Information and Software Technology 190 (2026) 107970

Contents lists available at ScienceDirect

Information and Software Technology

journal homepage: www.elsevier.com/locate/infsof

Accessibility evaluation of interaction modalities and cognitive process of self-service technologies' user interface in Japan

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ARTICLE INFO

Keywords:
Accessibility
Self-service technologies
Interaction modalities
Cognition

ABSTRACT

As more and more services are becoming available only in digital form, self-service technologies (SSTs) need to be accessible to ensure all citizens have equal opportunities to participate in society. However, SSTs' accessibility is still insufficient, and the overall picture of possible accessibility issues with SSTs is fragmented. In this study, we evaluated the accessibility of a sample of 20 SSTs in Japan by examining variables in user perception and action, factors related to cognitive accessibility, and user interface components. The findings are twofold. First, we illustrated the multimodalities in SST interaction based on the theory of human-computer interaction. Then, we identified SST user interface design practices that impact human cognition. This study illustrates the current reality of how accessibility is actualized and proposes future research directions and practices for the SST industry to develop and improve SSTs' accessibility.

1. Introduction

The number of users of digital services is constantly increasing, as more and more services are becoming available only in digital form [1,2]. Nowadays, people interact with digital services using self-service technologies (SSTs) almost everywhere in daily life [3–5]. According to The Digital Economy and Society Index [3], digital interaction has become the new norm of our society, and the target is to have all public services for citizens, as well as businesses, digitally available.

Despite regulations dictating better accessibility by law, prior research is very concerned about the sufficiency of SSTs' accessibility. The transient nature of interaction with SSTs poses additional challenges for the design, as people with a wide variety of user characteristics have short-duration interactions in single-user and multi-user contexts [6]. Therefore, the design of the user interfaces (UIs) of these technologies should be comprehensive, aesthetically calm, support short-duration interactions, and be immediately accessible and usable [7,8] so that all citizens have equal opportunities to participate in society also through digital services [9].

Prior studies offer important knowledge that practitioners can deploy to enhance the accessibility of SSTs. However, we argue that the overall picture of possible accessibility issues with SSTs is fragmented, since these studies investigate accessibility issues from one angle, for instance, perceivability, at a time. In addition, according to Web Accessibility Infrastructure Committee, there are many prescriptive accessibility standards in Japan, but no single standard that dictates the accessibility of SSTs, including physical, hardware, and software accessibility [10].

There is a gap in our knowledge of the overall state of accessibility and the issues that may arise during the interaction between users and SSTs. By this overall picture, we refer the factors in the interaction and communication between humans and SSTs (comparable to human-computer interaction) that include human output channels (movements and actions dedicated to interacting with the computer), computer input modalities (channels that the device offers for humans to input commands), computer output modalities (channels of information that the computer dedicates for the user), human input modalities (channels that humans use to receive information), and human cognition (the process from receiving information to taking further action).

The gap in the knowledge of overall SSTs' accessibility raises concerns about how SST suppliers and deployers can respond to the need for providing equal opportunities for citizens to interact with SSTs. We argue that there is first a need to categorize and align possible accessibility issues with human abilities to identify problem domains. Secondly, we need to explain what design practices can improve accessibility and discuss how these can be implemented. Therefore, we

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https://doi.org/10.1016/j.infsof.2025.107970
Received 4 February 2025; Received in revised form 6 November 2025; Accepted 10 November 2025
Available online 11 November 2025

set the following overall research question:

What accessibility issues exist in the user interfaces of self-service technologies in Japan?

To achieve this goal, we conducted a qualitative photographic review of 20 SSTs in Japan.

We identified the current extents and gaps in accessibility related to human output channels, SST input modalities, SST output media, human input channels, and human cognitive processes.

First, we found that voice-based channels are not utilized in our sample SSTs. Current SST interactions primarily rely on physical movements, therefore, alternative channels, such as voice commands instead of physical force, are missing from the SST context.

Secondly, SST interactions heavily rely on visual and auditory abilities. The sense of touch is underrepresented. While braille provides tactile information, haptic practices familiar from mobile phone technology have not yet been applied to SSTs.

Thirdly, our findings revealed a connection between UI components and human cognition, which can help SST designers consider how specific UI elements affect cognitive processes. For instance, UI's appearance and navigation, such as clicking buttons, directly impact to understanding of structure, management, and memory. Moreover, the use of colors in UIs significantly impacts metaphors, mental models, and overall accessibility. Therefore, it can be argued that the design of UI components has a primary effect on human cognition and understanding of SST usage.

As many of prior study focused on accessibility of touchscreen (c.f. [5,11]), our findings instead highlight that considerations of accessibility in touchscreen design alone is insufficient for providing accessible interaction with SSTs [4]. As a contribution to practice, we summarized the practices that the SST industry can apply to increase cognitive accessibility of SSTs. We illustrate the first-hand connection between these practices and human cognition. Additionally, we categorize these practices into UI components to understand their impact area on cognitive processes.

This study is conducted in Japanese context. Japan offers an interesting field due the fragmented standards for physical, hardware, and software accessibility [10]. There are around 4 million units of SSTs, of which about half are vending machines and the rest are ticket vending machines in train stations and entrance ticket vending machines at public facilities. Considering the size of its population and land area, Japan can be said to have the highest actual number of SSTs in the world [12,13].

This paper is structured as follows: Chapter 2 presents the background and related literature on SSTs accessibility. Chapter 3 describes the applied methodology. Our findings are presented in Chapter 4. In Chapter 5, we discuss the research contributions and practical implications, examine the trustworthiness of the results, and outline directions for future research. Chapter 6 concludes the paper.

2. Background and related literature

In this study, we define the term 'self-service technologies' as an umbrella term for devices that are purposed for public or business self-services. This study inspects the accessibility of technologies that are self-service terminals: Self-Ordering Kiosk (SOK), Self-Checkout (SCO), Vending Machine (VM), Ticket Vending Machine (TVM), Automatic Teller Machine (ATM), Self-Service Laundry (SSL), and Self-Service Locker (SSLo).

Japan's accessibility legislation is aligned with international standards like the EU Accessibility Act [9] and Section 508 in the U.S [14], making it easier for global companies to comply across markets. The document *Information Accessibility Good Practices 2024*, published by Japan's Ministry of Internal Affairs and Communications [15]., emphasizes that companies must ensure their devices and services information accessibility. Products should consider stakeholder needs, and accessibility should be embedded as a core element of the company's policy [16].

In Japan, there are accessibility standards for SSTs such as Japanese Industrial Standards (JIS) series. However, according to the Web Accessibility Infrastructure Committee (WAIC), there is no unified or comprehensive approach, especially in the context of kiosks, which integrate physical, touch-based, and other interactive technologies [10].

JIS X 8341 Accessibility Standards is Japan's national standard for accessibility, aligned with Web Content Accessibility Guidelines (WCAG) 2.0 AA-level, which applies to web content, but also influences the design of physical and digital self-service systems. WCAG prepared by the Web Accessibility Initiative of the World Wide Web Consortium, are considered one of the most important web development accessibility guidelines worldwide covering web pages, documents, and embedded software that are rendered or intended to be rendered within web pages [17,18]. The guidelines are divided into four principles: perceptible, functional, understandable, and robust, having three levels of requirements ranging from A (low) to AAA (highest) [19].

In the context of SST, Ministry of Land, Infrastructure, Transport and Tourism of Japan recommend hardware-related measures for TVM accessibility. These include appropriate heights for the operation panel and coin slot for wheelchair users, and emergency call device. Regarding touch-screen interfaces, sufficient color contrast and font size selection, as well as braille displays, and numeric keypads are recommended [20].

Regarding the accessibility of ATMs, there are currently no official guidelines issued by the Financial Services Agency, the official authority in this domain [21]. Therefore, the implementation of accessibility features might varies across banks. For instance, some banks provide ATMs equipped with headsets and numeric keypads, while others offer voice guidance and text enlargement functionalities [21].

Regarding accessibility regulations for self-check-in systems and self-checkout terminals, the WAIC [21] notes that no specific guidelines currently exist for hotel self-check-in systems or retail self-checkout kiosks. However, according to WAIC [21], JIS X 8341-3:2016 (Web Content Accessibility Standard) also applies to kiosks, etc. installed in public facilities.

Prior research shows a large body of accessibility literature addressing SST accessibility. Accessibility in the SST context has been investigated from different angles, including related laws and guidelines that are compared and analyzed.

To understand the knowledge of supply and deployment communities for SST accessibility, Petrie et al. [7] conducted interviews with 22 stakeholders. They argued that these stakeholders have little or no understanding of information accessibility and interaction in a digital environment. According to, the discussion about accessibility must also emphasize its relevance to business and the SST industry. The accessibility of self-service terminals should be developed with actors who have worked in the field for a long time and who have previously actively promoted accessibility. They concluded with the following recommendations: The legislation and responsibilities should be specified in the industry; The number of users and populations excluded due to inaccessibility should be identified; Accessibility should be included in tendering and procurement processes; Operators should gather information on accessibility issues to pass on to relevant stakeholders; Accessibility should be seen as a business opportunity that provides significant benefits to end-users through concrete techniques that are easy to implement and do not increase costs or require significant redesign; The level of awareness needs to be raised among stakeholders from physical to digital accessibility. The notion that accessibility is a responsibility and its implementation requires cooperation between all stakeholders in the SST value chain [7].

Blut et al. [1] conducted a meta-analysis of factors influencing customer acceptance of SSTs. Their meta-analysis revealed that ease of use and usefulness are key factors of acceptance, which aligns with the Technology Acceptance Model [22]. However, they also found that acceptance of SSTs depends on the type of technology, whether it is transaction/self-help, kiosk/Internet, public/private, hedonic/utilitarian, as well as the culture of the country where the device is located, including the ability to operate it. According to them, using SSTs in a public place may be embarrassing if one doesn't know how to use it, but on the other hand, it is also possible to ask for advice in a public place if necessary [1]. In contrast to acceptance, Reinders et al. [2] investigated the effects of forcing consumers to use technology-based self-service in ticketing and travel information contexts. They argue that forced use of technology-based self-service leads to negative attitudes towards both the use of technology and the service provider. In addition, forced use indirectly leads to detrimental effects on behavioral intentions. On the other hand, their results also show that providing interaction with an employee as a backup option mitigates the negative consequences of forced use. Users' previous experiences with technology-based self-service also led to more positive attitudes towards the self-service offered.

