.

Seven participants (7/19) discussed inadequate or incomplete instructions and feedback that make self-service devices only partly accessible. For example, self-service checkout machines at grocery stores often provide audio output that is incomplete, guiding the user through some, but not all, of the functionalities. One participant with a visual impairment described trying to use an accessible blood pressure monitor that provided audio instructions on how and where to position their arm, but did not read out the results or provide the results in any way other than by displaying them on-screen.

3.3.2.1.5 Design and User Interface Issues

Six participants (6/19) described their concerns regarding the design and user interface of self-service devices. Two participants (2/19) discussed the size of on-screen text and the visibility of the screen. They explained that the height and angle of a device may affect what users see on the screen and how they use it. Three participants (3/19, 16%) described having difficulty operating devices because of their short stature or because they use wheelchairs or mobility



aids. They mentioned that there is often inadequate space to position a wheelchair in front of a self-service device or to accommodate having to approach the device at an angle to reach it.

Two participants (2/19) noted how it would benefit many users if the height of all self-service devices could be adjusted while allowing adequate space to position a wheelchair or mobility aid in front of it. A participant referred to height-adjustable immigration kiosks at airports as an example. These kiosks immediately recognize a human face and adjust to its height so that the camera is level with the person's eyes.

Two participants (2/19) expressed dissatisfaction with dictation and audio recognition features in self-service devices, especially in loud and busy environments. One of these participants mentioned limited time frames to complete tasks while using a self-service device audio input.

Two participants (2/19) described their health and safety concerns about the cleanliness of self-service devices and the frequency with which they are sanitized. They described how for people with compromised immunity, touching high-contact surfaces can be unsafe, and antimicrobial surfaces alongside regular cleaning of input devices are preferable.

3.3.2.1.6 Preference for Use of Personal Devices

Six participants (6/19) described the advantages of using their personal devices (e.g., smartphones) with the self-service device. Four participants (4/19) explained that familiarity with the accessibility features in their personal devices allows efficient and effective navigation. Two (2/19) described how using their personal devices grants them greater independence, as they can troubleshoot issues in ways that they would not be able to with an unfamiliar public self-service device. Two participants with hearing impairments (2/19) described how using their personal devices might make interfacing with their hearing aids simpler, as the audio output could play directly to their hearing aids, making it more audible. Nevertheless, one participant did raise a concern about the equity of personal device integration, as not everyone has a smartphone, and self-service devices should have the option to operate in a self-contained way.

3.3.2.1.7 Absence of Regulations

Five participants (5/19) expressed concern about the lack of regulations related to accessibility in self-service devices. They considered that without consistent enforcement, manufacturers and companies are not incentivized into making systems accessible. One participant observed that, although the standards

for accessibility already exist, companies often do not appear to adhere to them, possibly to avoid incurring additional expenses when integrating accessibility features that are not required by law. Another participant explained that this lack of enforcement has serious implications for people with disabilities, potentially adding to any vulnerabilities. The participants described having to say their credit card PIN out loud to a staff member in a busy store to complete a transaction because there was no accessible payment option. One participant emphasized the importance of making all self-service devices accessible – without exception – given that accessing information and communications is a human right.

3.3.2.2 Industry and Regulation Insights

The three interview participants who represented the self-service and accessible device industry described having frequent conversations with clients who prioritize flashy, marketable features over accessible operations. In other words, a disproportionate amount of companies' manufacturing budgets are allocated toward features that entice and excite some users (e.g., LED lighting and facial recognition) rather than features that enhance usability and accessibility. The industry members repeatedly stated that the priority should be the user experience, and that features enabling basic accessible use should be implemented before all else. They also noted the challenges and limitations of implementing some technologies. For example, screen readers and word prediction are personalized features that build on users' behaviour over time, which is not possible on a communal device, although implementing lean versions of these technologies could improve accessibility.

Two of the participating industry members observed that self-service devices should be usable as well as accessible. One participant stated that it is best to offer several functioning accessibility technologies and avoid removing or disabling any of the features or functions that improve accessibility. They suggested offering more than one input method and more than one payment method, and adaptability of the user experience between different modes of use so that a consistent experience is still provided.

One participant noted that widespread accessibility was hampered by a gap in existing Canadian guidelines regarding instruction and feedback change. It is unclear whether the input method change is through the standard modes of input or those meant to enhance accessibility. This gap in the guidelines makes it difficult for various manufacturers to maintain consistency and therefore for users to expect a consistent experience.

All the participants in this group emphasized the importance of user flow testing for all devices by people with lived experience of disability.

3.3.3 Solutions Proposed by Interview Participants

3.3.3.1 Suggestions for User Interface

The interview participants proposed a number of solutions to improve the user interface of self-service devices. Many of these suggestions, such as, large buttons, greater spacing between keys, and large and high-contrast text, are already established in existing standards and accessibility guidelines.

User flow testing is critical to ensuring that accessibility guidelines have been adequately followed, especially in real-world settings where there is movement and noise. Furthermore, the participants recommended a greater focus on tactile features because many people with vision disabilities rely on touch or physical sensation to help them navigate. Suggested tactile features included physical buttons (instead of or in addition to touchscreens) to orient the user with the device, or a floor mat of a certain texture to help determine where to stand. Multiple modes of input and output should be offered on all self-service devices, wherever possible.

The participants considered it essential to standardize accessible mode activation so that users needed to memorize fewer features on the various self-service device types they use. Some participants suggested implementing a screen-reader mechanism similar to that found on some ATMs; these screen readers are activated by entering a particular number on the PIN pad. Another suggestion was to standardize the placement of common components, such as audio jacks or the universal symbol for accessibility.



"The participants noted that self-service devices are difficult to navigate when no instructions, directions, or feedback are built into the device."

The participants felt that ATMs were, in general, the most universally accessible self-service device and suggested that their design principles be more widely implemented.

3.3.3.2 Improved Instruction and Feedback

The participants noted that self-service devices are difficult to navigate when no instructions, directions, or feedback are built into the device. An initial step in mitigating such difficulties is a visual and audible guided tutorial explaining the layout of the device's input and output components (e.g., a help button, audio jack, card slot, etc.). This would help prevent accidentally triggering an undesired action and restarting the process. The option to skip or cancel the guided tour should be possible at any moment if the user is sufficiently familiar with the device.

The participants emphasized the importance of receiving feedback when interacting with a self-service device. It should be clear to all users where they are in the user flow and what action they have just performed. Information should not be read back only when personal information is being input and headphones are not plugged into the device. Overall, instruction and feedback should not be given exclusively through audio or through visual means, but in combination.

3.3.3.3 Personal Device Integration

There is a strong interest in using personal devices, particularly smartphones, with self-service devices, because these are often individuals' primary accessibility tools. The use of personal devices would allow users to minimize manual input through autofill functions, and save them having to remember preferred settings, potentially compensating for any accessibility shortcomings in the self-service device. However, the participants did acknowledge that enabling interoperability may be complicated by logistics (i.e., difficulty connecting wireless devices, transfer of data between devices, software that can interface with the self-service device, etc.) and privacy issues. One suggestion was to encourage the development of compatible applications as interfaces between smartphones and self-service devices and test these in accordance with accessibility guidelines.

Personal device integration also includes personal headsets; integration of headsets is hampered by inconsistent and incompatible hardware (e.g., many headphones are wireless or use USB Type-C connectors or lightning cables, whereas many self-service devices are equipped with 3.5 mm audio jacks). In this case, an option would be to exchange connector modules, as a modular approach to hardware would enable flexibility and allow users to upgrade their personal devices while remaining compatible with self-service devices.

Note that to avoid unequal access to services, self-service devices should not rely solely on the integration of personal devices as accessible tools; accessibility features should be always incorporated into the self-service devices and continue to be improved.

