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AidServer: Design and Research of a Communication Accessibility Service System for Hearing Impaired Servers in Silent Restaurants

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Abstract. This paper introduces a communication accessibility service system called AidServer, aimed at enhancing communication between deaf service staff and deaf customers in silent restaurants. Due to their limited communication abilities, deaf individuals often face challenges when seeking suitable employmen [1–4]. However, with the emergence of silent restaurants [5]deaf individuals have found new employment opportunities. AidServer comprises three components: a software application for deaf service staff, a service call button, and a wearable voice amplifier. We conducted laboratory system usability tests and real restaurant scenario applications to evaluate the effectiveness of the system. The results demonstrate that the AidServer system significantly improves communication efficiency between deaf service staff and deaf customers in real restaurant operations. The proposed system can increase the social participation and labor capabilities of deaf individuals, making it a valuable contribution to the field of communication accessibility.

Keywords. Hearing-Impaired people, employment of the disabled, communication aids, innovation, artificial intelligence.

1. Introduction

According to the World Federation of the Deaf approximately 72 million people worldwide are born with partial or complete hearing or speech impairments, making communication a significant challenge for them to integrate into the overall educational, social, and work environments[8]. However, the use of assistive technology has brought undeniable benefits, such as speech amplification, vibration or light displays,

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induction coupling, speech to text, speech synthesis, and motion recognition[9] . According to Dyzel et al. [10], the majority of existing technologies for hearing-impaired people focus on improving their ability to receive information, but less attention has been paid to their ability to express information, especially in the employment environment.

The United Nations Office of the High Commissioner for Human Rights considers the right to work a fundamental right of the High Commissioner for Human Rights[11], and the Convention on the Rights of Persons with Disabilities acknowledges the right of persons with disabilities to work on an equal basis with others Nations[12]. However, the lack of good language communication skills due to their physical condition makes hearing-impaired individuals one of the most difficult groups to employ. More inclusive work processes and communication accessibility are crucial in the workplace.

In this paper, we propose a communication accessibility service system for a silent restaurant to improve the communication and efficiency between hearing-impaired servers and customers in real restaurant operations. The AidServer system is developed based on the specific scenario workflow of hearing-impaired servers in a silent restaurant, including a software application, a service call button, and a wearable voice emitter, and uses artificial intelligence algorithms to compensate for the ability and perceptual defects of hearing-impaired individuals. We conducted usability tests on the system in laboratory and real restaurant environments, and the results showed that the AidServer system can effectively improve communication between hearing-impaired servers and customers in real restaurant operations.

Our proposed system is an innovative approach to improving communication accessibility and employment opportunities for hearing-impaired individuals, and we believe it has enormous potential for adoption in other employment environments.

2. Background

2.1. Assistive technology for people with disabilities

For people with disabilities, employment remains the best way to achieve independence and make their own choices. Assistive technology (AT) is crucial for eliminating employment barriers and improving work efficiency for disabled workers. In this regard, a range of technologies have been developed and studied, including screen readers, speech recognition software, specialized keyboards and mice, and augmented and virtual reality systems [13]. Some studies have evaluated the effectiveness of these technologies in improving productivity and work performance for people with disabilities, and there is growing interest in the role of assistive technology in promoting workplace accessibility [14] recently conducted a case study investigating the effectiveness of a mobile application designed to support communication between deaf employees and their colleagues. The study found that the application significantly improved communication and reduced stress levels for employees with hearing loss. Another study by Liu et al. proposed a wearable device that can translate spoken language into sign language in realtime [16].

This device has the potential to enhance communication between deaf employees and their hearing-impaired colleagues in the workplace. In Tokyo, Japan, a cafe called Dawnver uses substitute robots to replace disabled workers [17]. The substitute robot OriHime-D is a semi-robot (demirobot) developed by ANA Holdings Inc. and Ory

Research Institute to support employment for people with disabilities, including those with ALS, spinal cord injuries, or even paralysis, allowing them to remotely control the OriHime-D robot from home via the internet to communicate with customers and pick up cups of coffee and other items. The robot has built-in cameras and speakers, and the operator can hear and see what the robot hears and sees.In May 2021, technology company iFlytek released an upgrade plan for its ”iFlytek Listening” service, which provides real-time speech-to-text transcription in bilingual languages for free to hearing-impaired organizational users, expanding the provision of accessi- ble office environments and helping hearing-impaired individuals better integrate into the workplace[18].The development and implementation of such assistive technologies are crucial for promoting accessibility and inclusivity in the workforce, and their success stories provide enormous potential for future research and innovation[19, 20].

