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Development Report:

Development of a Communication Aid App with iOS Devices to Support Children/Persons with Speech Disabilities

Improvement in Obtaining Positioning Information with iBeacon as Near Field Radio Communication Technology

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Communication has such a vital function as the foundation of human social life that speech disabilities can drastically deteriorate people's quality of life. The author has developed a voice output communication aid (VOCA) to enable children/persons with speech disabilities to communicate with other people according to conversation situations with iOS devices with global positioning system (GPS), positional information acquiring technology (iBeacon), and a clock function installed. The developed technology is an application compatible with iOS (hereinafter, app) that displays a list of messages (hereinafter, VOCA interface) if any of them correspond to the information on the user's location and time of use as acquired by users with a portable information device with a GPS function, iBeacon function, and clock function installed. Users can communicate by selecting the icons of required messages from VOCA interfaces to reproduce registered voice data instead of their own voices. We have named the developed technology "Friendly VOCA" because its intentions are that: (1) users can communicate with other people with as few operations involved as possible; (2) it should be easy for users to learn and to operate. This paper reports the development processes of the Friendly VOCA and defines the ratios of preregistered VOCA interfaces displayed (hereinafter, correct answer rates) in acquiring positional information with GPS and with iBeacon. In Research Task 1, we have conducted experiments to verify the correct answer rates of the GPS system in outdoor use of the Friendly VOCA and in Research Task 2 we have conducted experiments to verify the correct answer rates of the iBeacon system in indoor use of the Friendly VOCA. The research results show that both the GPS system and iBeacon system can specify user's spatial information and display appropriate lists of messages. However, the experiments found that iBeacon signal transmitters can transmit signals over a distance of 50 m or more: to improve the correct answer rates of the iBeacon system, we may need to increase the distance between iBeacon signal transmitters or select devices with a shorter range of transmission.

Keywords: voice output communication aid, user friendly, iOS device, iBeacon, speech disability

1. Introduction

According to the Fiscal 2011 Survey on How Difficult It Is to Live in Japan published by the Ministry of Health, Labor and Welfare [1], there are 323,000 children/persons with hearing/speech disabilities, 246,000 children/persons with physical disabilities (with trunk dysfunction and congenital cerebral disturbance of motility), and 622,000 children/persons with mental disabilities. Many of those children/persons with disabilities cannot make spontaneous utterances and have difficulties in making utterances due to unclear articulation. These statistics are calculated from physical disability certificates and rehabilitation certificates. In practice, there will be many cases of disabled people who have not applied for such certificates, suggesting that there are potentially many more children/persons with speech disabilities.

Communication has such a vital function as the foundation of human social life that people with speech disabilities would be rendered unable to communicate and their quality of life (QOL) would be drastically reduced. As of April 2016, the elderly population in Japan amounts to 34,343,000. The survey by the Ministry of Health, Labor and Welfare shows that in 2012 the number of patients with cognitive dementia amounts to 4,620,000 and the number of persons with mild cognitive impairment that could develop into cognitive dementia amounts to approximately 4,000,000 [2]. Patients with cognitive dementia and persons with mild cognitive impairment, who have difficulties in making communication according to locations and situations, are also deemed to have speech disabilities. The sum of the above-mentioned disabled children/persons, patients with cognitive dementia, and persons with mild cognitive impairment makes the number of persons in Japan with some sort of speech disability approximately 9,811,000.

1.1. Trends of Supportive Approaches to Children/Persons with Speech Disabilities

The augmented alternative communication (AAC) approach is a well-known supportive approach to complement the communication function of children/persons with speech disabilities. In the AAC approach, devices to support communication are called communication aids (CAs). In particular, voice output communication aids (VOCAs) are used in situations where a quick response is essential such as greetings in daily life or responses to questions. VOCAs enable users to communicate by outputting recorded voices when buttons are pressed. In Japan, various VOCA models such as Cardinal, Chickadee, Super Talker, Message Mate, etc. are on the market [3] as portable conversation assistance devices[1] under the daily living technical aid system[2]. In addition, applications on smartphones are available for use as convenient tools in daily life whether users are disabled or not, where the above-mentioned VOCA function is transplanted (for example, Drop Talk, Voice4U, etc.).