3.3.3.4 Feature Promotion

A recurring theme in the interviews was the need for greater promotion of any accessible features. The participants explained that they often found out about an accessible device through word of mouth. Acceptance of self-service devices depended on knowing what accessibility features were available, and how to access and use them. Increasing awareness of self-service devices could be achieved through greater promotion, advertising, and training of on-site staff. The participants noted that company or organization websites are where users frequently look for information, so it is particularly important that websites clearly state that organizational self-service devices have accessibility features.

3.4 Recommendations for Inclusion of Technologies

Technologies recommended for consideration for integration with self-service interactive devices and inclusion in CSA/ASC B651.2 are facial detection, facial recognition, sign language avatars, gesture recognition, personal device integration, adaptive keyboards and word completion and prediction, screen readers, antiglare screens, text-to-speech technology, fingerprint recognition, iris recognition, voice command and dictation, text enlargement, and refreshable braille displays. Seven other technologies – facial gesture recognition, hand gesture recognition, eye tracking, palm and iris recognition, head-mounted pointers, single-switch entry devices, foot switches, and braille keyboards – are not a priority for consideration at this time, but may be in future.

Table 1 summarizes the assessment of technologies recommended for consideration for inclusion in CSA/ASC B651.2, as discussed in section 3.2. Table 2 summarizes the technologies that are not currently recommended for inclusion in CSA/ASC B651.2. The criteria are summarized as follows:

- **Privacy and security –** Privacy refers to the rights and obligations of individuals and organizations with respect to the collection, use, retention, disclosure, and disposal of personal information [22]. Security refers to protection of data from intentional or unintentional destruction, modification, or disclosure.
- **Usability testing –** Usability refers to the extent to which specified users can use a system, product, or service to achieve specified goals effectively, efficiently, and to their satisfaction in a given context of use [12]. Usability testing was considered complete ("yes") if empirically tested data on the usability of the technology included people with disabilities. Usability testing was considered "partial" if the testing either did not include people with disabilities or did not focus entirely on usability. The usability testing was considered "inadequate" if no testing had been conducted.
- **Integration –** A technology was considered "integrated" if the technology could be integrated into the self-service device, a "personal device" if the technology could be brought by the user on a personal device to attach to the self-service device, or "both" if both options were possible.
- **Readiness level –** The majority of the technologies reviewed in this report were commercially available.
- **Disabilities –** The research into the identified technologies considered the barriers experienced by people with disabilities that have, for the purpose of this report, been grouped into the following broad types: physical, vision, cognitive, and hearing. Listed in Tables 2 and 3 are the broad disability types that each technology could contribute to overcoming when integrated into self-service interactive devices.

For more information, refer to sections 2.1 and 3.2.

3.4.1 Technologies Recommended for Consideration for Inclusion in CSA/ASC B651.2

Although CSA/ASC B651.2 [7] refers to some of the technologies described in this report, the following technologies are recommended for consideration for inclusion in CSA/ASC B651.2.

Facial detection and facial recognition technologies are recommended for integration into self-service interactive devices for, respectively, the automatic detection and the authentication of users. In addition, it is important that the cameras used for facial detection and recognition accommodate a range of heights and take into account wheelchair and mobility aid users [129].

Table 1: Summary of assessment of technologies recommended for consideration for inclusion in CSA/ASC B651.2 Standard

Technology	Is privacy jeopardized?	Is security jeopardized?	Did usability testing include people with disabilities?	Can the technology be integrated into the self-service device?	Can the technology be brought by a user on their personal device?	Readiness level	Supported disabilities
Facial detection	Yes	No	Partial	Yes	not available	Commercially available	Vision, physical, Cognitive
Facial recognition	Yes	Yes	Yes	Yes	not available	Commercially available	Physical, vision, Cognitive
Sign language avatars	No	No	Yes	Yes	Yes	TRL 9	Hearing
Gesture recognition	No	No	Yes	Yes	not available	Commercially available	Vision, Cognitive, physical
Personal device integration	Yes	Yes	Inadequately	n/a	Yes	n/a	All disabilities
Adaptive keyboards, word completion, word prediction	No	No	Yes	Yes	not available	Commercially available	Physical, vision, Cognitive
Screen readers	Yes	No	Yes	Yes	Yes	Commercially available	Vision
Antiglare screens	No	No	Inadequately	Yes	not available	Commercially available	All disabilities
Text-to-speech capability	Yes	No	Yes	Yes	Yes	Commercially available	Vision, Cognitive
Fingerprint recognition	Yes	Yes	Yes	Yes	not available	Commercially available	Cognitive, physical
Iris recognition	No	Yes	Partially	Yes	not available	Commercially available	Physical
Voice command and dictation	Yes	No	Yes	Yes	not available	Commercially available	Vision, physical, Cognitive
Text enlargement	Yes	No	Partially	Yes	Yes	Commercially available	Vision
Refreshable braille displays	No	No	Yes	Yes	Yes	Commercially available	Vision, hearing

Table 2: Summary of assessment of technologies not currently recommended for consideration for inclusion in CSA/ASC B651.2

Technology	Is privacy jeopardized?	Is security jeopardized?	Did usability testing include people with disabilities?	Can the technology be integrated into the self-service device?	Can the technology be brought by a user on their personal device?	Readiness level	Supported disabilities
Facial gesture recognition	No	No	Yes	Yes	not available	TRL 6	Physical
Hand gesture recognition	No	No	Yes	Yes	not available	Commercially available	Vision, Cognitive, physical
Eye tracking	No	No	Partially	Yes	not available	Commercially available	Physical
Palm recognition	No	Yes	Partially	Yes	not available	Commercially available	Physical, Cognitive, physical
Head-mounted pointers	No	No	Inadequately	n/a	Yes	Commercially available	Physical
Single-switch entry devices	No	No	Inadequately	Yes	not available	Commercially available	Physical
Foot switches	No	No	Inadequately	Yes	not available	Commercially available	Physical
Braille keyboardss	No	No	Yes	Yes	not available	Commercially available	Vision

Facial recognition on smartphones frequently serves as a way of accessing a protected device without keying in a password or using fingerprint recognition. Facial recognition on personal devices and smartphones has been extensively studied, with overall positive results [129], [130]. While the grey and peer-reviewed literature report some concerns regarding the usability and security of biometric authentication, especially in terms of user behaviour and habituation [131]–[133], many users reported feeling comfortable with this technology and they do not struggle to adjust their actions to make biometric authentication systems work [30], [133].

Sign language avatars are recommended as an output technology. Although automatic translation of written languages to another written language or to speech is widespread, there has not been similar progress for sign languages, despite evidence supporting the need of such translation [133]. Interview participants and advisory panel members pointed out that refining and implementing this technology in self-service devices would allow users who communicate primarily through sign language to interact with the device more easily. That said, there are several limitations to virtual sign language displays, including the lack of a complete written form corresponding to the syntax of ASL or LSQ, the quality of signs, language modality, and display technology for animated, three-dimensional avatars [133]. Although additional usability testing may be necessary prior to widespread integration, virtual sign language displays are highly recommended for consideration for integration with self-service interactive devices and inclusion in CSA/ASC B651.2.

Adaptive keyboards, word prediction, and word completion are valuable additions for users who have trouble typing; however, either better integration of personal devices or improved user flow testing of these

technologies is needed. In fact, interviewed participants with vision disabilities have described word prediction and word completion features as cumbersome. These caveats will need to be taken into account when considering the integration of these technologies into self-service interactive devices and inclusion in CSA/ASC B651.2. It will also be necessary to consider extensive usability testing by people with different abilities before these technologies are implemented.

Gesture recognition devices are recommended for consideration for inclusion in CSA/ASC B651.2 because some common movements could be leveraged in self-service integrated devices. Furthermore, guidance is available on the development and implementation of gesture recognition devices into self-service devices to support individuals with vision, cognitive, or physical disabilities. In addition, the usability of this technology by individuals with physical disabilities may be impacted by which part of their body their disability affects.