2.2. Communication quality

The quality of communication in hearing-impaired populations has been an extensive area of research in the field of computer-human interaction (CHI). In recent years, various techniques have been proposed to improve the accessibility of communication for this population. Gugenheimer et al. proposed a physical interaction prototype that translates the spoken words of a hearing person into sign language projected onto the hearing person’s clothing for viewing by a deaf or hearing-impaired person [21]. On the other hand, Hong et al. propose a dynamic captioning technique that enhances video accessibility for hearing-impaired viewers [22]. Their approach uses techniques such as face detection and recognition, visual saliency analysis, and text-to-speech alignment to display captions word-by-word, high lighting changes in speech volume to help convey emotion. In addition, Mary Jane C. Samonte presented an electronic instructional aid system that uses assistive technologies such as speech-to-text, gamified learning, and handwritten character recognition to teach Filipino Sign Language (FSL) to students. These technologies provide an interactive and animated environment that introduces students to statistical topics and facilitates their learning process. These proposed technologies demonstrate the advancement and potential of assistive technology to improve the ease and quality of communication for the hearing-impaired population.

2.3. Emotion perception

Emotions play a crucial role in daily life, as the way people understand and express emotions can affect social relationships, coping strategies in difficult situations, and approaches to resolving interpersonal conflicts [24]. To assist individuals with disabilities in understanding emotions, an increasing number of assistive technologies have been developed. The Emotion Whisperer is a product specifically designed for visually impaired individuals, capable of converting body language and emotions into tactile feedbac[25] .The device captures facial images of others through glasses worn by visually impaired individuals and transmits them to a smart-phone[26]. The app on the smartphone recognizes emotions and ultimately converts them into vibrations of varying intensities. Visually impaired indi- viduals can perceive emotional information expressed through body language or facial expressions of people in front of them using this device [27].

Both visually and hearing-impaired individuals have sensory deficits, which prevent them from obtaining emotion-related information such as expressions and tones during social interactions [28]. Consequently, they often struggle to interpret others' emotions, leading to significant barriers in communication processes[]. Further research is required to fully explore the potential of technologies like The Emotion Whisperer in supporting the emotional perception of visually and hearing-impaired populations [30].

2.4. System Description

AidServer is an innovative communication accessibility service system specifically designed for silent restaurants, aiming to facilitate communication between deaf servers and customers. The system consists of three main components: a software application used by deaf servers, a service call button, and a wearable voice speaker (Figure1). The software application offers various functions, including call service and feedback, voice to text and text-to-voice conversion, voice emotion recognition, preset response, intelligent response recommendation, and data analytics.

3. Hardware Overview

3.1. Service Call Button

The service call button is designed to assist customers in conveying call information to deaf servers. The call button adopts a doorbell-like design and is 3D printed according to 80*98 mm dimensions. When a customer presses the call button, the call status indicator light on the call button illuminates, indicating that the call information has been sent. The software on the server's end receives a vibration alert, notifying them that a customer is attempting to communicate. By clicking "Received," the server can acknowledge the call and extinguish the call status indicator light. The service call button is developed using the Arduino integrated development environment and transmits signals to the software application within an 80-meter range via Bluetooth. The green power light illuminates when connected to power and flashes when the battery is low, prompting the user to charge. When the call button is pressed, the Bluetooth sends a command to the software application, and the red call status light turns on. When "Received" is clicked within the application, the application sends a cancel command to the call button, and the red light turns off.

3.2. Wearable Voice Speaker

The wearable voice speaker is a unique device designed to play synthesized speech responses from the software. It features a small cartoon figurine resembling a pineapple bun, measuring approximately 70*70 mm, with a safety pin on the back for easy attachment to the user's chest (Figure 1(b)). The speaker houses a 5.6*25 mm wireless Bluetooth speaker module, enabling it to connect with the software application.