These VOCAs are used on a daily basis as devices to support children/persons with speech disabilities in the fields of welfare for the disabled as well as special needs education. The latest VOCA has a function for registering plural message strata (hereinafter, VOCA interface) so that users can switch messages according to situations: with more than one message registered in each VOCA interface, users can use numerous messages by switching VOCA interfaces according to situations; in other words, users who can freely operate a lot of VOCA interfaces or messages can make conversations according to a diversity of locations and situations.

As numerous VOCA interfaces or messages are registered, users need to switch between more than one VOCA interface to display messages according to locations and situations. Many children/persons with intellectual disabilities and patients with cognitive dementia among others may be unable to determine which VOCA interface they should switch to in each situation: they have to rely on their supporters to switch VOCA interfaces. This constitutes a barrier to their self-reliance and participation in society (**Fig. 1**). It is, therefore, a pressing issue in communication support for children/persons with speech disabilities to develop VOCAs that can automatically switch between and display appropriate VOCA interfaces without requiring user's determinations, thus facilitating their independent communication.

On the other hand, we make conversations in specific situations (places and times) by exchanging messages in specific orders according to the said specific place and time as if using a playscript: in a fast-food restaurant, for example, enter the restaurant→clerk: greeting→clerk: questions about the customer's order→customer: order→clerk: ask if anything more→ .... This is a common flow of conversations and such a series of flows/frameworks of behaviors is called a "script" [4] in psychology. Invocation of the script concept for communication support could limit the number of messages that could be used in specific situations. In other words, (1) supporters specify the situations where users transmit messages, (2) supporters record messages in VOCA according to the specific situations, and (3) in the situations where users want to transmit messages, users select messages from an automatically selected list of messages and reproduce corresponding recorded voices, thus enabling users to communicate with other people.

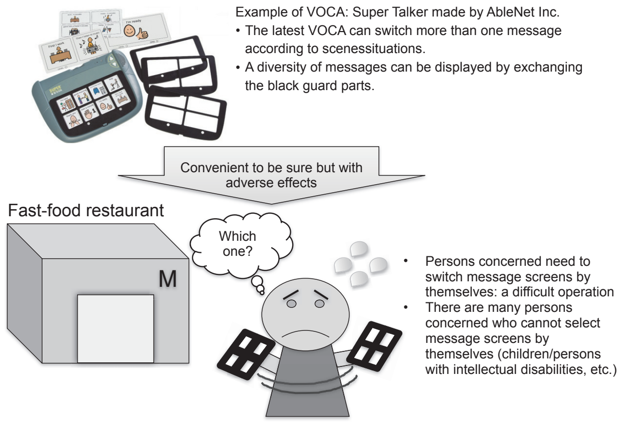

Fig. 1. Problem with current VOCA.

1.2. Issues and Purpose of This Study

The author [5] has used the global positioning system (GPS) function and clock function in constructing the above-mentioned technology of extracting VOCA interfaces according to situations and automatically displaying them.

Selections of VOCA interfaces according to situations can be made by specifying necessary VOCA interfaces by first recognizing the facilities (e.g., fast-food restaurant, school, etc.) users are going to use from user's positional information and then combining it with time information. They have thus developed a VOCA application (App) that possesses the functions of automatically displaying message screens according to situations by linking the user's positional information as acquired with the GPS function installed on a portable information device (e.g., iPad, iPhone, etc.) with the positional information database where message information is stored that will become necessary at certain locations (public facilities such a school or a station, at home, etc.) that users visit (**Fig. 2**).

Specifically: (1) start the App on a portable informa-

1. As a classification of the daily living technical aid system, mainly intended for children/persons with speech disabilities, this represents a portable conversation assistance device that augments or substitutes their communication by recorded voices, etc.
2. The daily living technical aid system, a welfare system for the disabled, aims to enhance welfare by providing or lending tools to the disabled to assist them in their daily life.