The ability to integrate personal devices such as smartphones or personal refreshable braille display devices, into self-service devices is recommended for consideration for inclusion in CSA/ASC B651.2 as this technology was a recurring theme in the literature review and in interviews with participants with lived experience of disability. There is evidence indicating the advantage of enabling people to use the personal devices they are comfortable with and a precedent for users to plug in or connect personal devices for the purposes of interpretation [135], [136]. Personal device integration increases usability by allowing people to use the technologies they are familiar with and that are adapted to their needs, patterns, and preferences.

Privacy concerns will need to be investigated, however, as the data collected would fall under the federal regulations of PIPEDA. As for all technologies that deal with identifiable data, manufacturers must be aware of the privacy laws and security concerns that govern their integration and implementation.

Voice command and dictation are recommended for consideration for inclusion in CSA/ASC B651.2 to improve accessibility, particularly for people with physical or vision disabilities. Usability of voice command features on personal and home devices has been extensively tested, with positive results, including by people with disabilities [137], [138]. That said, noise interference can limit the effectiveness of voice command in an open public space [139], and there are privacy and security concerns with using dictation, as mentioned by the participants. Physical barriers, soundproofing, and other environmental design strategies to reduce noise and isolate voices in the immediate area around a self-service device would be worth considering.

Two technologies recommended for authentication purposes are fingerprint recognition and iris recognition. Although there is little existing literature on usability testing and there are several concerns related to accessibility for people with vision, cognitive, and physical disabilities [77], as a result of their widespread adoption and immediate ability to authenticate users, these technologies may be valuable to integrate into self-service devices as long as other authentication options are also available. If fingerprint and iris recognition are fully tested with people with different disabilities, they have the potential to assist authentication in a way that enhances comfort by reducing the amount of physical input. Further usability testing is recommended before their inclusion in self-service devices.

Refreshable braille displays require either additional technologies embedded into the self-service devices or compatible hardware and software that allow a user to integrate a personal braille display device with the self-service device. As such, consideration must be given to how individuals access braille display options (i.e., how the option is enabled, whether the position of the menu item or physical button is consistent across self-service devices, whether this is intuitive), connect their personal refreshable braille display devices to the self-service devices, or where they are able to place their display to be able to use it. A small ledge or shelf in a consistent position may be useful here.

Antiglare technology has benefits for most users. Because text or images on a screen may be distorted when these are looked at from different angles, which limits usability [140], it is necessary to evaluate how both standing and seated users interact with a

technology to accommodate individuals with various mobility needs and take into account the different angles from which users, including those who use wheelchairs or mobility aids, will look at the device. Also essential is the need to conduct extensive testing when screen or text-enlargement technology is used in order that the resized content displayed on the screen remains usable when looked at from all angles. For example, when text is enlarged, it may not appear enlarged at all angles, since the viewing angle can change the shape and size of an object. Furthermore, it is necessary to consider whether screen/text enlargement will magnify to predetermined ratios (e.g., 125%, 150%, 175%, 200%) or if users can choose by how much to enlarge the screen or text.

It is also necessary to consider how people using text-to-speech technologies interact with this function when they do not have access to headphones. This may be a particular concern in a busy environment, where the quality and clarity of the audio are reduced.

Based on the extent of key informants' praise for screen readers, the inclusion of this technology into self-service interactive devices should be mandated. The interviewed participants described screen readers, particularly those that used the JAWS software, as significantly contributing to accessibility. Although this technology was developed to mitigate the technological barriers experienced by people with visual impairments, others also benefit from receiving information via audio [113]. However, the uniformity of navigational tools across screen readers is essential for the user experience and acceptance of the technology [141]. Further considerations raised during the research process include instances where individuals may require a screen reader to produce an audio transcript of confidential information, thus underscoring the need to protect privacy. Lastly, it is crucial to use clearly distinguishable voices for providing instructions and outlining descriptions of what is on a screen.

Finally multiple assistive technologies need to be able to interact smoothly with one another. For example, some interview participants said they wanted to be able to use text enlargement and a screen reader at the same time.

3.5 Recommendations for Future Research

As discussed at various points throughout this report, it is crucial to include people with lived experience of disability in research into accessible self-service devices and accessible technologies at large and prioritize their experience and input in any testing or training processes.

3.5.1 Usability Testing of Accessible Technologies

One of the major themes identified during the interviews with stakeholders was the inadequate design of accessible technologies in self-service devices and the overall low user experience. In addition, the lack of consistency in the design of different self-service devices resulted in users struggling to use them [97], [105], [126], [131]. In the medical device industry, the United States Food and Drug Administration (FDA) has recommended that manufacturers implement a comprehensive user-centred design and evaluation program for their technologies. The FDA guidance "Applying Human Factors and Usability Engineering to Medical Devices" [141] helps ensure that industry aligns medical devices with user needs and designs devices to minimize the number of errors. Similar guidelines, protocols, and certification programs for the usability of accessible self-service devices should be developed in Canada to benefit users with accessibility needs.

3.5.2 Training in Using Accessible Technologies

The development and implementation of accessible self-service devices in Canada is highly dependent on training end users and on-site support staff in the use of the technologies. The interviews revealed that users typically do not know which devices have accessibility features and are not familiar with the accessibility features or technologies in self-service devices. They also do not know if the technologies they are familiar with are available and if so, in what devices, or they do not know how to access them. In addition, support staff working in the facility or organization where the

self-service device is located may often be improperly trained on the correct use and activation of any accessibility features. In the future, training guidelines and resources (e.g., digital tutorials, audio guides, etc.) should be developed so that users of accessible technologies can receive training or support from trained service provider staff when using an unfamiliar self-service device. For example, staff training should include information of the needs of people with various disabilities and how to accommodate these when using with the technologies already implemented in the self-service device.

3.5.3 International Comparison of Accessible Technologies and Policies

The stakeholder interviews highlighted the differences between countries in regulations and policies for accessible technologies and accessible self-service devices. The participants described how accessible they found devices to be in the United States and their experiences while travelling in Europe. An in-depth global evaluation of accessibility policies and regulations is recommended to identify best practices for implementation in Canada.

3.5.4 Wayfinding for Self-Service Devices

Several research participants highlighted the difficulties associated with navigating open-concept spaces to locate and use accessible self-service devices. Accessibility features are critical for enabling users with disabilities to access services and information, and work is needed on the establishment of consistent and standardized wayfinding for accessible self-service devices.

4 Conclusions

Although self-service devices may include accessibility features, users with disabilities often struggle to use these technologies. Improved guidelines are needed for the design and evaluation of accessible self-service devices.

The following technologies should be considered for integration with self-service interactive devices and inclusion in CSA/ASC B651.2: facial detection, facial recognition, sign language avatars, gesture recognition, personal device integration, word completion and prediction, screen readers, antiglare screens, text-to-speech capability, fingerprint recognition, iris recognition, voice command and dictation, text enlargement, and refreshable braille displays. Although some of these technologies are present in CSA/ASC B651.2, this research proposes additional considerations.

Through the interviews with participants with lived experience of disability, several areas of consideration for the implementation of new technologies for self-service devices were identified. These include privacy and security, consistency, staff support, lack of feedback, inadequate accessibility, overall design, personal device integration, and regulations. Addressing the practical considerations for the integration of input and output technologies in self-service interactive devices has the potential to support a more secure and accessible experience for all users. Training guidelines for using self-service devices and training resources for the users of the accessible technologies that need to be consistently implemented across different self-service devices will help enable consistent, safe, and reliable user experiences for all.