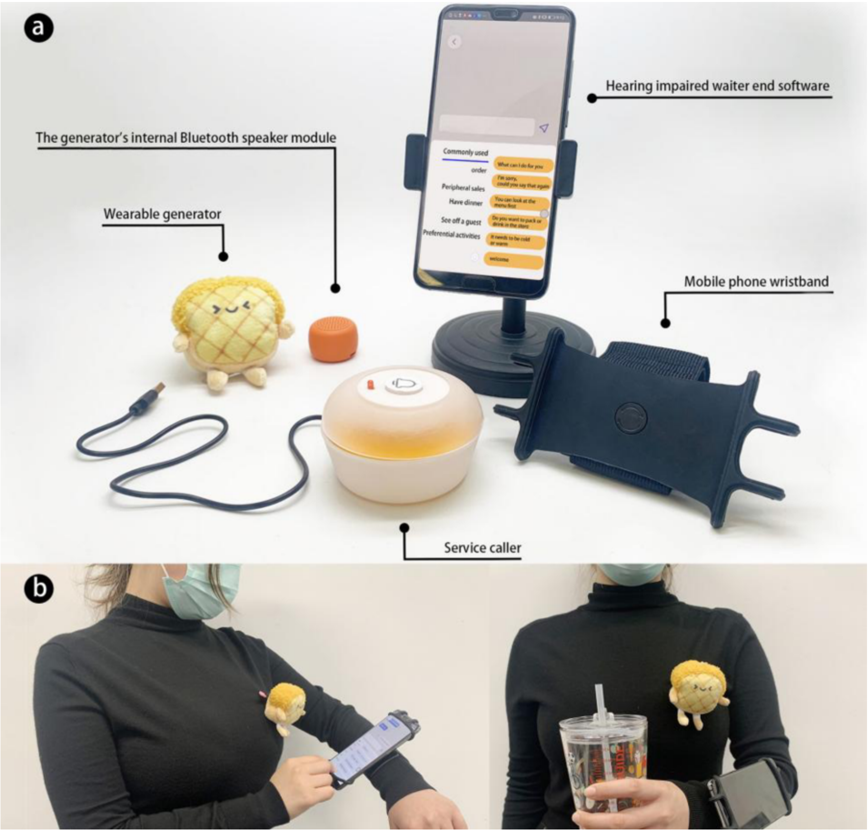

Figure 1 (a) Communication accessibility service system for silent restaurants; (b) usage schematic.

Via Bluetooth,the wearable voice speaker is designed to make the communication process more natural, providing customers with a sense of "communicating with the server" rather than "communicating with a mobile phone." The anthropomorphic cartoon image of the vocalizer is like a "voice assistant" for hearing-impaired users, which can increase the fun of communication.

3.3. Software Introduction

- Overall Functionality

We propose a software application comprised of three modules: Homepage, Communication Services, and Personal Settings (Figure 2). The software is designed to be compatible with wearable voice speakers and multiple service call buttons, allowing users to connect several devices simultaneously. Hardware devices can be easily added through the "Scan" or "+" symbol on the homepage. Furthermore, users can verify the Bluetooth connection status of their connected devices on the homepage. The Communication Services interface includes three sections: Communication Log, Independent Reply, and Quick Reply. The latter contains intelligent recommended replies and preset replies created by deaf servers based on user needs. In the Personal Settings page, users can flexibly modify the voice style of speech synthesis in the "Voice Settings" section. Moreover, users can browse software tutorials in the "Help Center" tab and provide feedback through the "Feedback" option, which aids in improving the software and system. Additionally, the Personal Settings page includes statistics of the user's weekly online time within the software.