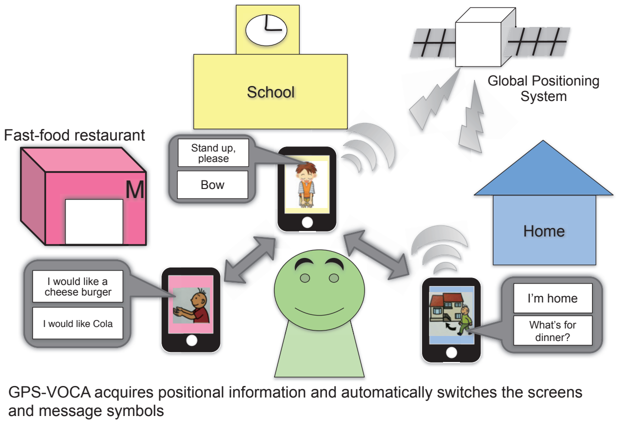

Fig. 2. Schematic diagram of GPS-VOCA [5].

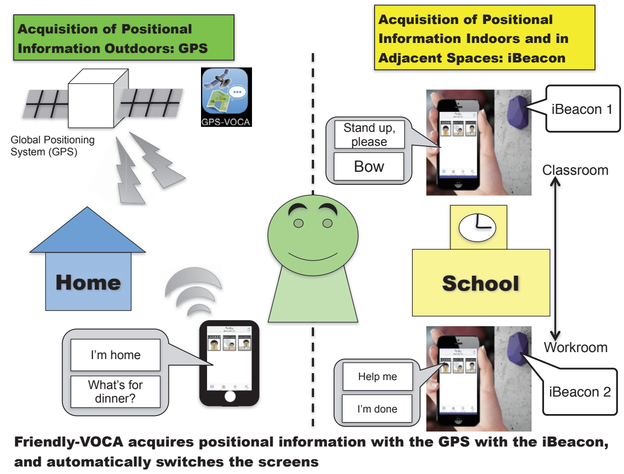

Fig. 3. Schematic diagram of Friendly VOCA.

tion device and install a marker on the locations children/persons with speech disabilities are going to visit on Google Maps; (2) register VOCA interfaces to display the messages (icons to distinguish from registered voices) users could use at such locations; (3) set an area (a radius from the marker) to display VOCA interfaces around the marker because there could be some errors in user's positional information as acquired with the GPS function; (4) carrying a portable information device where the App is started, users approach the locations where the marker is installed; (5) when users reach the set area and their positional information is updated, registered VOCA interfaces are displayed; (6) users select from the displayed VOCA interface messages those they want to use (tap the icons) and reproduce registered voices, thus accomplishing communication with other people.

The author has asked supporters of disabled children/persons (teachers, facility staff members, etc.) to conduct trials with the developed GPS-VOCA. The monitoring trials have revealed that it can acquire accurate GPS information in its outdoor use but errors as large as several tens of meters occur in indoor use. In particular, when a marker is installed in more than one room of a school or a welfare facility and VOCA interfaces to be used in each room are registered in the GPS-VOCA, its use has displayed VOCA interfaces for different rooms or no VOCA interfaces because it has failed to capture the registered marker. When using the system indoors, therefore, the radius from a marker would need to be set impractically as large as 50–200 m. This is why different VOCA interfaces were displayed in adjacent rooms, failing to support disabled children/persons in communication. Positional information acquired with the GPS function has failed to display specific VOCA interfaces to be used at the locations on different floors even if they might two-dimensionally represent the same location.