References

[1] Government of Canada. Accessible Canada Act (S.C. 2019, c. 10), (2019 Jun. 21). [Online]. Available: https://laws-lois.justice.gc.ca/eng/acts/A-0.6/FullText.html

[2] "Federal disability reference guide," Government of Canada, Ottawa, ON, Canada, Dec. 16, 2022. Accessed: 10-Apr-2023 [Online]. Available: https://www.canada.ca/en/employment-social-development/programs/disability/arc/reference-guide.html

[3] "Disability Inclusion and Accessibility," Employment and Social Development Canada, Ottawa, ON, Canada, Feb. 23, 2022. [Online]. Available: https://www.canada.ca/en/employment-social-development/corporate/reports/esdc-transition-binders/inclusion-2021-infographic.html

[4] "Assistive and Adaptive Technologies," *Queen's Alumni Review*, May 5, 2017. Accessed: Apr. 10, 2023. [Online]. Available: https://www.queensu.ca/alumnireview/articles/2017-05-25/assistive-and-adaptive-technologies

[5] R. Choi, "Accessibility findings from the Canadian Survey on Disability," Statistics Canada, Ottawa, ON, Canada, Oct. 27, 2021. [Online]. Available: https://www150.statcan.gc.ca/n1/pub/89-654-x/89-654-x2021002-eng.htm

[6] DCIL Administrator. "Adaptive vs. Assistive Technology." Dakotacil.org. https://dakotacil.org/2016/10/31/adaptive-vs-assistive-technology/#:~:text=In%20other%20words%2C%20%E2%80%9Cassistive%20technology,capabilities%20of%20people%20with%20disabilities.%E2%80%9D (accessed Apr 10, 2023).

[7] *Accessible design for self-service interactive devices including automated banking machines*, CSA/ASC B651.2:22, CSA Group, Toronto, ON, Canada, 2022. [Online]. Available: https://www.csagroup.org/store/product/CSA-ASC%20B651.2:22/

[8] Y. Vakulenko, D. Hellström, and P. Oghazi, "Customer value in self-service kiosks: a systematic literature review," *Int. J. Retail Distrib.,* vol. 46, no. 5., pp. 507-527, May 2018. https://doi.org/10.1108/IJRDM-04-2017-0084

[9] P. Duarte, S. C. Silva, M. A. Linardi, and B. Novais, "Understanding the implementation of retail self-service check-out technologies using necessary condition analysis," *Int. J. Retail Distrib.,* vol. 50, no. 13, pp. 140-163, Sep. 2022. https://doi.org/10.1108/IJRDM-05-2022-0164

[10] M. J. Bitner, A. L. Ostrom, and M. L. Meuter, "Implementing successful self-service technologies," *A.M.P.*, vol. 16, no. 4, pp. 96-109, Nov. 2002. https://doi.org/10.5465/AME.2002.8951333

[11] *Ergonomics of human-system interaction – Part 20: An ergonomic approach to accessibility within the ISO 9241 series*, ISO 9241-20:2021, International Organization for Standardization, Geneva, Switzerland, Nov. 2021. [Online]. Available: https://www.iso.org/standard/80709.html

[12] *Ergonomics of human-system interaction – Part 112: Principles for the presentation of information*, ISO 9241-112:2017, International Organization for Standardization, Geneva, Switzerland, Mar 2017. [Online]. Available: https://www.iso.org/standard/64840.html

[13] *Ergonomics of human-system interaction – Part 11: Usability: Definitions and concepts*, ISO 9241-11:2018(en), International Organization for Standardization, Geneva, Switzerland, 2018. [Online]. Available: https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-2:v1:en

[14] Architectural and Transportation Barriers Compliance Board, Sep. 21, 2022._Document ID: ATBCB-2022-0004-0001, *Americans With Disabilities Act Accessibility Guidelines for Buildings and Facilities; Architectural Barriers Act Accessibility Guidelines; Self-Service Transaction Machines and Self-Service Kiosks*. [Online]. Available: https://www.regulations.gov/document/ATBCB-2022-0004-0001

[15] Government of Canada, *Accessible Transportation for Persons with Disabilities Regulations (SOR/2019-244)*, Jun. 25, 2022. [Online]. Available: https://laws-lois.justice.gc.ca/PDF/SOR-2019-244.pdf

[16] B. DiCicco-Bloom and B. F. Crabtree, "The qualitative research interview," *Med. Edu.,* vol. 40, no. 4. pp. 314-321, Mar. 2006. https://doi.org/10.1111/j.1365-2929.2006.02418.x

[17] A. Galletta and E. C. William, *Mastering the Semi-Structured Interview and Beyond: From Research Design to Analysis and Publication*. New York, NY, USA: NYU Press, 2013. https://doi.org/10.18574/nyu/9780814732939.001.0001

[18] B. A. Gillham, *Research Interviewing: The Range of Techniques*, Milton Keynes, UK: Open University Press, 2005.

[19] "Technology readiness levels," Innovation Canada, Government of Canada, Ottawa, ON, Canada, Jan. 23, 2018. [Online]. Available: https://ised-isde.canada.ca/site/innovation-canada/en/technology-readiness-levels

[20] I. Tzinis, "Technology readiness level," NASA.gov, Oct. 28, 2012. Available: https://www.nasa.gov/directorates/heo/scan/engineering/technology/tec (accessed Jan. 24, 2023).

[21] Y. Lee, S. Park, J. Park, and H. K. Kim, "Comparative Analysis of Usability and Accessibility of Kiosks for People with Disabilities," Appl. Sci., vol. 13, no. 5, 3058, Feb. 2023. https://doi.org/10.3390/app13053058

[22] H.-F. Hsieh and S. E. Shannon, "Three approaches to qualitative content analysis," *Qual. Health Res.*, vol. 15, no. 9, pp. 1277-1288, Nov. 2005. https://doi.org/10.1177/1049732305276687

[23] *Electronic fee collection – System architecture for vehicle related tolling – Part 2: Vocabulary*, ISO/TS 17573-2:2020. International Organization for Standardization, Geneva, Switzerland, Jul. 2020. [Online]. Available: https://www.iso.org/standard/79158.html

[24] *Health informatics – Interoperability and compatibility in messaging and communication standards – Key characteristics*, ISO/TR 18307:2001(en). International Organization for Standardization, Geneva, Switzerland, 2001. [Online]. Available: https://www.iso.org/obp/ui/#iso:std:iso:tr:18307:ed-1:v1:en

[25] Office of the Privacy Commissioner of Canada, "PIPEDA in brief," *Office of the Privacy Commissioner of Canada*, Gatineau, QC, May 31, 2019. [Online]. Available: https://www.priv.gc.ca/en/privacy-topics/privacy-laws-in-canada/the-personal-information-protection-and-electronic-documents-act-pipeda/pipeda_brief/

[26] "Technology Readiness Level (TRL) Assessment Tool," Government of Canada, Ottawa, ON, Canada, Apr. 6, 2021. [Online]. Available: https://ised-isde.canada.ca/site/clean-growth-hub/en/technology-readiness-level-trl-assessment-tool

[27] "ISO/IEC JTC 1 Information technology," ISO, Available: https://www.iso.org/committee/45020.html (accessed Mar. 28, 2023).

[28] "ISO/IEC JTC 1/SC 35 User interfaces," ISO, Available: https://www.iso.org/committee/45382.html (accessed Mar. 28, 2023).

[29] "ISO/TC 159/SC 4 Ergonomic of human-system interaction," ISO, Available: https://www.iso.org/committee/53372.html (accessed Mar. 28, 2023).

[30] "ISO/TC 173/SC 7 Assistive products for persons with impaired sensory functions," ISO, Available: https://www.iso.org/committee/608504.html (accessed: Mar. 28, 2023).

[31] "ISO/IEC JTC 1/SC 37 Biometrics," ISO. Available: https://www.iso.org/committee/313770.html (accessed Mar. 28, 2023).

[32] J. P. Spradley, "The ethnographic interview," *Adm. Sci. Q.*, vol. 25, no. 3, pp. 526-530, Sep. 1980. https://doi.org/10.2307/2392270

[33] A. Bryman and E. Bell, Social Research Methods, 5th ed. Oxford, United Kingdom: Oxford University Press, 2019.