- Implementation of Communication Services

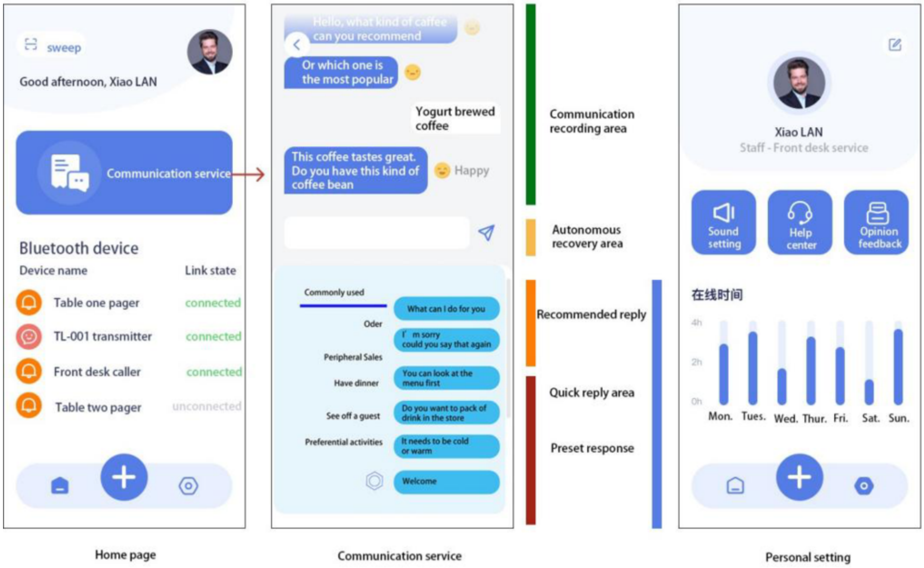

Figure 2. Software home page, communication services and personal settings

Communication services serve as the most crucial part of the software application, primarily encompassing four functions: voice-to-text and text to voice conversion, voice emotion recognition, preset replies, and intelligent recommended replies. The voice to text and text-to-voice conversion functions in the software application utilize the Real-time ASR interface [31] and Online Speech Synthesis interface [32] from the Xunfei Open Platform. Considering the different voice needs of male and female servers, we chose "Xu Jiu Cordial Male Voice" and" Xiao Jing Cordial Female Voice" from the basic announcers for voice style.

The voice emotion recognition function is implemented using the dialogue

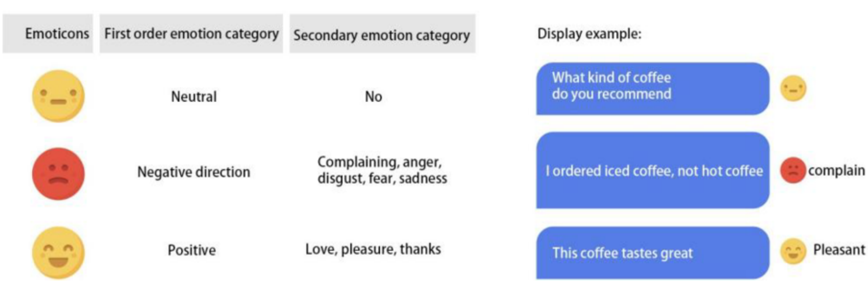

Figure 3 Baidu Intelligent Cloud's conversational emotion recognition interface on the front end of the software

emotion recognition interface from the Baidu Intelligent Cloud [33].This algorithm can automatically identify the primary and secondary emotion categories and their confidence levels based on the communication text. Primary emotions are divided into positive, neutral, and negative, with positive emotions further divided into liking, pleasure, and gratitude; negative emotions are divided into complaints, anger, disgust, fear, and sadness. This system invokes the primary and secondary emotion analysis results from the algorithm's returned parameters, displaying primary emotions as corresponding expression icons and secondary emotions as text on the software frontend, with neutral emotions only showing an icon (Figure 3). For the intelligent recommended reply function, we used Rasa Open Source 2.0 [34]to train the dialogue knowledge base data of this system, thereby achieving the effect of calling corresponding answers from the system's dialogue knowledge base based on the customer's text requirement information. The Rasa Stack is an opensource machine learning tool for creating context-aware AI assistants and chatbots, consisting of Rasa NLU and Rasa Core modules. Rasa NLU is a library for natural language understanding, converting user input into structured data. Rasa Core is a machine-learning-based dialogue management platform that trains data based on NLU input and historical conversations.