Lee et al. [4] examined accessibility functions and UI functions related to types of disability (visual impairment, hearing impairment, and physical disability) stated in accessibility guidelines and laws for SSTs. Their study included guidelines and laws such as Public Access Terminal Accessibility; Section 508 of the Rehabilitation Act; The US Air Carrier Access Act; Americans with Disabilities Act Standards for Accessible Design; The European Accessibility Act. Their research resulted in the classification of accessibility functions and the provision of solutions characterized by UI functions as follows: To supplement color identification ability, UI functions should avoid color coding and ensure sufficient contrast. To accommodate reaction time, the UI should provide enough time. To supplement and replace vision, UI functions should ensure the identification of the input method and provide tactile information, an input keypad, braille, audio output, and allow for text-size enlargement. To supplement cognitive ability, they suggest displaying seizure warnings. To supplement hand or arm movement, the UI should provide alternative controls based on hand or arm movement. However, their study did not include an examination of guidelines pertaining to cognitive abilities.

Lee et al. [23] conducted a focus group interview with individuals who have visual, hearing, and physical impairments to examine the accessibility and usability issues they encounter with self-service kiosks. They found that accessibility issues were related to essential functions, while usability issues were tied to psychological factors or personal preferences.

According to Caporusso et al. [24], the use of new technology, such as touch screens, may improve the appearance and feel of the device, but can make them less easy to use. Similarly, Jokisuu et al. [11] showed that touch screens can cause significant accessibility problems for people with disabilities. They explored input methods (tactile and haptics) that allow visually impaired people to use the touchscreen and interact with the ATM independently with 40 people with varying levels of visual impairment [11]. Their study revealed the challenges that the use of touchscreens may include. In the case of the visually impaired, the lack of tactile characteristics can be particularly problematic. According to Jokisuu et al. [11], tactile strips were rated significantly easier to use than a haptic touchscreen. Participants in their study were confident that they could enter their PINs as easily as with a traditional ATM number pad. The participants considered the concept of haptics to be significantly more difficult than any other concept, and the participants were not as sure how they would be able to use those independently. In addition, according to Jokisuu et al. [11], familiarity, voice instructions, and all auditory feedback are very important. However, they must be implemented carefully, especially attention should be paid to the order and amount of information provided to the user. It should be understood that not everyone knows how to use the touch screen and perform gestures such as double taps and swipes. Touch screen gestures familiar from personal mobile devices may not be able to be transferred to an ATM as such. In addition, the larger display of the ATM makes it difficult to maintain orientation at the interface during navigation [11].

Lin et al. proposed a speech-based interactive mobile application as a method to guide users navigating in the touchscreen UI of SSTs [5]. The app would allow users to take a picture of the self-service terminals' UI and use the phone's voice feedback to move it close to the button and touch it with the attached touch stick next to the camera behind the mobile phone. This assistive application proposed by Lin et al. [5] would allow users to access both touch screens of self-service terminals: capacitive and infrared touchscreens. The fact is that in practice, users have very little time to learn a new interface and interaction method when standing in front of a self-service terminal, for instance, an ATM [11]. Therefore, a solution that you can familiarize yourself with and learn how to use in advance can make using self-service terminals easier, regardless of its features. However, this proposal by Lin et al. [5] is due to the inaccessibility of current self-service terminals and does not allow service providers to omit the accessibility of their self-service terminals. Similarly, Guo et al. [25] proposed a mobile application that can be used to interpret pictures taken by users and provide guidance with physical interfaces such as microwaves, printers, etc. Their solution combined on-demand crowdsourcing (crowd workers segmenting and labeling pictures sent by users) and computer vision (providing real-time guidance in use).

Caporusso et al. [14] studied the ergonomics of automated payment systems. They examined the human factors in payment systems, particularly their usability for people with severe low vision. They evaluated the performance of commercially available vending machines in the three stages of purchase, i.e., product selection, payment, and collection. Their results revealed that poor design, lack of tactile information, and absence of non-visual feedback significantly impact accessibility and prevent most blind customers from independently choosing, paying for, and collecting the product. In addition, they found that modern automated vending machines do not support blind people at all. Even though participants were guided at every stage of the process, i.e., which product to choose, and the amount to be paid, they would not even be able to select a product without the help of an assistant. Henderson et al. [16] had similar findings with a broader audience when they inspected usability issues of SST, discovering that the absence of appropriate feedback, guidance, and coherence were key usability issues that led to a negative user experience. Collier and Kimes [27] highlighted the importance of speed. They argued that SSTs should be fast and accurate to enhance user satisfaction. They discovered that the convenience of SSTs affects perceived accuracy, speed, and intentions to explore these technologies.

In conclusion, prior research has primarily focused on specific technologies such as payment systems, touchscreens, and mobile applications to assist with SST use, as well as ticketing and travel information contexts. These studies have addressed issues faced by individuals with low vision, visual impairments, hearing impairments, and physical disabilities. Previous studies have examined the knowledge of SST accessibility and the relationship between accessibility and usability. To our knowledge, there are fewer studies attempting to map or inspect the overall picture of SST accessibility. However, we argue that it is important to understand the current state of SST accessibility so that gaps can be identified and addressed. The existing research literature does not sufficiently accommodate the need for a comprehensive understanding of SST accessibility, so that potential shortcomings can be identified and addressed in future research and practice. To address this gap, this paper presents design reviews aimed at clarifying the factors behind accessibility problems.

3. Research methodology

The authors employed a design review inspection method to examine and evaluate a design, identifying accessibility problems [28]. Design review serves as one of the quality control methods for system design [29]. Depending on the phases of system development, design reviews can occur at different levels, ranging from requirement review to critical design review [30]. In this study, we critically assessed twenty distributed products using a devised framework. The selected method is an extension of the structured walkthrough concept, aiming to provide a perspective on design that aligns with system requirements, particularly accessibility [29].

3.1. Data collection

Drawing inspiration from studies by Andrade et al. [31] and Basil [32], we employed photographs and videos for observational purposes to collect data for this study. While photography and videos are still relatively underutilized in the fields of HCI and information systems, they are widely used in disciplines such as anthropology, sociology, ecology, geography, medicine, nursing, and marketing research [32]. We chose this method because it allowed us to capture snapshots of reality within their situational context [31]. Additionally, it enables researchers to thoroughly examine and analyze the data by reviewing recorded videos and inspecting interaction details repeatedly [32]. Photographs and videos have also been valuable for probing human behavior, consumption patterns, activities, and responses during interactions [32].

The data were collected in June 2023 across Tokyo, Chiba, Saitama, and Kanagawa prefectures in Japan. We selected a sample of SSTs from streets, shops, malls, and other locations, regardless of their distributors. The selection of self-service kiosks in this study was based on convenience sampling, a non-probability sampling method commonly used in empirical software engineering research when access to the full population is limited or impractical [33]. SSTs were selected based on their availability, accessibility, and relevance to the research context. This approach was justified due to logistical constraints, such as limited access to a comprehensive sampling frame and the need to conduct fieldwork within a specific geographic area. As Baltes and Ralph [33] note, convenience sampling supports exploratory analysis in real-world settings and be appropriate in software engineering studies when the goal is to gain contextual insights rather than statistical generalizability.

The selection of SSTs for this study was guided by inclusion and exclusion criteria to ensure relevance and accessibility. Inclusion criteria required that the SST was operational at the time of the study, publicly accessible (i.e., not restricted to staff or closed groups), part of a specific organization, chain, or geographic area, provided a relevant service such as ticketing, food ordering, or product ordering, and was equipped with touchscreen technology. SSTs were excluded if they were out of service or under maintenance, located in restricted or inaccessible areas, did not offer services pertinent to the research focus, were prototypes or in testing phases rather than part of the regular service network.

We captured a total of 33 SSTs through photography and video, ultimately qualifying 20 of them for analysis. Samples are named as ID1 to ID20 (see Appendix A for detailed descriptions and example images of selected SSTs). The criteria for qualification were the quality of the video and photos taken, as well as the completeness of the interaction. One of the authors took videos with their personal mobile phone, capturing the interaction with the specific machine in a public space (e.g., on the street, at a station, or in a shopping mall, such as the entire purchase process from start to finish. The interaction with many devices, such as ATMs, involved privacy information, which is why the recorded data was not shared. The same author filmed, recorded, and analyzed the videos.

During the recording we did not film or record any individuals. The authors used the device themselves. We did not use the machine in a way that could damage it, cause disruption, or violate its terms of use. We observed the user interface of the machine, including the size and placement of the buttons. In this study, we did not examine the physical size of the machine, such as its height. Moreover, we did not conduct systematic testing or measurements on the machine but used it to perform a single basic task, such as purchasing a ticket. The task was carried out without interfering with the normal use of the machine.

The recordings included various types of SSTs: self-ordering kiosks (STK), self-checkouts (SCO), vending machines (VM), ticket vending machines (TVM), automatic teller machines (ATM), self-service laundries (SSL), and self-service lockers (SSLo). However, we did not record the manufacturing year of the devices or the release year of the interface, as we focused on examining the current state as it appears in public spaces, and therefore did not analyze and compare the features of the devices with each other.

The philosophical underpinnings of research involving photography can encompass both objective and subjective perspectives [32]. In our case, we collected data objectively which means that we did not investigate users' behavior (subjective). In the objective analysis, we did not evaluate how SST devices meet the requirements of a specific standard, because previous studies have already revealed that meeting a standard does not necessarily fulfill all accessibility needs. Instead, in this study, we examined a comprehensive view of the factors related to accessibility between humans and SSTs, focusing on analyzing them through the basic phases of interaction, namely perceivability, cognition, and action.

3.2. Coding procedure and data analysis

To find a wide range of possible accessibility issues in the SSTs, we composed an analysis framework including three lenses to analyze taken photographs and videos. We interpreted our data deductively, which means that we formulated a pre-defined coding scheme and aimed to identify factors related to pre-defined components. We adopted the basic process of human–computer interaction by Schomaker et al. [34] to identify the phases of interaction between humans and SSTs. We derived the phases of the interaction process into the following areas for inspection: (1) human output channels; (2) SST's input modalities; (3) SST's output media; (4) human input channels; and (5) human cognitive processes [34] (Fig. 1 illustrates the basic phases of human-SST interaction).