To solve the above-mentioned problem, in indoor use the method to acquire positional information needs to be improved. We have investigated the positional information acquisition technology iBeacon [6–8] that uses the near-field radio communication technology "Bluetooth Low Energy."

iBeacon is a standard function installed on Apple's iOS 7 and later models [6]. The positions of mobile telephones and other such devices with Bluetooth functions can be measured and specified by installing iBeacon signal transmitters inside a school, a store, or other facilities. However, the iBeacon is only usable when individual identification numbers transmitted by the iBeacon (UUIDs) are first registered in the developed App so that it can identify the UUIDs when it receives any radio signals transmitted by individual iBeacon transmitters.

For the developed GPS-VOCA to identify iBeacon and process individual UUIDs as positional information, the method using the GPS functions to display the VOCA interfaces that correspond to the registered markers (the GPS system) and the method for identifying the UUIDs of the iBeacon and displaying linked VOCA interfaces only if identified UUIDs correspond with the registered ones (the iBeacon system) need to coexist inside the App. We have invented a method for allowing both methods to coexist: the iBeacon system, where iBeacon signal transmitters are installed in the rooms and other locations to be used by users to identify their UUIDs and switch VOCA interfaces, is mainly used indoors; the GPS system is only used indoors if there are no iBeacon signal transmitters installed or with no registered iBeacon (**Fig. 3**).

Using the developed GPS-VOCA as a basic technology, this study aims to: (1) develop an App to display VOCA interfaces according to the situations (locations and time) to be used by users both outdoors and indoors by making the GPS system and the iBeacon system coexist (what we call Friendly VOCA[3]); (2) define the ratios of preregistered VOCA interfaces displayed (correct answer rates of displayed VOCA interfaces that correspond to user's or supporter's intentions).

3. The App we have developed, aimed at achieving the goal that users can communicate with other people with as few operations involved as possible, is a VOCA that should be much easier for users to learn and operate than conventional systems, hence we call it "Friendly VOCA."

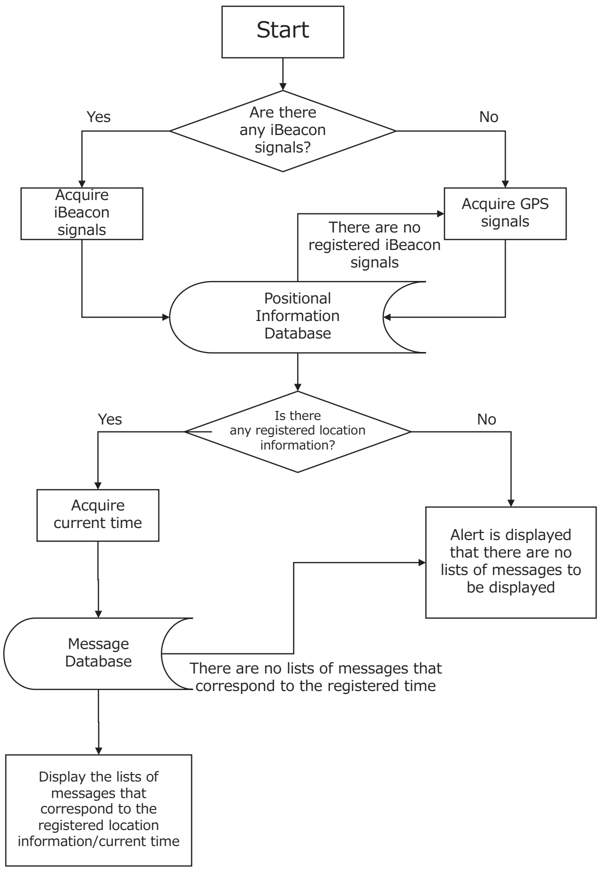

Fig. 4. Flow chart of Friendly VOCA.