3.4. Workflow

When the hearing-impaired server is not in proximity to the customer, and the customer requires service, they can press the call button on the table. This action sends call information to the server's software application, alerting the hearing-impaired server through visual and vibrational cues. Upon confirming the receipt of this information within the application, the call device provides feedback to the customer via indicator light status. During face-to-face communication between the hearing-impaired server and the customer, the software application receives the customer's voice request and converts it into textual information through Automatic Speech Recognition (ASR). Natural Language Understanding (NLU), based on Natural Language Processing (NLP) techniques, employs emotional speech processing technology to analyze the customer's voice according to pitch, speed, and other parameters combined with textual content. The software application is thus able to convey emotional information from the customer's voice request to the hearing-impaired server. In terms of response, the software application offers three modes: preset responses, independent responses, and intelligent recommended responses. Preset responses involve the server storing commonly used high-frequency conversation text within the software application. Independent responses refer to the server directly inputting a corresponding response text in the software application based on the customer's current needs and emotions. Intelligent recommended responses rely on NLU and Dialog Management (DM). Once the voice is recognized and converted into text, it undergoes word segmentation, part-of-speech tagging, named entity recognition, dependency parsing, and other processing, in conjunction with sentiment analysis results to identify the customer's intent. The system's dialogue knowledge base then retrieves suitable response texts for the hearing-impaired server to choose from. Upon selecting an appropriate response mode, the software converts the text response information into voice information via Text to Speech (TTS) technology, which is ultimately broadcast to the restaurant customer through a wearable speaker. The restaurant's system terminal collects data on the duration of software application usage by all hearing-impaired servers, stores conversation datasets between customers and servers during the service process, and provides an API interface for restaurant managers to export data.The duration of software usage by hearing-impaired servers reflects their service communication work hours and indirectly reveals the restaurant's peak customer flow periods and the level of service demand. The conversation datasets not only filter customer evaluations of the restaurant and preferences for dishes but also assess the service level of hearing-impaired staff. Moreover, these datasets continuously enrich the restaurant's response database, gradually improving the accuracy of intelligent recommended responses and enhancing the efficiency of hearing-impaired servers (Figure 4).

4. Usability Testing

The experimental section of this study involved usability testing of the system prototype to ensure its seamless functioning and support for communication between hearing and hearing-impaired individuals across various restaurant contexts. The

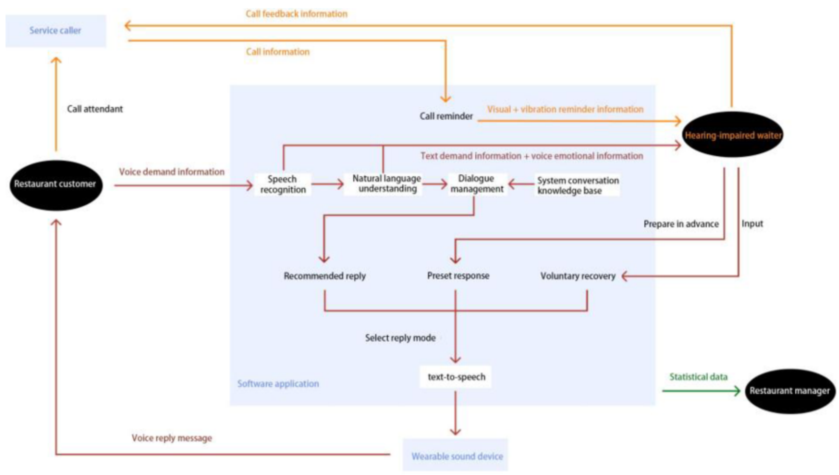

Figure 4 System workflow

primary objectives of the testing were to evaluate the interaction flow, ergonomic design, and facilitation of daily communication, takeout communication, and training through the system. The authors employed scenario interpretation and role-playing to assess the system's functionality and conducted semistructured post-test interviews with six participants to obtain feedback on system usability.

4.1. Participant & apparatus

The usability test included six participants, (3female; M = 23.82 years, SD = 1.87 years), all of whom were able-bodied listeners. Each participant assumed the roles of a hearing and a hearing-impaired individual in two separate scenarios. The authors established three restaurant communication scenarios, each with corresponding tasks: ordering food at a Sichuan restaurant, learning how to use Xiaodu Smart Screen 1S, and communication between a hearing-impaired waiter and a hearing-impaired delivery person. Subjects were permitted to utilize the system according to the theme and role of the selected scenario and accomplish the target task via communication content. Participants portraying hearing-impaired individuals were instructed to wear noise-canceling Bluetooth headphones, listen to music, wear a mask, and remain silent during the scenario interpretation, simulating the experience of a hearing-impaired person.

4.2. Procedure

The experimental procedure commenced with a 15-minute presentation by the authors to six subjects on the usability testing process and the communication accessibility system's functionality. Subjects were then divided into three groups for the first round of interpretation. Prior to the interpretation, participants chosen to portray hearing-impaired individuals were given 5 minutes to prepare for the scenario based on the scene context. They were also allotted 5 minutes to prepare phrases that might be used in the scenario employing a pre-determined response function. Each group was granted 8 minutes for scene interpretation. Once the three groups completed the first interpretation round, they were assigned a second 8-minute round of interpretation on the same topic, with the individual who played the hearing-impaired role in the first round assuming the hearing role in the second round (Figure 5).