In Fig. 1, the interaction flow illustrates the communication between humans and SSTs, based on the fundamental model of human-computer interaction proposed by [34]. Studies by Mäkipää and Vartiainen [35]; Mäkipää [36] discuss potential variables related to accessibility during different interaction phases. According to their research, human output channels involve abilities such as movement, voice, and sight, which can vary among individuals. SST's input modalities encompass various forms of interaction, including movements, force, sound, and image presentation. SST's output media include diverse presentational styles (e.g., text, images, videos, animations, graphs, tables, and sounds) that convey the content and functionalities of SST's UI. Designing content and functionalities to be perceivable through visual, auditory, tactile, olfactory, gustatory, and vestibular senses is crucial, considering that human input channels are limited to varying levels of sensory perception (sight, hearing, touch, smell, taste, and balance). The human cognitive process is multifaceted, involving data interpretation, organization, information generation, storage, retrieval, analysis, manipulation, and comprehension [37]. Human cognitive abilities vary in terms of attention focus, memory, thinking speed, reading and writing skills, language comprehension, problem-solving, decision-making, reaction time, psychomotor functions, emotional processing, perceptual functions, higher-level cognition, domain-specific knowledge, self-awareness, and time perception [36].

Human interaction with an IT artifact, in this case, SST involves three fundamental processes: perception, cognition, and action [38]. Considering these processes, we have developed three lenses to assess and

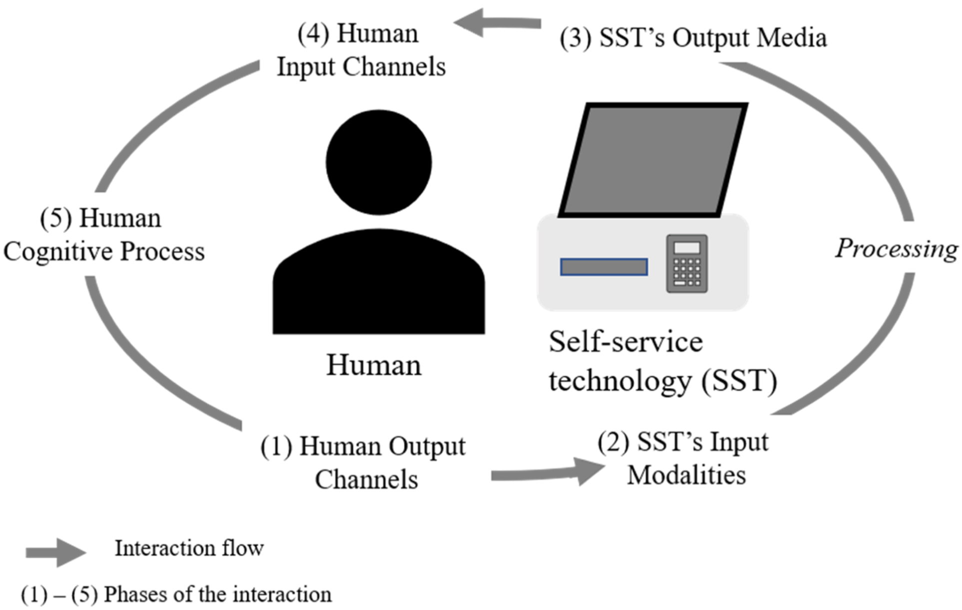

Fig. 1. Analysis framework based on human-computer interaction model [34].

analyze the current state of SST accessibility.

Through the first lens, we interpret possible variables related to perception and action. The second lens focuses on factors related to cognition, where we review the UI design using heuristics. Lastly, the third lens aims to identify relevant UI components to specify problem areas.

The coding procedure proceeded as follows: One of the authors reviewed the videos, photographs, and any notes taken for each device, and filled in a spreadsheet-based data extraction form, which included both the first and second analytical lenses. An example of the data extraction form is presented in Appendix B. After this, the second author reviewed the completed forms to verify whether they aligned with their own interpretation. No discrepancies were found in the interpretations.

Next, we consolidated all spreadsheets. Then, the first author interpreted which UI component each identified design practice represented. For example, audio and visual outputs were categorized under the UI component *Metaphors*, while the use of icons, images, and colors represented the UI component *Navigation*. These interpretations were then reviewed by the second author, and after discussions, we reached a final consensus on the UI components for each finding. The three lenses are described in detail in the following subchapters.

3.2.1. First lens: possible variables in perception and action

With the first lens, we analyzed variables related to perception and action as follows: (1) Human Output Channels: We interpreted how the user (using movement of limbs, voice, or sight) is intended to perform the action. (2) SST's Input Modalities: We interpret through which channels (providing movements, force, sound, or showing images) the SST is designed to take input from the user. (3) SST's Output Media: We interpret what type of output media (text, image, video, graphs, tables, or sound) is utilized in the SST. (4) Human Input Channels: We interpret with which senses (sight, hearing, touch, smell, taste, or balance) the user is intended to perceive the information and interaction. Table 1 illustrates the variables of the components and codes used in the analysis.

Table 1
Variables and the codes related to perception and action (adopted from Mäkipää and Vartiainen [35].

Phase	Variables	Codes
(1) Human Output Channels	Movement; Voice; Sight	How the user is intended to perform the action?
(2) SST's Input Modalities	Movements; Force; Sound; Images	In what way the SSTs take an input from the user?
(3) SST's Output Media	Text; Image; Video; Graphs; Tables; Sound	What type of SST output media is utilized?
(4) Human Input Channels	Sight; Hearing; Touch; Smell; Taste; Balance	With what sense the user is intended to perceive the information and interaction?

3.2.2. Second lens: factors related to cognitive accessibility

With the second lens, we analyzed factors related to (5) Human

Table 2
Variables in human cognitive process and related heuristics.

Phase	Variables in Human Cognitive Process [36]	Heuristics [39]
(5) Human Cognitive Process	Focusing attention; Perceptual functions	Help is provided for the user focus and help restore the context if attention is lost.
	Comprehension-knowledge; Memory	A clear structure with easy-to-follow sections, short paragraphs, and manageable chunks are used.
	Thinking and speed of processing	The user is helped to understand the content and orientate themselves in the content.
	Reading and writing; Mental functions of language	An easy-to-follow writing style is used.
	Solving problems	Rapid and direct feedback is provided.
	Calculating and quantitative knowledge; Making decisions and reaction speed; Psychomotor functions and sequencing complex movements and speed	Users are helped to complete their work and helped to avoid mistakes and guided to correct them.
	Emotional functions	Help is provided.
	Higher-level cognitive functions and domain specific knowledge	The cognitive skills required to use the content are minimized.
	Experience of self and time functions	Adaptability and personalization are enabled, so that symbols, text, and other features are familiar and helpful to the user.

Cognitive Process. We interpreted which elements are provided to support cognitive processes. The reviews were conducted by assessing the design for compliance with the recommendations provided by the World Wide Web Consortium (W3C). For this lens, we adopted the 'Cognitive Accessibility Roadmap and Gap Analysis' provided by W3C to analyze the state of cognitive accessibility and meet the needs of people with cognitive and learning disabilities [39]. The analyze included heuristics presented in Table 2. Subsequently, we aligned these heuristics with the corresponding cognitive abilities. It is important to note that the connection between a heuristic and a specific cognitive ability is not always unambiguous; one heuristic may be interconnected with several cognitive abilities, depending on the individual. In this study, we reasoned the direct connection between the cognitive variable and a particular heuristic, as presented in Table 2.

3.2.3. Third lens: identify related user interface component

With the third lens, we specified and aligned our findings with related UI components. We adopted the definition of UI components provided by Marcus [40,41]. According to Marcus [40,41], UI can be divided into the following components: metaphors, mental models, navigation, interaction, and appearance. We identified the relevant UI component for the items discovered using the first and second lenses. Detailed descriptions of the UI components are presented in Table 3.

4. Findings

The findings section is twofold. First, we present the findings from the first lens, which inspects possible variables in user perception and actions. Next, we synthesize these findings with those from the second lens, which examines factors related to cognitive accessibility. Finally, we integrate the results from the third lens, which identifies relevant user interface components.

4.1. Possible variables in user perception and action

We identified variables related to Human Output Channels, SST's Input Modalities, SST's Output, and Human Input Channels. Table 4 summarizes how the user is intended to perform the action, the way SSTs take input from the user, the type of SST output media utilized, and the human senses intended for perceiving information and interaction. The Table 4 also illustrates how data saturation was achieved, as recurring Human Output Channels and SST's Input Modalities can be observed across the cases,

In the following sub-subchapters, variables and the codes related to perception and action are described in detail.

Table 3
User interface components [40–42].

UI Component [40,41]	Description [40–42]
Metaphors:	Essential concepts in words, images, sounds, touch
Mental Models	Organization of data, functions, tasks, roles
Navigation	Movement through mental models via windows, dialogue boxes, breadcrumb, slider, search field, pagination, slider, tags, icons etc.
Interaction	Input/output techniques, feedback, overall behavior of systems including checkboxes, radio buttons, dropdown lists, list boxes, buttons, toggles, text fields, date field etc.
Appearance	Visual, verbal, acoustic, tactile Information visualizations/ sonifications are representations of structures and processes. They may be abstract or representational. Techniques include tables, forms, charts, maps, and diagrams, tooltips, icons, progress bar, notifications, message boxes, modal windows etc.

4.1.1. How is the user intended to perform the action? (Summary of human output channels)

According to our data sample, the interaction of all twenty SSTs was based on movements as a human output channel. Hand movement is required to press buttons on the UI. Sight as an output channel was not used. Surprisingly, none of the sample SSTs provided an opportunity for users to interact with voice.

4.1.2. In what way the SST will take an input from the user? (Summary of SST's Input Modalities)

Three devices recognized users' movements by responding to motion as a signal to wake up the system when the user approached the device. All twenty SSTs provided a touchscreen as their primary input modality. However, we were unable to determine whether the technology behind the touchscreen was capacitive or infrared. We categorized human-produced force as an SST input modality, including haptic or tactile interactions such as clicking digital buttons on the GUI to perform actions or pressing physical buttons (e.g., on a numpad) for tasks like calling for help or cancelling a process. Among the SSTs, ATMs and TVMs at the railway station IDs: 1-3, 12, and 16-19 offered braille support. Other input modalities covered various actions required from users, serving as input for the SSTs. These are: Placing products into a basket reader (ID4); Using a barcode reader (either a handheld device or a fixed reader); Inserting money or cards; Making NFC payments; Retrieving payment cards; Receiving change; Obtaining receipts (IDs: 5-7, 10); Solely inputting a card (ID11); Handling money, card insertion, card retrieval, change retrieval, and ticket retrieval (IDs: 8, 12, 15-19). It is notable that none of the sample SSTs accepted input via voice or sight.