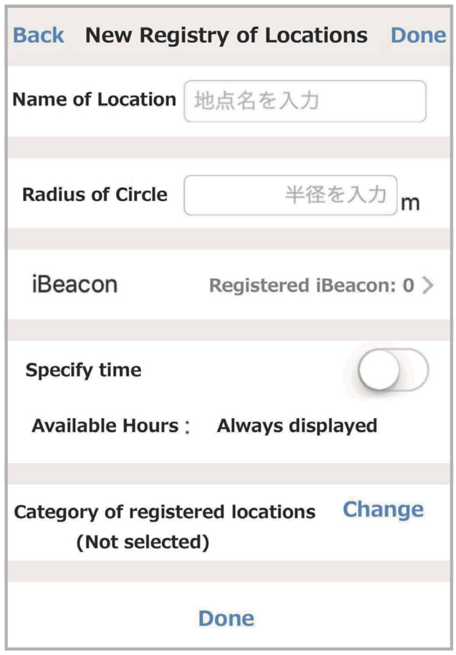

Fig. 5. Setting interfaces of GPS, iBeacon, and time.

2. Development Research

2.1. Purpose

We have learned from the previous research [5] that locations can be better specified by the GPS system outdoors (where iBeacon signals cannot be received) and by the iBeacon system indoors (where iBeacon signals can be received.) We have developed an App based on the flow chart shown in **Fig. 4**.

2.2. Method and Procedures

We have developed Friendly VOCA based on Apple's iOS-installed portable information devices (iPhone and iPad). The OS version of the portable information device at the time of development is iOS 8–9 and we have used Apple's X code (Version 6.1–6.3) as the application development environment.

2.3. Results and Consideration

The GPS system's functions to acquire and register positional information and the VOCA functions are based on our developed GPS-VOCA. The VOCA functions are of the type that one to nine button screens are arranged for each VOCA message so that messages can be recorded and reproduced by pressing down appropriate buttons. This method is similar to the VOCA interfaces adopted by commercially available VOCA App's (Drop Talk, etc.). In this study, we have added the functions to acquire and register positional information using the iBeacon system (functions to register UUIDs as positional information; see **Fig. 5**).

The developed Friendly VOCA, when started, presents a screen to acquire information from both GPS and iBeacon. As the homes of users (children/persons with speech disabilities) and the facilities they use are greatly diverse, it has no positional information or voice messages registered in the initial state and a message that "it has failed in acquiring GPS/iBeacon" is displayed.

Users and their supporters tap "settings" in the menu to present the "settings menu" screen, where they can input the category of the facility, register information acquired by the GPS system (installation of markers on Google Maps) and by the iBeacon system (registry of UUIDs of individual iBeacon signal transmitters), and register VOCA interfaces (recording of voices to be reproduced and registry of icons for discrimination).

When locations to be used are searched or registered on Google Maps as information acquired by the GPS system, they are linked with Google Maps so that the present location can be displayed and positional information can be specified by searching the locations by their names, addresses, etc. To efficiently match GPS information with registered message information, users can freely set a specified radius from a marker that should be regarded as the same location. The radius of the area displayed on Google Maps reflects such set values.

The iBeacon information can be used as positional information by registering an individual UUID for each iBeacon signal transmitter and installing such a registered iBeacon signal transmitter in a specific location (room, etc.). When users receive signals from registered iBeacon signal transmitters, the stored database is searched for whether the received UUIDs are registered and whether there are any corresponding VOCA interfaces if the received UUIDs are registered. Using the above-mentioned processes, when users approach a specific iBeacon signal transmitter, its corresponding VOCA interface is displayed so that users can communicate according to the situation. In this study, we have used MB004-AC [8] made by Aplix Inc., which had already obtained the certification of conformance to technical standards at the time of our development, as the iBeacon signal transmitters for the development and evaluation experiments.

As for the VOCA functions, users (children/persons with speech disabilities) and their supporting adults (supporters) newly register or edit messages using the "add/edit messages" menu. In addition to letters, pictures and symbols can also be registered so that children/persons with speech disabilities can easily select messages.

We assume that the settings to register locations, messages, etc., would be set by supporters of children/persons with speech disabilities, so that when children/persons with speech disabilities use the Friendly VOCA, it could present from among such preregistered VOCA interfaces only candidate VOCA interfaces that are most likely to be used by them based on the GPS information, iBeacon information, and time (**Fig. 5**). Children/persons with speech disabilities can display messages by merely selecting messages they want to transmit from among the presented lists.