Upon completing all interpretation tasks, the authors conducted user interviews with each of the three subject groups. Interview questions addressed software button size, typing ease, wearable speaker experience, most helpful features, and system improvement suggestions. The usability testing and interviews yielded valuable insights into system functionality and potential enhancements for future development. The entire scene interpretation and user interview process was video-recorded with participants' consent. The mobile device employed for this test was the Huawei P20 Pro.

Figure 5 Usability Testing Process

4.3. Results

The usability test results demonstrated the successful use of the system by all three subject groups in completing tasks across different scenarios. Notably, the autonomous response feature helped address occasional inaccuracies in speech recognition. The emotion recognition function accurately identified listener appreciation emotions. The majority (83%) of subjects found the system easy to use and master, with only one expressing concerns regarding hearing-impaired users. All subjects agreed that preset and intelligent recommended response functions improved efficiency. Subjects identified the preset response feature as the most helpful during testing. Although speech recognition was accurate for standard Mandarin, concerns arose regarding dialect recognition. Subjects also noted that the speech synthesis of the prototype was unnatural and suggested a more emotive voice for enhanced customer experience. Subject 3 appreciated the thoughtful design of displaying voice playback progress.

5. User Study

In this study, we aimed to investigate the effectiveness and user experience of a new communication tool, AidServer, designed to assist deaf individuals in service environments. To achieve this goal, we conducted a three-day experiment at a silent caf`e owned and operated by a deaf couple. The main research methods employed in the experiment were questionnaires, semi-structured interviews, and observations. Prior to the experiment, we obtained the consent of the caf`e owner and set up the experimental environment at the cash register, which is the main communication area of the caf`e (Figure 6).

6. Procedure

On the first day of the experiment, we demonstrated the use of the AidServer system to the deaf caf`e owners in a training coach manner. The experiment lasted 20 minutes, during which we verified that the deaf owners had fully mastered the system and how to use it. They then began using the preset response function to create a preset response library for the caf`e, which was used in the experiment for the following two days. While the deaf owners were setting up the preset library, we placed the prototype system in the store along with a service call button that customers could use to alert the deaf owners. We also provided a mobile phone holder for communication during the ordering process and adjusted the playback volume of the wearable speaker worn by the deaf staff. To minimize the impact on the caf`e's operations, we retained the existing pen and paper tools in the store during the experiment. Over the next two days, the caf`e served 19 customers, 18 of whom successfully completed the ordering process with the assistance of the AidServer system. One customer switched to pen and paper tools due to poor Mandarin pronunciation, resulting in subpar speech-to- text recognition. After completing their orders, customers were invited to fill out an experience questionnaire, and those who completed the questionnaire received a cash reward of 5 RMB. Customers were also selected for semi-structured interviews. We used WeChat as a feedback portal, where any issues or ideas discovered by the deaf owners while using the system during operation could be promptly recorded in our WeChat conversation history, preventing the loss of transient thoughts after testing. Throughout the experiment, we observed and recorded the participants' behavior, reactions, and other details about their instore communication using the system.

Figure 6 Systematic teaching and experimental field layout

7. Results

7.1. Questionnaire survey

We conducted a questionnaire survey on a silent restaurant communication system for people with hearing impairments, collecting data from 13 questionnaires, including 9 from regular customers and 4 from new customers. The results showed that the 13 participants rated their satisfaction with the communication experience with the restaurant owner during the meal with an average score of 4.31(S = 0.63), an average score of 3.85(S = 0.69) for communication efficiency, and an average score of4.38(S = 0.65) for the smoothness of communication. All of these scores were higher than the neutral rating of 3 points. For the previous experience of using paper and pen tools for communication in the restaurant, the average satisfaction score of the 9 regular customers was2.56(S = 0.88), the average score for communication efficiency was 2.11(S = 0.78), and the average score for communication smoothness was 4.22(S = 0.67). These results indicate that the system can meet the customers' needs for smooth communication in a silent restaurant, providing a more efficient communication method than written communication and delivering a higher level of communication satisfaction for customers.