4.1.3. What type of computer output media is utilized? (Summary of SST's Output Media)

All twenty SSTs primarily used text as a media format for buttons, selections, and informational texts (IDs: 1-20). Additionally, all SSTs employed images to illustrate various steps in the process (IDs: 2, 3, 5, 7, 10-12, 15-19). For instance, some images depicted mobile phone placement for the user (ID1), indicated the slot for inserting money (IDs: 8, 12), or showcased product images (IDs: 4, 6, 9, 13, 14, 20). Only one SST included a video to demonstrate the payment process (ID6). However, animations were effectively used to illustrate subsequent steps (IDs: 1-4, 10, 11, 17). For example, animations showed how to place a mobile phone on the reader (ID1), scan a voucher (ID10), or insert a payment card into a slot (IDs: 2, 3, 11). Animations were also used to depict processing states (IDs: 2, 3, 6, 11, 16-18) and guide users through the next steps. Other forms of output media included a processing bar (ID1), and some products were designed with movement to capture the user's attention (ID9). Notably, graphs were not utilized in the sample SSTs. Instead, tables were employed to display payment and cash balances (ID1), present products scanned with a barcode reader (IDs: 5, 7), list ordered products (ID6) and show product prices (ID10). Sound (beeps) played a significant role in the interaction with SSTs. Beeps provided acoustic feedback when users clicked buttons (IDs: 1, 5, 7, 8, 10, 11, 15), inserted money (IDs: 2, 3, 5, 7, 12, 17), or interacted with card slots (IDs: 2, 3, 5, 7, 12, 17) and ticket slots (IDs: 16, 18, 19). In one instance, a mobile phone placement into a tray triggered a beep after successful placement (ID1). Additionally, the barcode reader emitted beeps while reading products (IDs: 5, 7).

Voice guidance is widely used for various purposes during different phases of interaction with SSTs. For instance, it assists users during money insertion (IDs: 18, 19) or starts after money has been inserted for payment (ID15). The voice provides updates on processing status (IDs: 15, 18, 19) and reminds users to take tickets (ID15), retrieve their cards (ID17), or collect change (ID4). Announcements indicate product arrivals (ID6) or prompt users to retrieve items (ID15). Some SSTs offer simple greetings ("welcome," ID2) or express gratitude at task completion (ID1). Additionally, light indicators near slots (IDs: 1-5, 7-8, 10, 12, 16-19) guide users on actions such as money insertion, change retrieval,

Table 4
Summary of the human input and output channels required and SST's input and output modalities and medias available in samplers (marked as check marks [✓]).

			1) Human Output Channels			(2) SST's Input Modalities					(3) SST's Output Media										(4) Human Input Channels					
ID	Type	Context	Movement	Voice	Sight	Movements (gesture) (gesture)	Force (haptic and tactile) tactile)	Sound	Images	Other	Text	Images	Video	Animation	Graphs	Tables	Sound	Voice	Light	Other	Sight	Hearing	Touch	Smell	Taste	Balance
1	ATM	Convenience store	✓				✓			✓	✓	✓		✓		✓	✓	✓	✓		✓	✓	✓			
2	ATM	Convenience store	✓				✓			✓	✓	✓		✓			✓	✓			✓	✓	✓			
3	ATM	Department store	✓				✓			✓	✓	✓		✓			✓	✓	✓		✓	✓	✓			
4	SCO	Shop	✓				✓			✓	✓	✓		✓			✓				✓	✓				
5	SCO	Shop	✓				✓		✓	✓	✓	✓				✓	✓	✓	✓		✓	✓				
6	SCO	Restaurant	✓				✓				✓	✓	✓	✓		✓	✓	✓			✓	✓				
7	SCO	Convenience store	✓				✓		✓	✓	✓	✓				✓	✓	✓	✓		✓	✓				
8	SSLo	Airport	✓				✓			✓	✓	✓					✓	✓	✓		✓	✓				
9	SST	Shop	✓				✓				✓	✓		✓							✓					
10	SST	Restaurant	✓				✓			✓	✓	✓		✓		✓	✓	✓			✓	✓				
11	SST	Hotel	✓				✓			✓	✓	✓		✓			✓		✓		✓	✓				
12	SST	Railway station	✓			✓	✓			✓	✓	✓					✓	✓	✓		✓	✓	✓			
13	STK	Restaurant	✓				✓				✓	✓									✓					
14	STK	Restaurant	✓				✓				✓	✓									✓					
15	TVM	Outside	✓				✓			✓	✓	✓					✓	✓			✓	✓				
16	TVM	Railway station	✓				✓			✓	✓	✓		✓			✓	✓	✓		✓	✓	✓			
17	TVM	Railway station	✓			✓	✓			✓	✓	✓		✓			✓	✓	✓		✓	✓	✓			
18	TVM	Railway station	✓				✓			✓	✓	✓		✓			✓	✓	✓		✓	✓	✓			
19	TVM	Railway station	✓			✓	✓			✓	✓	✓					✓	✓	✓		✓	✓	✓			
20	VM	Railway station	✓				✓				✓	✓					✓				✓	✓				

Table 5
Summarized interpretations of the heuristic evaluations of the practices to improve cognitive accessibility.

Related Variable	Heuristic	Retrieved Practices from Sample UIs	Related UI Component
Focusing attention; Perceptual functions	Help is provided for the user focus and help restore the context if attention is lost.	Next task is demonstrated with the example images, animation, video; Voice guidance, Progress bar; Sound output; Icons; and Light indicator.	Appearance; Mental models; Metaphors
Comprehension-knowledge; Memory	A clear structure with easy-to-follow sections, short paragraphs, and manageable chunks are used.	Payment process shows one step at time; Breadcrumb; Progress bar; Page number; and Regular tasks such as buy a ticket is separated from other functions.	Mental models; Appearance
Thinking and speed of processing	The user is helped to understand the content and orientate themselves in the content.	Use of demonstrating animation/image of the task; Voice guidance; Images with the text of the products are provided; Icons to describe the content are provided; and Steps after the payment process.	Appearance; Mental model
Reading and writing; Mental functions of language	An easy-to-follow writing style is used.	Prescriptive language.	Appearance
Solving problems	Rapid and direct feedback is provided.	Sound feedback when clicking the buttons; Sound feedback is provided if user is not acting; and Colors in the menu indicates the focus area.	Metaphors; Appearance
Calculating and quantitative knowledge; Making decisions and reaction speed; Psychomotor functions and sequencing complex movements and speed	Users are helped to complete their work and helped to avoid mistakes and guided to correct them.	Demonstrating image of the task; Voice guidance for each step; Voice guidance repeat the instruction if the user do not act; Voice guidance (insert card or money, remind to take the money, receipt, take card back, and remind to take tickets; Sound feedback is provided to alarm; Voice guidance thanks you; and "Cancel button", “Plus”, and “Minus” buttons are provided for user control.	Metaphors; Appearance
Emotional functions	Help is provided.	Call for Human help.	Mental model
Higher-level cognitive functions and domain specific knowledge	The cognitive skills required to use the content are minimized.	Products and inserted amount of money are listed and calculated; Animation of the step is provided; Amount of information in one view is minimized; and Colors in the buttons for the next phases are indicating “deactivated” as long as the current step in the process is done.	Appearance; Mental model
Experience of self and time functions	Adaptability and personalization are enabled, so that symbols, text, and other features are familiar and helpful to the user.	Function to larger the size of buttons; and Function to larger font size.	Mental model

payment card insertion, and Near Field Communication (NFC) -based payments (ID20).

4.1.4. *With what sense the user is intended to perceive the information and interaction? (Summary of human input channels)*

The primary interaction method for all twenty samples relied on sight as a human input channel. UIs predominantly used visual presentation (IDs: 1-20). Similarly, light indicators near the slots conveyed visual information (IDs: 1-5, 7-8, 10, 12, 16-20). Sample SSTs provided acoustical information (hearing as a human input channel) thought the voice guidance (IDs: 1-3; 5; 8; 10;12; 15-19), sound outputs e.g. for clicking buttons (IDs: 2;3;5;9;10;11;12;15-19), inserting money, taking change, card back and receipt or tickets (IDs: 2;3;4; 10) or when not making any action (IDs:2;3;10), during product selection, payment, and product collection (ID20). Notably, all ATMs, and TVMs at the railway station (IDs: 1-3;12;16-19) provided braille as an alternative channel for information and interaction. In a case of human input channel, braille can be included to the haptic perception (touch).

4.2. *Factors related to cognitive accessibility*

We have identified certain practices that can be categorized under a single heuristic, thus contributing to improved cognitive accessibility. In Table 5, we present a synthesized view of these practices, which enhance cognitive accessibility.

In the following sub-subchapters, practices retrieved from the heuristic evaluation are described in detail heuristic by heuristic.

4.2.1. *Help is provided for the user focus and help restore the context if attention is lost*

We identified practices for enhancing user focus and attention. For instance, the next task is demonstrated using example images (IDs: 2, 3, 5-8, 10-12, 15, 16, 18, and 19) or animations (IDs: 1, 4, and 17) that illustrate the necessary actions. During the payment phase, images showcase the location of slots (IDs: 16, 18, and 19). Voice guidance (IDs: 2, 5, 6, 8, 10, and 12) assists users in understanding the next steps. Additionally, a progress bar (ID1) or page number (e.g., 1/4) indicates the amount and position of pages (ID13). Sound output alerts users if they are waiting too long (IDs: 2 and 3). Icons paired with text on buttons clarify their meaning (ID11), while a light indicator highlights the focus area (ID20). Lastly, free navigation, acting as a ‘Back button,’ allows users to restore context (IDs: 1, 4-8, 10, 14, 16, 18, and 19), whereas back and forward buttons are absent (IDs: 2, 3, 11, 12, 15, and 17).

We also identified practices that contradict each other. For instance, having two similar-looking menu bars side by side (ID14) can confuse users, as it blurs the distinction between the main menu and secondary menu. Additionally, buttons with text only (IDs: 8, 16, 18, and 19) may lack clarity. Regarding voice guidance, there are some areas for improvement. In some cases, voice guidance only states “Device is processing” and then reminds users to take their tickets (ID15). Alternatively, it instructs users to click the button they prefer (ID16). Or, it only mentions taking the payment card back (ID17) without providing further details. When inserting a card or money, it states the processing status (IDs: 18 and 19). Or in some cases, voice instructions are provided only at the end of the task (IDs: 2, 3, and 17). ID4 had also a voice instruction button available (default Off).