[34] M. Bengtsson, "How to plan and perform a qualitative study using content analysis," *NursingPlus Open*, vol. 2, pp. 8-14, 2016. https://doi.org/10.1016/j.npls.2016.01.001

[35] L. S. Nowell, J. M. Norris, D. E. White, and N. J. Moules, "Thematic analysis: Striving to meet the trustworthiness criteria," *Int. J. Qual. Meth.*, vol. 16, no. 1, Sep. 2017. https://doi.org/10.1177/1609406917733847

[36] M. Vaismoradi, J. Jones, H. Turunen, and S. Snelgrove, "Theme development in qualitative content analysis and thematic analysis," *J. Nurs. Educ. Pract.,* vol. 6, no. 5, Jan. 2016. https://doi.org/10.5430/jnep.v6n5p100

[37] P. Backman and C. Kennedy, "Canadian and privacy concerns: Biometric identification perspective," *Aird and Berlis*. Available: https://www.airdberlis.com/docs/default-source/articles/biometric-identification-and-privacy-concerns.pdf?s. (accessed Feb 16, 2023).

[38] Face detection: What is it and how does this tech work?," *RecFaces*, Available: https://recfaces.com/articles/what-is-face-detection. (accessed Feb 16, 2023).

[39] K. D. Manley, J. C. Chan, and G. L. Wells, "Improving face identification of mask-wearing individuals," *Cogn. Research,* vol. 7, no. 1, Mar. 2022. https://doi.org/10.1186/s41235-022-00369-7

[40] A. Kumar, A. Kaur, and M. Kumar, "Face detection techniques: A Review," *Artif. Intell. Rev.,* vol. 52, no. 2, pp. 927-948, Aug. 2018. https://doi.org/10.1007/s10462-018-9650-2

[41] C. Stouffer, "What is facial recognition and how does it work," *Norton*, Available: https://us.norton.com/blog/iot/how-facial-recognition-software-works. (accessed Feb 16, 2023).

[42] O. Ciftci, E.-K. (C.) Choi, and K. Berezina, "Let's face it: Are customers ready for facial recognition technology at quick-service restaurants?," *Int. J. Hosp. Manag.*, vol. 95, p. 102941, May 2021. https://doi.org/10.1016/j.ijhm.2021.102941

[43] M. R. Firmanda, B. Sena Bayu Dewantara, and R. Sigit, "Implementation of illumination invariant face recognition for accessing user record in Healthcare Kiosk," 2020 *IES*, Surabaya, Indonesia, 29-30 Sep. 2020, pp. 371-376. https://doi.org/10.1109/IES50839.2020.9231644

[44] H. Baqeel and S. Saeed, "Face detection authentication on Smartphones: End users usability assessment experiences," in 2019 *ICCIS*, Sakaka, Saudi Arabia, 3-4 Apr. 2019, pp. 1-6. https://doi.org/10.1109/ICCISci.2019.8716452

[45] *Information technology – Biometric data interchange formats – Part 5: Face image data (Adopted ISO/IEC 19794-5:2011, second edition, 2011-11-01, including adopted amendment 1:2014, amendment 2:2015 and technical corrigendum 1:2016 to amendment 2:2015)*, CSA ISO/IEC 19794-5:20, CSA Group, Toronto, ON, Canada, 2020. [Online]. Available: https://www.csagroup.org/store/product/2427982/

[46] *Information technology – Biometric performance testing and reporting – Part 5: Access control scenario and grading scheme*, ISO/IEC 19795-5:2011, International Organization for Standardization, Geneva, Switzerland, Mar. 2011. Available: https://www.iso.org/standard/51768.html

[47] *IEEE Approved standard for performance evaluation of biometric information: Facial recognition*, IEEE P2884-2023, Institute of Electrical and Electronics Engineers, New York, NY, USA, Jun. 5, 2023. Available: https://standards.ieee.org/ieee/2884/10304/

[48] *Information technology – Use of biometrics in video surveillance systems – Part 1: System design and specification*, CSA ISO/IEC 30137-1:20, CSA Group, Toronto, ON, Canada, 2020 [Online]. Available: https://www.iso.org/standard/64935.html

[49] M. Hamedi, S. H. Salleh, T. S. Tan, K. Ismail, J. Ali, C. Dee-Uam, C. Pavaganun, and P. P. Yupapin, "Human facial neural activities and gesture recognition for machine-interfacing applications," *Int. J. Nanomed.*, vol. 2011, no. 6, pp. 3461-3472, 2011. https://doi.org/10.2147/IJN.S26619

[50] Fraunhofer-Gesellschaft, "Mobile control with facial gestures," *ScienceDaily*, Available: https://www.sciencedaily.com/releases/2017/07/170712074322.htm. (accessed Feb 16, 2023).

[51] A. Barreto, S. Scargle, and M. Adjouadi, "A practical EMG-based human-computer interface for users with motor disabilities," *J.R.R.D.*, vol. 37, no. 1, pp. 53-64, 2000. Accessed: Jan. 24, 2023. [Online]. Available: https://digitalcommons.fiu.edu/ece_fac/26

[52] J. Varona, C. Manresa-Yee, and F. J. Perales, "Hands-free vision-based interface for computer accessibility," *J. Netw. Comput. Appl.*, vol. 31, no. 4, pp. 357-374, Nov. 2008. https://doi.org/10.1016/j.jnca.2008.03.003

[53] D. Rozado, J. Niu, and M. Lochner, "Fast human-computer interaction by combining gaze pointing and face gestures," *A. C. M. Trans. Access. Comput.*, vol. 10, no. 3, pp. 1-18, Aug. 2017. https://doi.org/10.1145/3075301

[54] *Ergonomics of human-system interaction – Part 960: Framework and guidance for gesture interactions*, ISO/TS 9241-960:2017, International Organization for Standardization, Geneva, Switzerland, Sep. 2017. [Online]. Available: https://www.iso.org/standard/62535.html

[55] Ergonomics of human-system interaction – Part 430: Recommendations for the design of non-touch gestural input for the reduction of biomechanical stress, ISO/TS 9241-430:2021, International Organization for Standardization, Geneva, Switzerland, Dec. 2021. [Online]. https://www.iso.org/standard/80270.html

[56] Ergonomics of human-system interaction – Part 910: Framework for tactile and haptic interaction, ISO 9241-910:2011, International Organization for Standardization, Geneva, Switzerland, Jul. 2011. [Online]. https://www.iso.org/standard/51097.html

[57] Ergonomics of human-system interaction – Part 940: Evaluation of tactile and haptic interactions, ISO 9241-940:2017, International Organization for Standardization, Geneva, Switzerland, Nov. 2017. [Online]. https://www.iso.org/standard/61362.html

[58] "Physical pointers: Accessibility," *Wunder*, Available: https://wunder.io/wunderpedia/accessibility/digital-assistive-technologies/physical-pointers/ (accessed Feb 16, 2023)

[59] Ergonomics of human-system interaction – Part 410: Design criteria for physical input devices, ISO 9241-410:2008, International Organization for Standardization, Geneva, Switzerland, Feb. 2008. [Online]. Available: https://www.iso.org/standard/38899.html

[60] Ergonomics of human-system interaction – Part 411: Evaluation methods for the design of physical input devices, ISO/TS 9241-411:2012, International Organization for Standardization, Geneva, Switzerland, May 2012. [Online]. Available: https://www.iso.org/standard/54106.html

[61] C.I.E. Group, "Understanding Voice Control for Home Automation," *How does Voice Activation work?*, https://cie-group.com/how-to-av/videos-and-blogs/voice-control. (accessed Feb 27, 2023)

[62] F. Chavez-Sanchez and L. M. Colin, "Apples and oranges: A framework for the usability evaluation of voice vs graphical user interfaces: A command-event based method proposal," Proceedings of the 2nd *Conf CUI*, Bilbao, Spain, pp. 1–3, 2020, https://doi.org/10.1145/3405755.3406169

[63] E. Corbett and A. Weber, "What can I say?: addressing user experience challenges of a mobile voice user interface for accessibility," Proceedings of the 18th International *Conf MobileHCI*, Florence, Italy, pp. 72–82, 2016, https://doi.org/10.1145/2935334.2935386

[64] Information technology – User interfaces – Voice commands – Part 1: Framework and general guidance, CAN/CSA-ISO/IEC 30122-1:18, CSA Group, Toronto, ON, Canada, 2018. [Online]. Available: https://www.csagroup.org/store/product/2704332/

[65] Information technology – User interfaces – Voice commands – Part 2: Constructing and testing, ISO/IEC 30122-2:2017, CSA Group, Toronto, ON, Canada, 2018 [Online]. Available: https://www.csagroup.org/store/product/CAN-CSA-ISO-IEC%2030122-2%3A18/

[66] Ergonomics of human-system interaction – Part 154: Interactive voice response (IVR) applications, ISO 9241-154:2013, International Organization for Standardization, Geneva, Switzerland, Feb. 2013. Available: https://www.iso.org/standard/52172.html

[67] Information technology – Document processing and related communication – User interface to telephone-based services – Voice messaging applications, ISO/IEC 13714:1995, International Organization for Standardization, Geneva, Switzerland, Feb. 1995. [Online]. Available: https://www.iso.org/standard/22721.html

[68] J. Vincent, "Amazon's palm reading starts at the grocery store, but it could be so much bigger," *The Verge*,https://www.theverge.com/2020/10/1/21496673/amazon-one-palm-reading-vein-recognition-payments-identity-verification (accessed Feb 1, 2023).