7.2. Semi-Structured Interviews

In this round of interviews, we invited 6 participants, including 1 hearing-impaired restaurant owner (code-named D1) and 5 customers (code-named P1-5), comprising 4 regular customers and 1 new customer. We used open coding analysis to organize and analyze the interview records, mainly categorizing them from four perspectives: overall system evaluation, software application evaluation, service call device evaluation, and wearable speaker evaluation.

Overall System Evaluation. The system is designed for easy learning and smooth usage by individuals with hearing impairments. There are no breakpoints in the interaction process, and the dimensions of both the human-machine interface and button sizes are suitable. From the perspective of the silent restaurant manager, D1, the importance ranking of the six main functions of the system is as follows: call ser- vice and feedback function, voice-to-text conversion function, preset reply function, data statistics function, intelligent reply recommendation function, and voice emotion recognition function. As D1 stated, "When the restaurant area is relatively large, it is difficult for people with hearing impairments to discover when customers need assistance just by using their eyes... I hope to analyze from the conversation records which coffee is the most popular and what the customers think of the restaurant." Six participants rated the system satisfaction as 4 out of 5 points. All six participants believe that the system can play a positive role in addressing communication barriers in silent restaurants and provide a better service experience. For example, D1 said, "This system is very helpful for deaf people to start their own businesses. I hope it can be launched soon. Once it's online, I will use it in my store, making communication with customers much more convenient." P2 said, "I was pleasantly surprised when I heard 'Welcome to Sign Language Coffee' when I first entered the store because, in the past, customers had to write down their orders. Now there is even voice guidance, which feels almost like a normal restaurant." P3 also mentioned, "This system not only solves the communication problems of deaf and mute people in the restaurant but also helps in fixed communication positions such as supermarket cashiers." However, the system is slightly lacking in device management and is expected to add power management functions for hardware devices. For example, D1 mentioned, "If there are many call devices in the restaurant, it would be cumbersome to check the battery levels individually. The same goes for speakers. It would be more convenient to see the battery levels of all devices in the system through the software and charge them accordingly." At the same time, participants expect the system to have more comprehensive considerations in terms of commercialization. As P1 mentioned," If this system is sold to silent restaurants, the database of the smart reply function needs to provide a simpler management method for the store."

Software Application Evaluation. D1 stated that the most helpful features during the business process were the voice-to-text conversion function, preset reply function, and intelligent recommended reply function. These functions improved the efficiency of responses for hearing-impaired individuals, proving to be "especially useful for hearing-impaired people with low literacy levels." Although the voice emotion recognition function was conceptually able to assist hearing-impaired waitstaff in understanding customer needs, its effectiveness was hindered by algorithmic limitations. As P4 commented, "The concept of emotion recognition is novel in this application, and it would be more impactful if it could recognize a richer range of emotions." However, D1 mentioned, "I thought it was a great feature when it was introduced, but some emotions were inaccurate during use, which affected my judgment... Also, the colors representing positive and neutral emotions were too similar, making it difficult to distinguish them unless closely examined, but negative emotions were very obvious."

Service Caller Evaluation. The service caller's aesthetic design was praised by D1, P3, and P4, and was deemed suitable for various types of restaurants by P3. However, D1, P2, and P5 suggested incorporating an antitheft fixed function.

Wearable Vocalizer Evaluation. The wearable vocalizer made the communication process appear more natural. Users hoped for the option to customize the appearance of the wearable vocalizer according to the restaurant's theme. Moreover, indicating the progress of voice playback through the vocalizer helped enhance the perception of "communicating with the hearing-impaired." For example, P4 mentioned, "When I order, my phone is covered by the counter, and the sound comes from the owner, creating an illusion that the owner is talking to me." P2 added, "The appearance of this vocalizer does not match its voice. If the voice were cuter, it would match the appearance, and if the voice were closer to the image of the waiter, the vocalizer could be designed to be more discreet." D1 stated, "I think the appearance of this vocalizer is too cute; I hope I can customize it... When playing the voice, I have to look down at the playback status. If the vocalizer could directly vibrate to notify when the playback is complete, I could look at the customer while the voice is playing."