4.2.2. A clear structure with easy-to-follow sections, short paragraphs, and manageable chunks are used

We identified practices to enhance the clarity of the UI. The payment process displays one step at a time (IDs: 2-5, 10-12, 15-19), and a breadcrumb trail is also available (ID1). Users benefit from a progress bar (IDs: 6, 7, and 8) and page numbers (IDs: 13 and 14). Separating regular tasks, such as buying a ticket, from other functions simplifies navigation (ID19). Button colors to select tickets for a certain train line are same as train line colors (ID19). However, we observed some areas for improvement. Having two similar menu bars side by side can confuse users, blurring the distinction between the main menu and secondary menu (ID6). Additionally, inconsistent button colors may cause confusion (ID9). Furthermore, the starting page contains numerous items and similar-looking buttons, making it challenging for users to find their starting point (IDs: 9, 16, 18).

4.2.3. The user is helped to understand the content and orientate themselves in the content

Practices to help users understand the context include demonstrating animations or images of the task (IDs: 1-5, 7, 10-12, 15, 17, and 19). Voice guidance explains the entire process initially (IDs: 8 and 10), or it assists in understanding the next step (ID3). Images with product text are provided (IDs: 6, 13, and 14), along with icons describing the content (ID11). The payment process is shown step by step (IDs: 18 and 19). Steps after the payment process are considered (e.g., preparing your bag to insert products) (ID5). In our experience, voice guidance is not very helpful when used solely as a reminder to take a receipt (ID1). Demonstrating images for selecting buttons are also not very helpful (e. g., 'Click the blue button to select'—when all buttons are blue) (ID3). Voice guidance remains useful for understanding subsequent steps (ID2). However, an excessive number of info texts across different locations can be confusing (ID16). Additionally, the appearance of 'processing' is only conveyed through text (ID19). Considering the time limit, emphasizing sounds to create urgency, and providing an overview of the whole process would be beneficial (ID9).

4.2.4. An easy-to-follow writing style is used

In overall, many provided short and prescriptive text (IDs: 1-3, 5, 7, 8, 10-12, 15, 17-19). In some cases, additional information in the middle of the process confused the main task and filled the screen (e.g. welcome text in the middle of the task saying thank you for using this bank) (ID2). IDs 4 and 14 included the names and sizes of the products in text format. ID13 listed the product names without any additional text. ID6 displayed the product names and prices using both text and images. ID20 displayed the product prices in text format. IDs 7 and 9 provided only text for message dialogs and buttons, which required reading time that did not fit the context. Similarly, IDs 18 and 19 presented all buttons in written text without any icons. In contrast, ID8 featured all buttons in text, accompanied by images and icons to aid understanding.

4.2.5. Rapid and direct feedback is provided

Direct feedback is effectively utilized in sample UIs. For instance, the following practices have been identified: sound feedback (beeps) when clicking buttons (IDs: 1-3, 5, 6, 8, 10-12, 15-20). Additionally, an alarm sound is provided if the user does not act quickly enough (IDs: 2, 3, 10, 11). Furthermore, colors in the menu indicate the focus area (ID6).

4.2.6. Users are helped to complete their work and helped to avoid mistakes and guided to correct them

Sample SSTs revealed practices that indicate the importance of keeping users engaged and ensuring task completion. For instance, images demonstrating the task are often provided (IDs 1-3, 5, 7, 10, 11, 15). Voice guidance accompanies each step (ID10) and repeats instructions if the user does not act (IDs 12, 16). During the payment process, voice guidance instructs users to insert a card or money (IDs 18, 19), reminds them to take the money (IDs 2, 11), advises them to collect the receipt (IDs 5, 10), prompts them to retrieve their card (ID17), and reminds them to take their tickets (ID15). Additionally, sound feedback alerts users when they receive their tickets and/or change (IDs 18, 19). At the end of the task, voice guidance expresses gratitude, signaling the process's completion (ID1). Other helpful practices include providing a "cancel" button (IDs 12, 16). In the case of buttons in SCO for rescanning products, "Plus" and "Minus" buttons allow users to adjust the number of products (in case they accidentally scanned items) (ID5).

4.2.7. Help is provided

In this section, we examined whether the SSTs offers a help request function. The "Call for Help" or "Call for Staff" button is available for IDs 2-4, 6-8, 11, 13, 16, 18, and 19. However, the function varied depending on the service provider. For IDs 5 and 10, the "Call for Staff" button is provided only at the end of the buying process while ID 7 includes the "Call for Staff" button at every step. ID 17 offers the "Call for Help" button in two locations. IDs 1 and 14 feature both "Call for Help" and "Info" buttons. IDs 11 and 15 do not include a "Call for Help" button and ID 20 provides a telephone number for the call center.

4.2.8. The cognitive skills required to use the content are minimized

The following practices, aimed at reducing cognitive load, were identified: Products and the inserted amount of money are listed and calculated (IDs: 1, 5, 7, 10, 12, 16, 18, 19). Animation of the steps is provided (ID1). The amount of information in one view is minimized (ID9). Colors in the buttons for the next phases indicate 'deactivated' status as long as the current step in the process is completed (IDs: 2-5, 6, 7, 10, and 13). In contrast, buttons such as 'home,' 'search,' 'back,' and 'forward' are indicated solely by icons (ID13), requiring users to understand the meaning of these icons. However, some icons may not be easy to recognize (ID14).

4.2.9. Adaptability and personalization are enabled, so that symbols, text, and other features are familiar and helpful to the user

The sample set of SSTs provided less for adaptability or personalization (IDs: 1-20). Only ID3 provided a function for larger buttons and fonts, which can be included in features that enable adaptability and personalization.

5. Discussion

This paper first collates possible variables in user perception and action with SST UIs and presents an overview of the channels utilized in the context of SSTs in Japan. As a second contribution, this study reveals current trends in SST UI design and illustrates how they affect users' cognitive processes, specifically cognitive accessibility. As a third contribution, we align current practices with UI components [40,41] to illustrate areas in UI design that have been addressed in terms of accessibility and areas that remain unexplored. Lastly, we propose future research directions in SST UI research and provide practical recommendations.

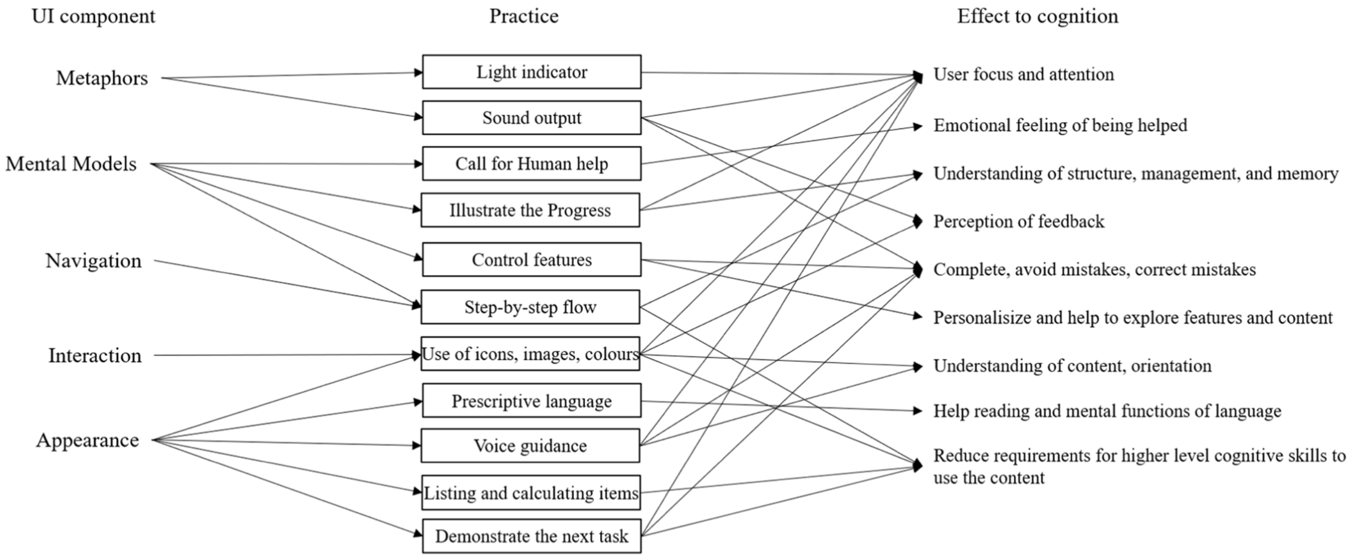

Fig. 2. Synthesis of UI components, practices, and effects to cognition.

To address the research question, *"What accessibility issues exist in the user interfaces of self-service technologies in Japan?"* we identified the following extents and gaps in accessibility:

(1) *Human Output Channels*: First-hand interaction with SSTs requires physical movements, so voice-based channels are not utilized in our sample SSTs. Therefore, alternative channels, such as voice commands instead of physical force, are missing from the SST context.
(2) *SST Input Modalities*: Current SST interactions primarily rely on physical movements. These input modalities limit users to using other human output channels for interaction. SST usage often involves external tasks beyond the UI, such as handling payments via SST slots, using barcode readers, or utilizing mobile phones for payment or identification. Therefore, SST accessibility extends beyond the UI to include the devices and external tools necessary for SST operation.
(3) *SST Output Media*: Among the 20 sampled SSTs, voice instructions, sound outputs (beeps and alarms), and light indicators are commonly used for interaction. SST UIs typically employ prescriptive text, images, animations, or videos to guide users through tasks. However, none of the sample SSTs fully integrate all these output media, and some remain underutilized. For instance, voice guidance does not accompany every step.
(4) *Human Input Channels*: SST interactions heavily rely on visual and auditory abilities. The sense of touch is underrepresented. While braille provides tactile information, haptic practices familiar from mobile phone technology have not yet been applied to SSTs.
(5) *Human Cognitive Processes*: We align identified practices with cognitive processes. Fig. 2 illustrates the first-hand connection between these practices and human cognition. Additionally, we categorize these practices into UI components to understand their impact area on cognitive processes.

5.1. Research contributions

In the context of SST, previous studies have predominantly focused on investigating payment systems and touchscreens, as well as developing mobile applications to assist SST usage by addressing issues faced by individuals with low vision, visual impairments, hearing impairments, and/or physical disabilities. For instance, Lee et al. [23] conducted a focus group interview with people with visual, hearing, and physical impairments to explore accessibility versus usability issues related to self-service kiosks. They found that accessibility issues were tied to essential functions, while usability issues were influenced by psychological factors and personal preferences. Blut et al. [1] performed a meta-analysis of factors influencing customer acceptance of SSTs. Their analysis revealed that ease of use and usefulness are critical factors for acceptance, aligning with the Technology Acceptance Model [22]. However, they also observed that SSTs acceptance varies based on factors such as the type of SST (transactional/self-help, kiosk/Internet), public/private context, hedonic/utilitarian aspects, and the cultural context of the country where the device is located. According to Blut et al. [1], using SSTs in public places can be embarrassing if users are unfamiliar with their operation, but on the other hand seeking assistance in such settings is also possible.