[69] D. Liliana, "The combination of palm print and hand geometry for biometrics palm recognition" *Semantic scholar*, 2012. https://www.semanticscholar.org/paper/The-combination-of-palm-print-and-hand-geometry-for-Liliana/f698221cb79fc53536288d4affd409f06b7e3131#citing-papers (accessed Feb 1, 2023)

[70] M. Liebowitz, "Japanese bank introduces palm-scanning ATMs," NBCNews.com. https://www.nbcnews.com/id/wbna47019911 (accessed Feb. 1, 2023).

[71] Information technology – Biometric data interchange format – Part 15: Palm crease image data, ISO/IEC 19794-15:2017, International Organization for Standardization, Geneva, Switzerland, May 2017. [Online]. Available: https://www.iso.org/standard/63865.html

[72] Center for Devices and Radiological Health, "Applying human factors and usability engineering to medical devices: Guidance for Industry and Food and Drug Administration Staff," U.S. Food and Drug Administration, Rockville, MD, USA, Feb. 3, 2016. [Online]. Available: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/applying-human-factors-and-usability-engineering-medical-devices

[73] M. M. H. Ali, V. H. Mahale, P. Yannawar, and A. T. Gaikwad, "Overview of fingerprint recognition system," presented at the 2016 *ICEEOT*, Chennai, Tamil Nadu, India, pp. 1334-1338, Mar 3-5, 2016. https://doi.org/10.1109/ICEEOT.2016.7754900.

[74] R. Triggs, "How fingerprint scanners work: Optical, capacitive, and Ultrasonic explained," *Android Authority*, https://www.androidauthority.com/how-fingerprint-scanners-work-670934/ (accessed Feb 1, 2023).

[75] D. Thakkar, "Fingerprint reference point detection and feature extraction," *Bayometric*, https://www.bayometric.com/fingerprint-reference-point-detection-and-feature-extraction/ (accessed Feb 1, 2023).

[76] S.K. Singla, A.S. Arora, "Biometric and its issues for disabled," *IJSTM* vol. 2, no. 2, pp. 37–41, 2010. https://www.academia.edu/download/30939956/1146080820111637301.pdf#page=41

[77] S. Furnell, K. Helkala, N. Woods, "Accessible authentication: Assessing the applicability for users with disabilities," *Comput. Secur.*, vol. 113, p. 102561, Feb. 2022. https://doi.org/10.1016/j.cose.2021.102561

[78] Information technology – Biometric data interchange formats – Part 8: Finger pattern skeletal data, ISO/IEC 19794-8:2011, International Organization for Standardization, Geneva, Switzerland, Dec. 2011. [Online]. Available: https://www.iso.org/standard/50869.html

[79] Information technology – Biometric data interchange formats – Part 2: Finger minutiae data, ISO/IEC 19794-2:2011, International Organization for Standardization, Geneva, Switzerland, Dec. 2011. [Online]. Available: https://www.iso.org/standard/50864.html

[80] IEEE Approved draft standard for performance evaluation of biometric information: Fingerprint recognition, IEEE P2891-2023, Institute of Electrical and Electronics Engineers, New York, NY, USA, Jun. 5, 2023. Available: https://standards.ieee.org/ieee/2891/10306/

[81] "Iris recognition," *NEC,* 2022. https://www.nec.com/en/global/solutions/biometrics/iris/index.html (accessed Feb 1, 2023)

[82] S. E. Baker, A. Hentz, K. W. Bowyer and P. J. Flynn, "Contact lenses: Handle with care for iris recognition," 2009 IEEE 3rd *Int. Conf. BTAS*, Washington, DC, USA, 2009, pp. 1-8, doi: 10.1109/BTAS.2009.5339050.

[83] *Information technology – Biometric data interchange formats – Part 6: Iris image data*, ISO/IEC 19794-6:2011, International Organization for Standardization, Geneva, Switzerland, Oct. 2011. [Online]. Available: https://www.iso.org/standard/50868.html

[84] Information technology – Biometric sample quality – Part 6: Iris image data, ISO/IEC 29794-6:2015, International Organization for Standardization, Geneva, Switzerland, Jul. 2015. [Online]. Available: https://www.iso.org/standard/54066.html

[85] Photobiological safety of lamps and lamp systems, IEC 62471 Ed. 1.0 b:2006, International Electrotechnical Commission, Geneva, Switzerland, 2006.

[86] J. Jullion, "Braille writing with Braille keyboards," *T Base Communications*, https://tbase.com/braille-writing-with-braille-keyboards/#:~:text=What%20is%20a%20Braille%20Keyboard,to%20create%20that%20braille%20character (accessed Feb 16, 2023).

[87] Accessible design – Application of braille on signage, equipment and appliances, ISO 17049;2013(en), International Organization for Standardization, Geneva, Switzerland, 2013. [Online]. Available: https://www.iso.org/obp/ui/#iso:std:iso:17049:ed-1:v1:en

[88] "World braille usage," Perkins School for the Blind, https://www.perkins.org/resource/world-braille-usage/ (accessed Jul 10, 2023).

[89] AccessComputing. "What is Nemeth Code?," Washington.edu. https://www.washington.edu/accesscomputing/what-nemeth-code#:~:text=Nemeth%20Code%20is%20a%20special,his%20doctoral%20studies%20in%20mathematics (accessed Mar. 23, 2023).

[90] Kellogg, V. Talla, and S. Gollakota, "Bringing gesture recognition to all devices - USENIX," in the 11th *USENIX Symposium on NSDI*,, Seattle, WA, USA, April, 2014. https://www.usenix.org/system/files/conference/nsdi14/nsdi14-paper-kellogg.pdf.

[91] A. Nelson, S. McCombe Waller, R. Robucci, C. Patel, and N. Banerjee, "Evaluating touchless capacitive gesture recognition as an assistive device for Upper Extremity Mobility Impairment," *RATE*, vol. 5, pp. 1–13, 2018. https://doi.org/:10.1177/2055668318762063.

[92] N. Alnaim, M. Abbod, and A. Albar, "Hand Gesture Recognition Using Convolutional Neural Network for People Who Have Experienced A Stroke," Presented at 2019 3rd *ISMSIT*, Ankara, Turkey, pp. 1-6, 2019. https://doi.org/:10.1109/ISMSIT.2019.8932739.

[93] Ergonomics of human-system interaction – Part 971: Accessibility of tactile/haptic interactive systems, ISO 9241-971:2020, International Organization for Standardization, Geneva, Switzerland, Dec. 2020. [Online]. https://www.iso.org/standard/74511.html

[94] Information technology – Gesture-based interfaces across devices and methods – Part 11: Single-point gestures for common system actions, ISO/IEC 30113-11:2017, International Organization for Standardization, Geneva, Switzerland, Aug. 2017. [Online]. Available: https://www.iso.org/standard/62863.html

[95] Information technology – User interfaces – Gesture-based interfaces across devices and methods – Part 12: Multi-point gestures for common system actions, ISO/IEC 30113-12:2019, International Organization for Standardization, Geneva, Switzerland, Nov. 2019. [Online]. Available: https://www.iso.org/standard/74362.html

[96] "Introduction to 7 Common Adaptive Switches," *tecla*. Available: https://gettecla.com/blogs/news/introduction-to-assistive-switches (accessed April. 10, 2023).