8. Discussion

In this study, we introduced AidServer, a communication accessibility service system designed to improve communication between deaf service staff and deaf customers in silent restaurants. The AidServer system comprises a software application for deaf service staff, a service call button, and a wearable voice amplifier. Our investigation into the effectiveness of this system involved both laboratory system usability tests and real restaurant scenario applications. Our findings indicate that the AidServer system significantly enhances communication efficiency between deaf service staff and deaf customers during real restaurant operations. This improvement in communication is in line with previous studies that emphasized the importance of accessible communication tools for the deaf community[35, 36]. By addressing the communication challenges faced by deaf individuals in the workplace, the AidServer system holds great potential for increasing the social participation and labor capabilities of deaf individuals. These results contribute to the growing body of research on communication accessibility solutions for deaf individuals[37-39]. The AidServer system not only offers a practical solution for enhancing communication in silent restaurants but also provides valuable insights into the development of communication tools tailored to the unique needs of the deaf community. As the AidServer system is specifically designed for silent restaurant environments, further research may be necessary to evaluate its applicability and effectiveness in other settings and industries. Additionally, future research could explore potential improvements and customizations to the AidServer system to better accommodate the varying communication needs of deaf individuals. Such improvements may include the integration of sign language recognition technology or the development of more advanced voice amplification features[40] or voice recognition[41]. By building upon the success of the AidServer system, researchers and developers can continue to advance the field of communication accessibility and promote greater inclusion and equal opportunities for deaf individuals in the workplace and beyond. In conclusion, the AidServer system has demonstrated its effectiveness in improving communication between deaf service staff and deaf customers in silent restaurants. By addressing the unique communication challenges faced by deaf individuals, the proposed system has the potential to increase social participation and labor capabilities, making it a significant contribution to the field of communication accessibility.

9. Conclusion

In this paper, we presented the development of AidServer, an innovative communication accessibility service system specifically tailored for silent restaurants. Our system employs artificial intelligence technology to address the communication challenges faced by hearing-impaired waitstaff. By integrating speech-to-text technology, emotional speech processing techniques, and intelligent voice interaction capabilities, we have effectively enhanced the ability of hearing-impaired individuals to receive and convey information efficiently. Through our research studies, we demonstrated that AidServer is successful in addressing communication issues in real-world restaurant operations, garnering positive feedback from hearing customers. These findings suggest that our system has the potential to significantly contribute to the creation of a more inclusive and accessible work environment for individuals with hearing loss. Looking ahead, we hope that the AidServer system serves as a catalyst for future research focused on developing similar solutions for employment environments catering to people with disabilities. By promoting accessibility and inclusivity in the workplace, we can foster a more equitable society that values the unique skills and talents of all individuals, regardless of their physical or sensory limitations.

10. Limitations And Future Work

During the development and testing phases of our research, we encountered numerous constraints, particularly the reliance on open-source algorithms, which significantly impacted the quality of our outcomes. A key limitation was the imprecision of the sentiment recognition segment of our analysis, despite our efforts to ensure robust performance. This accuracy deficiency resulted in low user satisfaction, revealing areas in need of improvement. An important aspect to highlight is that our work was completed prior to the release of chatGPT, an advanced AI language model. Consequently, this resource was not utilized during the research and test phases. Our reliance on open-source models consequently influenced the performance and user satisfaction of our software solution. In future endeavors, we intend to circumvent these limitations by enhancing our system's functionality and refining its algorithms. Our key objective is to deliver improved functional outcomes, increase user satisfaction, and enhance the overall effectiveness of our tool. We also plan to harness the power of more advanced AI systems, like chatGPT, to heighten the accuracy of the sentiment recognition feature in our software. By integrating more sophisticated AI language models, we anticipate a significant elevation in the precision and efficiency of our tool. Another limitation that we faced was the ongoing impact of the COVID-19 pandemic, which restricted the second round of our experiment to a single cafe. The chosen establishment was relatively small, with only basic service links. This constraint may have affected the validity and reliability of our experimental data and results, as the sample size and setting were not as diverse as desired. To address this issue in future studies, we will aim to carry out effect validation experiments across various types of quiet restaurants. By doing so, we can collect more data and gather feedback from a wider range of participants and environments. This approach will help us establish the reliability and generalizability of our system and experimental findings. Furthermore, we will consider implementing robust statistical methods to analyze the data and mitigate the effects of potential biases. In conclusion, while our study has encountered limita- tions, these challenges provide valuable insights into areas for future improvement. By addressing these issues and refining our methodology, we hope to enhance the system's performance and demonstrate its utility in a broader range of real-world applications. Ultimately, our goal is to create a reliable and effective tool that meets the diverse needs of users in the context of quiet restaurant settings.

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