The findings of our study revealed a connection between UI components and human cognition. For instance, UI design practices related to appearance and navigation, such as clicking buttons, directly impacting human cognition. The crucial question is how these UI components are designed. Therefore, it can be argued that UI component design has a primary effect on human cognition and understanding of SST usage. However, our findings also highlight that considering accessibility in UI (touchscreen) design alone is insufficient. The current SST context involves interactions not only with the device's UI but also, in many cases, with the user's mobile phone (smartphone). Consequently, SST UIs should be viewed as a comprehensive set of interactions and operations that encompass UI (touchscreen), the device itself, and any necessary user devices. In many cases of sample SSTs, the interaction was not limited to a dyadic relationship between a human and a machine as presented by Schomaker et al. [34]. Instead, it involved a triadic configuration where the user engages simultaneously with the SST unit and their personal smartphone for instance in food ordering, and payment processes. This configuration introduces more complex interaction flows, such as the distribution of tasks across devices, shifts in user attention, and contextual dependency.

Petrie et al. [7] emphasized that accessibility should also be relevant to business. They advocated for viewing accessibility as both a business opportunity and a corporate responsibility, providing significant benefits to end-users. However, achieving accessibility requires cooperation among all stakeholders in the SST value chain. Our findings highlighted object-level accessibility issues in UIs that SST distributors need to consider. For instance, the use of colors in UIs significantly impacts metaphors, mental models, and overall accessibility. However, UI designers often face limitations due to company brand colors. In such cases, effective communication between stakeholders and awareness of accessibility become crucial.

As a methodological contribution for studies evaluating user interfaces, we recommend collecting data in video format rather than image format. Videos allow for inspection of acoustics, animations, transitions, and visual feedback that cannot be adequately identified from static images. Although we also captured photographs during our study, they ultimately proved less useful during the analysis phase.

5.2. Practical implications

The findings provide guidance for considering accessibility in practice. Comparing our results to previous studies, Caporusso et al. [24]; Jokisuu et al. [11] highlighted the lack of tactile information and non-visual feedback, which hinder blind customers from independently choosing, paying, and collecting products from vending machines. Henderson et al. [26] also addressed the importance of appropriate feedback, guidance, and coherence in resulting in better usability. Our study supports these arguments (see Table 4). Overall, SSTs should provide non-visual feedback, not only for blind customers but also to enhance cognitive accessibility for all users interacting with SSTs. While many sample SSTs offer non-visual voice guidance, it is not consistently provided at every step of the interaction process. To fully complement tasks, non-visual feedback and voice guidance should cover the entire process.

Lee et al. [4] examined UI functions related to various disabilities (visual impairment, hearing impairment, and physical disability). They emphasized the importance of designing UI functions with sufficient contrast, adequate time for use, avoidance of color coding, provision of tactile information, input keypads, braille, audio output, and options for text-size enlargement. Additionally, they addressed concerns related to display seizures and recommended alternatives for control based on hand or arm movement. Our study complements these findings by providing an illustration (see Fig. 2) of practices and their direct connection to cognitive factors. We summarized the following practices that the SST industry can apply to increase cognitive accessibility of SSTs:

- To help user focus and attention: Use light indicators, sound output, icons, images, colors, voice guidance, and demonstrate the next task.
- To increase the emotional feeling of being helped: Provide a “call for help” function and connect it to systems involving human-to-human interaction.
- To help users to understand, manage, and memorize UI structure: Illustrate the progress and provide step-by-step flows.
- To help users to perceive feedback: Utilize sound outputs, icons, images, and colors.
- To help users to complete the task, avoid mistakes and correct mistakes: Utilize sound outputs and offer features for user control, allow backward navigation, provide voice guidance, and demonstrate the next step.
- To allow personalization that helps user to explore features and content: Enable adjustments for font size and button size.
- To help users to understand and orient the content: Use icons, images, colors, and voice guidance.
- To help users to read: Provide concise and prescriptive language.
- To reduce higher cognitive requirements to use the content: Implement step-by-step flows, icons, images, and colors, list and calculate selected products, and demonstrate the next task.

5.3. Trustworthiness of the results

To ensure rigorousness of the extent study, we applied Lincoln and Cuba’s [43] the Four-Dimensions Criteria meant for qualitative studies. This criterion consists of credibility, dependability, confirmability, and transferability, which correspond respectively to the quantitative criteria of internal validity, reliability, objectivity, and external validity or generalizability. Specifically, credibility is analogous to internal validity, dependability to reliability, confirmability to objectivity, and transferability to external validity [44].

Credibility pertains to the extent to which the researcher’s observations and conclusions can be regarded as trustworthy, and the degree to which they offer thorough and coherent interpretations of the data [44]. When we used the devices to collect data, there was time pressure on completing the task because the task, such as purchasing a ticket, was carried out under normal conditions without special arrangements. As a result, something might have been missed during data collection. Furthermore, the researcher’s own expectations and prior experiences with SSTs may have shaped the interpretation. As Zahle [45] argues, qualitative researchers may unintentionally emphasize data that aligns with their assumptions, while overlooking contradictory elements. However, in this context, video-based data was useful as it allowed us to examine functionalities in detail. In our research design, maturation, meaning participants’ possible change over time, was not relevant as our study did not include participants. Therefore, we also did not assess measurement effects on the subject. On the other hand, it should be noted that SST devices and their functionalities are continuously being developed, which means the sample may change over time. Related to selection bias, various devices were initially selected for the sample, but only those that were comparable were included in the final dataset, with the criterion being that the device must have a touchscreen.

Dependability refers to the repeatability of the study and the ability to obtain the same results again if the study is conducted using the same design [44]. We recorded devices in four different prefectures: Tokyo, Chiba, Saitama, and Kanagawa. However, we do not consider the location of the sampled devices to be of major significance to our study, as the same devices are used nationwide by railway companies, retail chains, restaurant chains, convenience stores, and bank ATMs. Related to experiment conditions, our sample was collected in real-world settings, so the deviation of experimental conditions from reality does not apply to our study.

Confirmability, in turn, aims to demonstrate that the findings and their interpretations are not based on the researchers’ imagination but are clearly grounded in the data [44]. To improve the accuracy of the analysis, we cross-checked the results. The first author carried out the groundwork for retrieving the data using a data extraction form, which was then confirmed by the second author.

Transferability refers to the extent to which the results of a qualitative study can be generalized or transferred to other contexts or settings

[44]. Although the SSTs were selected randomly, they were still chosen deliberately based on their relevance to the purpose of the study. We included devices that are widely used across the country, as well as devices that are unique to specific contexts. This study does not aim to demonstrate statistical significance, but rather to provide detailed insights into how specific UI elements affect the overall accessibility of the device. Using three analytical lenses, we aimed to gain a deep understanding of the level of accessibility of the sampled devices. The influence of the researchers' own backgrounds on the data analysis was minimized by using a data extraction form. However, the third analytical lens including identifying and categorizing UI components into the following categories: metaphors, mental models, navigation, interaction, and appearance were influenced by researchers' prior experience. Both authors have over ten years of experience in user interface research.

5.4. Future research

In our study, we excluded the analysis of task characteristics and contexts, focusing instead on human factors and UI design practices. However, we recommend that future studies involve users to inspect task performance stages and consider the steps involved in interactions. These task stages can be based, for instance, on the 'seven stages of action' proposed by Norman, which include variables related to task complexity, motivation, engagement, and users' mental and physical activities [46]. During a task, individuals progress through stages such as establishing the goal, forming intentions, specifying action sequences, executing actions, perceiving system states, interpreting those states, and evaluating them in relation to their goals and intentions.

This study attempts to interconnect cognitive accessibility heuristics with related variables in human cognitive abilities. However, these connections cannot be scientifically justified in the extent of this study because they are reasoned. Nevertheless, we focused on capturing practices related to the design of user interface components and their connection to relevant heuristics. We encourage future studies to explore context-related factors affecting user performance, given that the context of SST use is environmentally sensitive. The context can vary in terms of environmental factors, users' emotional states, socio-cultural aspects, and socio-technical factors. Cultural, political, sociological, and historical aspects of the context influence the user [36]. Additionally, users' expectations based on past experiences, prejudices, evoked memories, unmet expectations, and confidence significantly impact how they perceive and experience the accessibility of SSTs [47]. We also recommend further investigations in the area of SST and human output channels, particularly exploring the use of voice and gaze in interactions, as these alternative channels are not yet widely implemented. Additionally, while touch screens are prevalent in SSTs, haptic feedback via UI has not been widely utilized, although it could offer a novel way to interact.

6. Conclusions

In this study, we photographed and recorded videos of twenty SSTs and their user interfaces in Japan. To examine the state of accessibility, we developed a qualitative analysis framework consisting of three lenses.

With the first lens, we analyzed how users are intended to interact with the SSTs using limb movement, voice, or sight. We interpreted the SSTs' input channels and types of output media. With the second lens, we identified the elements provided to support users' cognitive processes. With the third lens, we aligned our findings with related UI components: metaphors, mental models, navigation, interaction, and appearance [40,41].

Our analysis using the first lens revealed that current SST interactions primarily rely on physical movement. As a result, we found that neither sight nor voice-based channels were used in any of the SSTs in our sample.

The analysis using the second lens revealed that all twenty SSTs primarily used text as the output media format for buttons, selections, and informational content. The user interfaces predominantly relied on visual presentation. Although voice guidance was widely used for various purposes during different phases of interaction with the SSTs, it was insufficient for completing tasks. Therefore, the primary interaction method for all twenty samples relied on sight as a human input channel.

Thirdly, our findings revealed a connection between UI components and human cognition that can help SST designers consider the effects of specific UI components on cognitive processes. We illustrate the relationship between current UI design practices related to metaphors, mental models, navigation, interaction, and appearance, and their impact on human cognition and understanding of SST usage. In addition, we found that the sample set of SSTs offered limited adaptability or personalization, which could enhance the experience of self-related and time-related functions.

This study contributes to existing knowledge by providing in-depth, rich data describing the accessibility of SSTs. While many prior studies have focused on the accessibility of touchscreens, our findings highlight that considering touchscreen design alone is insufficient for ensuring accessible interaction with SSTs.