[97] "Creating accessible content for people who use eye-tracking devices,"*Bureau of Internet Accessibility*. Available: https://www.boia.org/blog/creating-accessible-content-for-people-who-use-eye-tracking-devices (accessed Fe20b 1. 2023).

[98] D. Fluckinger, "Retail facial recognition and eye tracking the next Tech Wave, maybe," TechTarget.com. https://www.techtarget.com/searchcustomerexperience/news/252477356/Retail-facial-recognition-and-eye-tracking-the-next-tech-wave-maybe (accessed Feb. 1, 2023).

[99] Ergonomics of human – system interaction – Part 400: Principles and requirements for physical input devices, ISO 9241-400:2007, International Organization for Standardization, Geneva, Switzerland, Feb. 2007. [Online]. Available: https://www.iso.org/standard/38896.html

[100] *Web Content Accessibility Guidelines (WCAG) 2.1*, World Wide Web Consortium, Cambridge, MA, USA, Jun. 5, 2018. [Online]. Available: https://www.w3.org/TR/WCAG21/#motion-actuatio

[101] Accessibility requirements for ICT products and services, EN 301 549 V3.2.1, European Telecommunications Standards Institute, Sophia Antipolis, France, Mar. 2021. [Online]. Available: https://www.etsi.org/deliver/etsi_en/301500_301599/301549/03.02.01_60/en_301549v030201p.pdf

[102] V. G. Duffy, Q. Gao, J. Zhou, M. Antona, and C. Stephanidis, "HCI International 2022 – Late Breaking Papers: HCI for Health, Well-being, Universal Access and Active Aging," *Springer, vol. 13521, 2022.*

[103] Charlie, "Keyboards for people with disabilities," bltt.org. https://bltt.org/keyboards-for-disabled-people/ (accessed Feb. 2, 2023).

[104] J. Martin, "Word prediction technology: What it is and how it works," Understood.org, https://www.understood.org/en/articles/word-prediction-technology-what-it-is-and-how-it-works (accessed Feb. 2, 2023).

[105] M. Maiorana-Basas and C. M. Pagliaro, "Technology use among adults who are deaf and hard of hearing: A national survey," *J. Deaf Stud. Deaf Educ.*, vol. 19, no. 3, pp. 400-410, 2014. https://doi.org/10.1093/deafed/enu005

[106] A. Pradhan, K. Mehta, and L. Findlater, "'Accessibility came by accident': Use of voice-controlled intelligent personal assistants by people with disabilities," presented at the 2018 CHI, Montreal, QC, Canada, Apr. 21-26, 2018. https://doi.org/10.1145/3173574.3174033

[107] V. Ashok, S. M. Billah, Y. Borodin, and I. V. Ramakrishnan, "Auto-suggesting browsing actions for personalized web screen reading," presented at the 27th ACM UMAP, Larnaca, Cyprus, Jun. 9-12, 2019. https://doi.org/10.1145/3320435.3320460

[108] H. Takyi, V. Watzlaf, J. T. Matthews, L. Zhou, and D. DeAlmeida, "Privacy and Security in Multi-User Health Kiosks", *Int. J. Telerehab.*, vol. 9, no. 1, pp. 3-14, Jun. 2017. https://doi.org/10.5195/ijt.2017.6217

[109] B. Ballmann, Understanding network hacks: Attack and defense with Python. Berlin: Springer Berlin, 2016.

[110] S. S. Hassan, S. D. Bibon, M. S. Hossain, and M. Atiquzzaman, "Security threats in bluetooth technology," *Comput. Secur. J.*, vol. 74, pp. 308-322, May 2018. http://doi.org/10.1016/j.cose.2017.03.008

[111] S. Shrestha, E. Irby, R. Thapa, and S. Das, "SOK: A systematic literature review of bluetooth security threats and mitigation measures," presented at EISA, Copenhagen, DK, Nov. 12-13, 2021. https://doi.org/10.2139/ssrn.3959316

[112] W. Albazrqaoe, J. Huang, and G. Xing, "Practical bluetooth traffic sniffing," presented at the 14th ACM MobiSys, Singapore, SG, Jun. 26-30, 2016. https://doi.org/10.1145/2906388.2906403

[113] "Screen reading technology and refreshable braille displays," AFB.org. https://www.afb.org/blindness-and-low-vision/using-technology/assistive-technology-videos/screen-reading-technology (accessed Apr. 04, 2023).

[114] "JAWS for kiosk," TPGi.com. https://www.tpgi.com/accessibility-solutions/jaws-kiosk (accessed Apr. 11, 2023).

[115] Information technology – Gesture-based interfaces across devices and methods – Part 60: General guidance on gestures for screen readers, ISO/IEC 30113-60:2020, International Organization for Standardization, Geneva, Switzerland, Oct. 2020. [Online]. Available: https://www.iso.org/standard/77179.html

[116] Information technology – Gesture-based interfaces across devices and methods – Part 61: Single-point gestures for screen readers, ISO/IEC 30113-61:2020, International Organization for Standardization, Geneva, Switzerland, Nov. 2020. [Online]. Available: https://www.iso.org/standard/75586.html

[117] Murf.AI. "Phonemes and their Role in Text to Speech Pronunciation." Murf Resources. https://murf.ai/resources/what-are-phonemes (accessed Mar. 23, 2023)

[118] Ergonomics – Accessible design – Spoken instructions of consumer products, ISO 24551:2019. International Organization for Standardization, Geneva, Switzerland, Oct. 2019. [Online]. Available: https://www.iso.org/standard/72307.html

[119] "Refreshable Braille Displays," *The American Foundation for the Blind*. Accessed 23-Feb-2023 [Online]. Available: https://www.afb.org/node/16207/refreshable-braille-displays.

[120] Information technology – Individualized adaptability and accessibility in e-learning, education and training – Part 1: Framework and reference model, ISO/IEC 24751-1:2008, International Organization for Standardization, Geneva, Switzerland, Oct. 2008. [Online]. https://www.iso.org/standard/41521.html

[121] "Why you need an anti-glare Screen & How It Works," *Lenovo.* https://www.lenovo.com/ca/en/glossary/anti-glare-screen/?orgRef=https%253A%252F%252Fwww.google.com%252F (accessed Jul. 10 2023).

[122] "Screen magnifiers: Who and how they help," boia.org. https://www.boia.org/blog/screen-magnifiers-who-and-how-they-help (accessed Apr. 11, 2023).

[123] K. Piff, "Make your self-service kiosks accessible," YourDolphin.com. https://blog.yourdolphin.com/blog/make-your-self-service-kiosks-accessible (accessed Apr. 11, 2023).

[124] "Top 4 large touch screen advantages," AdvancedKiosks.com. https://advancedkiosks.com/top-4-large-touch-screen-advantages/ (accessed Apr. 11, 2023).

[125] M. Kipp, A. Heloir, Q. Nguyen, "Sign language avatars: Animation and comprehensibility," in IVA 2011, Reykjavik, Iceland, Sep. 15-17, 2011. https://doi.org/10.1007/978-3-642-23974-8_13

[126] Canadian Association of the Deaf – Association des Sourds du Canada. "Language." cad-asc.ca. https://cad.ca/issues-positions/language/#:~:text=In%20Canada%20there%20are%20two,Maritimes%20Sign%20Language%20(MSL) (accessed Feb. 28, 2023).