We demonstrate how certain accessibility issues are related to human abilities and how these issues are reflected in UI design. We provide design recommendations for practitioners by identifying accessibility challenges in the current reality so that they can be addressed in future products entering the market.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Microsoft Copilot in order to assist with grammar checking. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

CRediT authorship contribution statement

Juho-Pekka Mäkipää: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Junichi Iijima:** Writing – review & editing, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank The Scandinavia-Japan Sasakawa Foundation (GA24-FIN-0083) for supporting this research.

Appendix A

Appendix A includes the description and example images of selected self-service technologies (ID1-ID20). Table A1.

Table A1
Description selected self-service technologies (ID1-ID20).

ID	Type	Functions/tasks performed	Place	Sample Format and Duration	Context
1	ATM	IC card recharge	Ikebukuro, Tokyo	Video 1:01min	Convenience store
2	ATM	Cash withdraw	Maihama, Chiba	Video 1:31; Photo (2)	Convenience store
3	ATM	Cash withdraw	Shinjuku, Tokyo	Photos (7); notes	Department store
4	SCO	Scan items; make payment	Ikebukuro, Tokyo	Video 1:49min	Shop
5	SCO	Scan items; make payment	Ikebukuro, Tokyo	Video 3:20min; Photo (3)	Shop
6	STK	Search menu; place order	Ikebukuro, Tokyo	Video 0:32; video 0:46; video 0:17min; photos (3)	Restaurant chain
7	SCO	Scan items; make payment	Maihama, Chiba	Photos (4); notes	Convenience store
8	SSLo	Overall picture	Narita, Narita	Video 0:16; Photos (2)	Airport
9	SST	Self made t-shirt design; place order	Shibuya, Tokyo	Video 0:29 min; Video 0:33min; Photos (5)	Shop
10	SCO	Make payment	Ikebukuro, Tokyo	Video 1:45min	Restaurant chain
11	SST	Hotel check-out	Shinjuku, Tokyo	Video 0:23	Hotel
12	SST	IC card recharge	Hasuda, Saitama	Video 0:47; Photo (1)	Railway station
13	STK	Search menu; place order	Shibuya, Tokyo	Photo (1); notes	Restaurant chain
14	STK	Search menu; place order	Ikebukuro, Tokyo	Photo (2)	Restaurant chain
15	TVM	Buy tickets	Ueno, Tokyo	Video 0:41min; Photo(1)	Outside the gate of Zoo
16	TVM	Buy tickets	Fujisawa, Fujisawa	Video 1:40min	Railway station
17	TVM	IC card recharge	Maihama, Chiba	Video 0:48	Railway station
18	TVM	Buy tickets	Shinjuku, Tokyo	Video 0:24; video 0:53; photos (5)	Railway station
19	TVM	Buy tickets	Shinjuku, Tokyo	Video 0:27	Railway station
20	VM	Select items; purchase items	Hasuda, Saitama	Video 0:12min; Photo (1)	Railway station

Fig. A1.

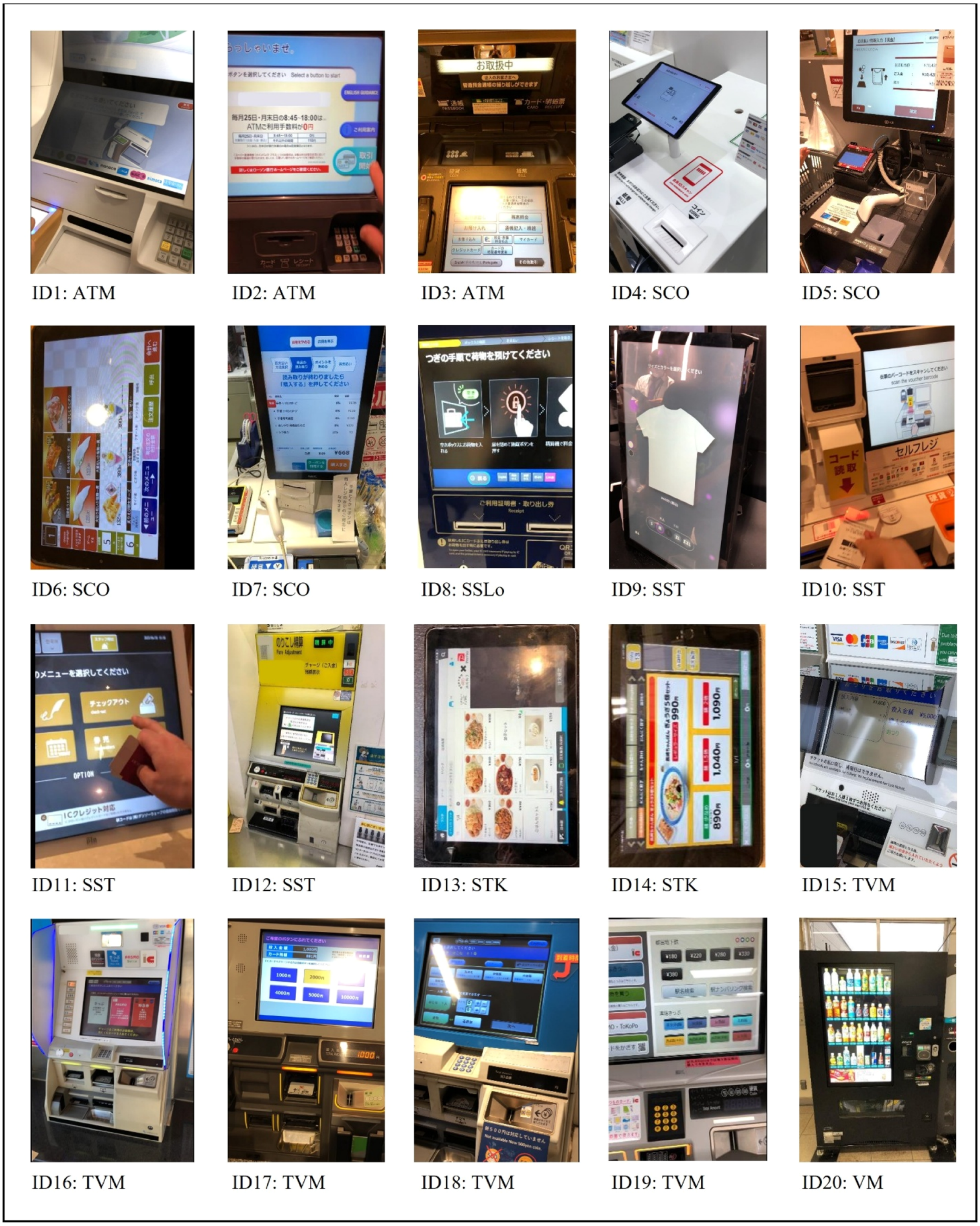

Fig. A1. Example images of selected self-service technologies (ID1-ID20).

Appendix B

Appendix B presents an example of the data extraction form used in the study.
Fig. B1.

Data Extraction Form

ID	Type	Functions/tasks performed	Place	Sample Format; Duration	Context
1	ATM	IC card recharge	Ikebukuro, Tokyo	Video 1:01min	Convenience store

First lens: Possible variables in perception and action

Example Images/Screen Shots From the Video	Component	Variables	Identified Variable Required	Code	Interpretation (evidence) Yes (how?)/No
	(1) Human Output Channels	Movement	x	How the user is intended to perform the action?	Hand movement is required to press buttons.
		Voice	-		-
		Sight	-		-
	(2) Computer Input Modalities	Movements (gesture)	-	In what way the SST will take an input from the user?	-
		Force (haptic and tactile)	x		Input is based on touchcreen technology; physical buttons (number pad) are provided as an alternative input method to insert amount of money; Braille is provided.
		Sound	-		-
		Images	-		-
		Other	x		Money insertation; card insertation; mobile phone placement to reader; take the card back; take the change.
	(3) Computer Output Media	Text	x	What type of computer output media is utilized?	Buttons, selection, and infotext.
		Images	x		Next step and e.g. mobile phone placement to the reader is demonstraded with an image.
		Video	-		-
		Animation	x		Next step and e.g. mobile phone placement to the reader is demonstraded with an animated video; processing bar is illustrated.
		Graphs	-		-
		Tables	x		Payment and money balance is on table form.
		Sound	x		Sound indicator for cliking buttons, mobile phone placement; money insertation; change alert; and card slot.
		Voice	x		Voice is provided to say thank you at the end of the task.
		Light	x		Light indicator is placed for the slots.
		Other	-		-
	(4) Human Input Channels	Sight	x	With what sense the user is intended to perceive the information and interaction?	Visual presentation; Light indicator in the slots.
		Hearing	x		Voice guidance; Sound output.
		Touch	-		-
		Smell	-		-
		Taste	-		-
		Balance	-		-

Second lens: Factors related to cognitive accessibility

Component	Variables	Code (Heuristics)	Interpretation notes (evaluation)
(5) Human Cognitive Process	Focusing attention; Perceptual functions	Help is provided for the user focus and help restore the context if attention is lost.	The next task is demonstraded with the example animation that show the places to perfom the action; progress bar helps to you to wait
	Comprehension-knowledge; Memory	A clear structure with easy to follow sections, short paragraphs, and manageable chunks are used	The payment process shows one step at time; breadcrumb is available.
	Thinking and speed of processing	The user is helped to understand the content and orientate themselves in the	Demonstrating animation of the task is provided. Voice guidance is not very helpful
	Reading and writing; Mental functions of language	An easy to follow writing style is used;	Text is short and prescriptive.
	Solving problems	Rapid and direct feedback is provided;	Sound feedback when clicking the buttons.
	Calculating and quantitative knowledge; Making decisions and reaction speed; Psychomotor functions and sequencing complex movements and speed	Users are helped to complete their work and helped to avoid mistakes and guided to correct them.	Demonstrating image of the task is provided; inserted amount of money are listed and calculated; voice guidance thanks you at the (easy to understand the process is end); breadcrumb and progress bar are
	Emotional functions	Help is provided	Help (info) button is provided; Call for help phone is provided.
	Higher-level cognitive functions and domain specific knowledge	The cognitive skills required to use the content are minimized.	Cancel button is provided; Animation helps to understand.
	Experience of self and time functions	Adaptability and personalization are enabled, so that symbols, text, and other features are familiar and helpful to the	No adabtability.

Fig. B1. Example of data extraction form.

Data availability

No data was used for the research described in the article.

References

[1] M. Blut, C. Wang, K. Schoefer, Factors influencing the acceptance of self-service technologies: a meta-analysis, J. Serv. Res. 19 (2016) 396–416, https://doi.org/10.1177/1094670516662352.
[2] M.J. Reinders, P.A. Dabholkar, R.T. Frambach, Consequences of forcing consumers to use technology-based self-service, J. Serv. Res. 11 (2008) 107–123, https://doi.org/10.1177/1094670508324297.
[3] European Commission. Digital Economy and Society Index (DESI) 2022 2022.
[4] Y. Lee, H. Jeon, H.K. Kim, S. Park, Literature Review on Accessibility Guidelines for Self-service Terminals, 2020.
[5] W. Lin, T. Li, L. Liu, Q. Zhu, "Unfold and go touch": a portable method for making existing touchscreens accessible to blind and low vision people in self-service terminals, in: Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems, New York, NY, USA, Association for Computing Machinery, 2023, pp. 1–7, https://doi.org/10.1145/3544549.3585819.
[6] C. Stephanidis, G. Salvendy, M. Antona, J.Y.C. Chen, J. Dong, V.G. Duffy, et al., Seven HCI grand challenges, Int. J. Hum.–Comput. Interact. 35 (2019) 1229–1269, https://doi.org/10.1080/10447318.2019.1619259.
[7] H. Petrie, J.S. Darzentas, C. Power, Self-service terminals for older and disabled users: attitudes of key stakeholders, in: K. Miesenberger, D. Fels, D. Archambault, P. Peňáz, W. Zagler (Eds.), Computers Helping People with Special Needs, Computers Helping People with Special Needs, 8547, Springer International Publishing, Cham, 2014, pp. 340–347, https://doi.org/10.1007/978-3-319-08596-8_53.
[8] D. Vogel, R. Balakrishnan, Interactive public ambient displays: transitioning from implicit to explicit, public to personal, interaction with multiple users, in: Proceedings of the 17th annual ACM symposium on User interface software and technology, Santa Fe NM USA, ACM, 2004, pp. 137–146, https://doi.org/10.1145/1029632.1029656.
[9] Ministry of Social Affairs and Health. The European Accessibility Act n.d. https://stm.fi/en/the-european-accessibility-act (accessed May 25, 2023).
[10] Web Accessibility Infrastructure Committee. キオスクのアクセシビリティ (後編) 2025. https://waic.jp/news/ciaj-column-19/(accessed July 15, 2025).
[11] E. Jokisuu, M. McKenna, A.W.D. Smith, P. Day, Touchscreen accessibility in self-service terminals, J. Technol. Person. Disabil. (2016).
[12] Japan Vending Systems Manufacturers Association. 日本自動販売システム機械工業会 2022.
[13] N.ikkei Compass, 自動販売機・券売機業界 市場規模・動向や企業情報｜NIKKEI COMPASS - 日本経済新聞 n.d. https://www.nikkei.com/compass/industry_s/0186, September 30, 2023. accessed
[14] Section508.gov, n.d. https://www.section508.gov/manage/laws-and-policies/, July 15, 2025. accessed
[15] The Ministry of Internal Affairs and Communications. Publication of "Information Accessibility Good Practices 2024." MIC ICT Policy n.d. https://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/pressrelease/2025/3/19_1.html (accessed July 15, 2025).
[16] The Ministry of Internal Affairs and Communications. ICT x Japan -Policy Information - 2025.
[17] J. Martins, R. Gonçalves, F. Branco, A full scope web accessibility evaluation procedure proposal based on Iberian eHealth accessibility compliance, Comput. Human. Behav. 73 (2017) 676–684, https://doi.org/10.1016/j.chb.2016.12.010.
[18] G. Vera-Amaro, J.R. Rojano-Cáceres, Towards accessible website design through artificial intelligence: a systematic literature review, Inf. Softw. Technol. 186 (2025) 107821, https://doi.org/10.1016/j.infsof.2025.107821.
[19] W3C. Web Content Accessibility Guidelines (WCAG) 2.2 n.d. https://www.w3.org/TR/WCAG22/(accessed April 28, 2024).
[20] M.inistry of Land, Infrastructure, Transport and Tourism. バリアフリー:公共交通関係のガイドライン - 国土交通省 n.d. https://www.mlit.go.jp/sogoseisaku/barrierfree/sosei_barrierfree_mn_000001.html (accessed July 23, 2025).
[21] Web Accessibility Infrastructure Committee. キオスクのアクセシビリティ (前編). ウェブアクセシビリティ基盤委員会 (WAIC) 2025. https://waic.jp/news/ciaj-column-18/(accessed July 15, 2025).
[22] F.D. Davis, User acceptance of information technology: system characteristics, user perceptions and behavioral impacts, Int. J. Man. Mach. Stud. 38 (1993) 475–487, https://doi.org/10.1006/imms.1993.1022.
[23] Y. Lee, S. Park, J. Park, H.K. Kim, Comparative analysis of usability and accessibility of kiosks for people with disabilities, Appl. Sci. 13 (2023) 3058, https://doi.org/10.3390/app13053058.
[24] N. Caporusso, K. Udenze, A. Imaji, Y. Cui, Y. Li, S. Romeiser, Accessibility evaluation of automated vending machines, in: G. Di Bucchianico (Ed.), Advances in Design for Inclusion, Advances in Design for Inclusion, 954, Springer International Publishing, Cham, 2020, pp. 47–56, https://doi.org/10.1007/978-3-030-20444-0_5.
[25] "Anthony," A. Guo, X. Chen, H. Qi, S. White, S. Ghosh, C. Asakawa, et al., VizLens: a robust and interactive screen reader for interfaces in the real world, in: Proceedings of the 29th Annual Symposium on User Interface Software and Technology, New York, NY, USA, Association for Computing Machinery, 2016, pp. 651–664, https://doi.org/10.1145/2984511.2984518.
[26] H. Henderson, K. Grace, N. Gulbransen-Diaz, B. Klaassens, T.W. Leong, M. Tomitsch, From parking meters to vending machines: a study of usability issues in self-service technologies, Int. J. Hum.–Comput. Interact. 40 (2024) 4365–4379, https://doi.org/10.1080/10447318.2023.2212228.
[27] J.E. Collier, S.E. Kimes, Only if it is convenient: understanding how convenience influences self-service technology evaluation, J. Serv. Res. 16 (2013) 39–51, https://doi.org/10.1177/1094670512458454.
[28] Harley A. UX Expert Reviews. Nielsen Norman Group. https://www.nngroup.com/articles/ux-expert-reviews/, 2018 accessed September 27, 2023.
[29] B. Inmon, Professional development seminars: Design review methodology for a data base environment, in: Proceedings of the ACM '82 conference, New York, NY, USA, Association for Computing Machinery, 1982, pp. 229–230, https://doi.org/10.1145/800174.809814.
[30] G. Huet, S.J. Culley, C.A. McMahon, C. Fortin, Making sense of engineering design review activities, AIEDAM 21 (2007) 243–266, https://doi.org/10.1017/S0890060407000261.
[31] A. Andrade, C. Urguhart, Manchester Metropolitan University, Arthanari T, The University of Auckland. Seeing for understanding: unlocking the potential of visual research in information systems, JAIS 16 (2015) 646–673, https://doi.org/10.17705/1jais.00406.
[32] M. Basil, Use of photography and video in observational research, Qualit. Market Res.: Int. J. 14 (2011) 246–257, https://doi.org/10.1108/13522751111137488.
[33] S. Baltes, P. Ralph, Sampling in software engineering research: a critical review and guidelines, Empir. Softw. Eng. 27 (2022) 94, https://doi.org/10.1007/s10664-021-10072-8.
[34] L. Schomaker, S. Münck, K. Hartung, A taxonomy of multimodal interaction in the human information processing system, Rep Esprit Proj 8579 (1995).
[35] J.-P. Mäkipää, T. Vartiainen, How to Incorporate Accessibility to Design Principles for IS Artefacts?, in: Proceedings of the 33rd International Conference on Information Modelling and Knowledge Bases EJC 2023, 2023, https://doi.org/10.18690/um.feri.5.2023.10.
[36] J.-P. Mäkipää, Explaining accessibility: possible variables in users' abilities, tasks, and contexts in IT artefact use, THCI 15 (2023) 414–441, https://doi.org/10.17705/1thci.00096.
[37] K.S. McGrew, CHC theory and the human cognitive abilities project: Standing on the shoulders of the giants of psychometric intelligence research, Intelligence 37 (2009) 1–10, https://doi.org/10.1016/j.intell.2008.08.004.
[38] J.H. Gerlach, F.-Y. Kuo, Understanding human-computer interaction for information systems design, MIS Q. 15 (1991) 527–549, https://doi.org/10.2307/249456.
[39] W3C, Cognitive Accessibility Roadmap and Gap Analysis. https://w3c.github.io/coga/gap-analysis/#sotd, 2021 accessed September 25, 2023.
[40] A. Marcus, User interface design and culture, in: N. Aykin (Ed.), Usability and Internationalization of Information Technology, Lawrence Erlbaum Associates, Mahwah, New Jersey, London, 2005, pp. 51–78.
[41] A. Marcus, et al., Cross-cultural user-experience design, in: D. Barker-Plummer, et al. (Eds.), Diagrams 2006, LNAI 4045, Springer, Berlin Heidelberg, 2006, pp. 16–24.
[42] Usability.gov, AS for P. User Interface Elements. https://www.usability.gov/how-to-and-tools/methods/user-interface-elements.html, 2013 (accessed October 7, 2023).
[43] Y.S. Lincoln, E.G. Guba, But is it rigorous? Trustworthiness and authenticity in naturalistic evaluation, New Direct. Progr. Evaluat. 1986 (1986) 73–84, https://doi.org/10.1002/ev.1427.
[44] O.C. Enworo, Application of Guba and Lincoln's parallel criteria to assess trustworthiness of qualitative research on indigenous social protection systems, Qual. Res. J. 23 (2023) 372–384, https://doi.org/10.1108/QRJ-08-2022-0116.
[45] J. Zahle, Bias and debiasing strategies in qualitative data collection, Philos. Sci. 92 (2025) 606–623, https://doi.org/10.1017/psa.2024.70.
[46] D. Norman, Cognitive Engineering. User Centered System Design: New Perspectives on Human-Computer Interaction, 1986, pp. 31–61.
[47] A. Aizpurua, M. Arrue, M. Vigo, Prejudices, memories, expectations and confidence influence experienced accessibility on the Web, Comput. Human. Behav. 51 (2015) 152–160, https://doi.org/10.1016/j.chb.2015.04.035.