[127] L. C. Quandt, A. Willis, M. Schwenk, K. Weeks, and R. Ferster, "Attitudes toward signing avatars vary depending on hearing status, age of signed language acquisition, and avatar type," *Front. Psych*., vol. 13, Feb. 2022. https://doi.org/10.3389/fpsyg.2022.730917

[128] F. C. Yang, C. Mousas, and N. Adamo, "Holographic sign language avatar interpreter: A user interaction study in a mixed reality classroom," *Comput. Animat. Virt. W.*, vol. 33, no. 3-4, pp. 1-14, Jun./Jul. 2022. https://doi.org/10.1002/cav.2082

[129] R. Sanchez-Reillo, R. Blanco-Gonzalo, J. Liu-Jimenez, M. Lopez, and E. Canto, "Universal access through biometrics in mobile scenarios," presented at 47th ICCST, Medellin, Colombia, Oct. 8-11, 2013. https://doi.org/10.1109/CCST.2013.6922051

[130] C. Bhagavatula, B. Ur, K. Iacovino, S. M. Kywey, L. F. Cranor, and M. Savvides, "Biometric authentication on iPhone and Android: Usability, perceptions, and influences on adoption," presented at 2015 NDSS, San Diego, CA, USA, Feb. 8-11, 2015. https://doi.org/10.14722/usec.2015.23003

[131] H. Hofbauer, L. Debiasi, S. Kränkl, and A. Uhl, "Exploring presentation attack vulnerability and usability of face recognition systems," *IET Biometrics*, vol. 10, no. 2, pp. 219-232, Mar. 2021. https://doi.org/10.1049/bme2.12015

[132] F. Wolf, R. Kuber, and A. J. Aviv, "'Pretty close to a must-have': Balancing usability desire and security concern in biometric adoption," presented at CHI '19, Glasgow, Scotland, UK, May 4-9, 2019. https://doi.org/10.1145/3290605.3300381

[133] L. M. Mayron, Y. Hausawi, and G. S. Bahr, "Secure, usable biometric authentication systems," presented at UAHCI 2013, Las Vegas, NV, USA, July 21-26, 2013. https://doi.org/10.1007/978-3-642-39188-0_21

[134] R. Wolfe, J. C. McDonald, T. Hanke, S. Ebling, D. Van Landuyt, F. Picron, V. Krausneker, E. Efthimiou, E. Fotinea, and A. Braffort, "Sign language avatars: A question of representation," *Information*, vol. 13, no. 4, pp. 1-17, Apr. 2022. https://doi.org/10.3390/info13040206

[135] J. N. Gilmore, "Design for everyone: Apple Airpods and the mediation of accessibility," *Crit. Stud. Media Comm.*, vol. 36, no. 5, pp. 482-494, Sep. 2019. https://doi.org/10.1080/15295036.2019.1658885

[136] J. H. Christensen, G. H. Saunders, L. Havtorn, and N. H. Pontoppidan, "Real-world hearing aid usage patterns and smartphone connectivity," *Front. Digit. Health*, vol. 3, 2021. https://doi.org/10.3389/fdgth.2021.722186

[137] D. S. Zwakman, D. Pal, and C. Arpnikanondt, "Usability evaluation of artificial intelligence-based voice assistants: The case of Amazon Alexa," *S. N. Comput. Sci.*, vol. 2, no. 28, pp. 1-16, Jan. 2021. https://doi.org/10.1007/s42979-020-00424-

[138] B. Leporini, M. C. Buzzi, and M. Buzzi, "Interacting with mobile devices via voiceover," presented at the 24th OzCHI, Melbourne, AU, Nov. 26-30, 2012. https://doi.org/10.1145/2414536.2414591

[139] J. Vanus, M. Smolon, R. Martinek, J. Koziorek, J. Zidek, and P. Bilik, "Testing of the voice communication in Smart Home Care," *H.C.I.S.*, vol. 5, no. 1, pp. 1-22, Jun. 2015. https://doi.org/10.1186/s13673-015-0035-0

[140] Ingenium Accessibility, "Accessibility standards for exhibitions," accessibilitycanada.ca. https://accessibilitycanada.ca/wp-content/uploads/2019/07/Accessibility-Standards-for-Exhibitions.pdf (accessed Feb. 2, 2023).

[141] S. M. Billah, V. Ashok, D. E. Porter, and I. V. Ramakrishnan, "Ubiquitous accessibility for people with visual impairments: Are we there yet?," presented at the CHI '17, Denver, CO, USA, May 6- 11, 2017. https://doi.org/10.1145/3025453.3025731

Appendix A: Interview Questions

A.1 People With Lived Experience of Disability and Advocates

- What is your name?
- What disabilities do you identify with?
- How much experience do you have with technologies in general? Do you consider yourself a tech savvy person?
- What is your experience with accessible technologies? Can you tell us what you have used in the past?
- How much experience do you think other people with disabilities have with a self-service interactive devices (e.g., accessible kiosks)?
- If yes: have you heard of any issues with accessible kiosks in the past?
- How much experience do you have with self-service interactive devices (e.g., accessible kiosks, check-in tablets at medical offices, check-in kiosks at the airport, ordering kiosks and point of sales at restaurants like McDonalds)
- Have you used a self-service interactive device as a kiosk in the past? Which ones? Can you tell us about it?
- Did you find it accessible?
- What were your major problems when using the device?
- If you needed help, how did you get support?
- What would you like an accessible system in a self-service interactive devices (e.g., kiosk) to do for you? What would be your ideal system?
- We are reviewing the following list of accessible technologies that can be used in a self-service interactive devices. Which of the following technologies do you have previous experience with?
    - Facial detection and facial recognition
    - Voice command
    - Voice recognition
    - Screen readers
    - Mobile payments in multiple methods
    - Fingerprint recognition
    - Braille keyboard and display
    - On-screen or virtual keyboards
    - Eye-tracking software
    - Dictation
    - Word prediction
    - Adaptive keyboard
    - Predictive keyboards (word completion)
    - Text to speech
- What are your major concerns when using accessible kiosks (prompt for privacy, confidentiality, safety, etc.)?
- Is there anything else you want to discuss?
- Do you have any suggestions of other people with lived experiences that would be interested in participating in our study?

A.2 Industry and Regulation

- What is your name?
- What's your role in your organization?
- What does your organization work with?
- What industry do you work in?
- What service does your industry offer? How do you offer it? Do you use kiosks to deliver it?
- What types of accessible technologies are you planning to integrate into your products in the future? Are you currently exploring new technologies to help increase the accessibility of your systems/products?
- What is your experience working with accessible design?
- How much experience does your company have with accessible kiosks?
- We are reviewing the following list of accessible technologies that can be used in a self-service interactive devices. Which of the following technologies has your company previously explored?
    - Facial detection and facial recognition
    - Voice command
    - Voice recognition
    - Screen readers
    - Mobile payments in multiple methods
    - Fingerprint recognition
    - Braille keyboard and display
    - On-screen or virtual keyboards
    - Eye-tracking software
    - Dictation
    - Word prediction
    - Adaptive keyboard
    - Predictive keyboards (word completion)
    - Text to speech
- Do you have a system for making products accessible? If yes, how does it look like?
    - Do you include people with lived experience as part of your design/consultation process?
- Do you have any training in place for using accessible technology? If yes, what does it look like?
- Do you use accessibility focused usability testing when developing your products? If yes, what does it look like?
- What are your major concerns when making accessible kiosks, if there are any (prompt for privacy, confidentiality, safety, etc.)
- Do you follow any standards?
- Is there anything else you want to discuss?
- Do you have suggestions of other companies or people that we could interview for this project?

CSA Group Research

In order to encourage the use of consensus-based standards solutions to promote safety and encourage innovation, CSA Group supports and conducts research in areas that address new or emerging industries, as well as topics and issues that impact a broad base of current and potential stakeholders. The output of our research programs will support the development of future standards solutions, provide interim guidance to industries on the development and adoption of new technologies, and help to demonstrate our on-going commitment to building a better, safer, more sustainable world.

CSA GROUP™

© 2023 Canadian Standards Association. All Rights Reserved.