For example, **Fig. 6** shows one of VOCA interfaces displayed at dinner time at home. It displays a minimum list of messages to be used by users to facilitate their selections of messages and to ensure their smooth communication.

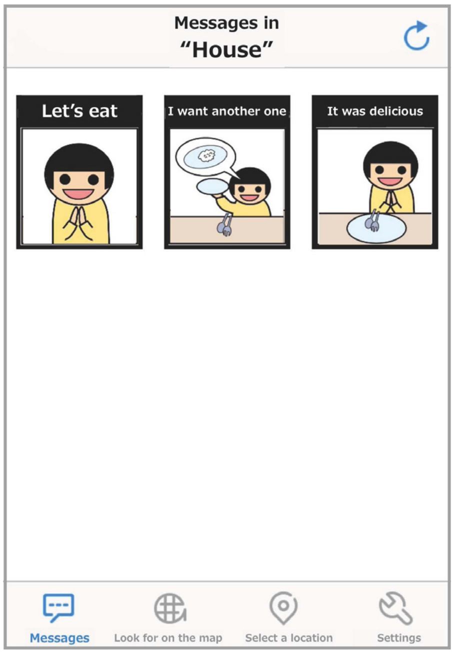

Fig. 6. Interfaces of VOCA interfaces.

3. Research Task 1: Experimental Evaluation of the GPS System

3.1. Purpose

The purpose of this research task is to experimentally verify whether the GPS system installed on the Friendly VOCA selects and displays the VOCA interfaces that correspond to the current locations and time and to review its feasibility based on its correct answer rates.

3.2. Method

We use Apple's iPhone 6 (Softbank's portable telephone line) as an experimental device. As of September 2016, which is when we conducted the evaluation experiments, the latest iOS version was 9.3.5.

We have registered 15 locations and VOCA interfaces to be displayed at these locations in the Friendly VOCA installed on the above-mentioned experimental device. In Research Task 1, to verify whether the Friendly VOCA can acquire information on positions and time with its GPS system during outdoor use and can select and display VOCA interfaces that correspond to the acquired information, we have installed a marker at the door of a building and have registered the area circling the marker and the time when VOCA interfaces are displayed. As adjacent buildings are the subjects of the experiments, we have decided to make the radius of an area 30 m so that areas of locations do not overlap.

Experimenters carrying an experimental device randomly walked from one location to another and reloaded the location information at the time when they arrive at the door of a registered building. After the location information is reloaded, they measured the number of times corresponding VOCA interfaces have been displayed. They repeated the measurements ten times within the set time and ten times after the set time at each of the 15 registered locations.

3.3. Results and Consideration

The total number of measurements is 150 within the set time and 150 beyond the set time. Erroneous VOCA interfaces have been displayed in none of the 150 measurements within the set time: the GPS system installed on the Friendly VOCA has functioned correctly 100% of the time in selecting and displaying VOCA interfaces that correspond to the registered situations (locations and time).

The GPS-VOCA we developed earlier also demonstrated errors as small as a few meters in selecting and displaying VOCA interfaces by the GPS system used outdoors. Those experimental results seem to suggest that in outdoor use the GPS system installed on the Friendly VOCA has demonstrated sufficiently practical correct answer rates in selecting and displaying VOCA interfaces.

Since we have used only one kind of experimental device and mobile phone in this study, it will be crucial to verify it using multiple OS versions, devices, and mobile phones and check whether it still demonstrates high correct answer rates.

4. Research Task 2: Experimental Evaluation of the iBeacon System

4.1. Purpose

The purpose of Research Task 2 is to experimentally verify whether the Friendly VOCA can acquire the UUIDs of iBeacon and select and display VOCA interfaces that correspond to user's position information and to review its feasibility based on the correct answer rates.

4.2. Preliminary Experiment 1

To study how to install iBeacon signal transmitters, prior to the experiments involving participants we have checked the reception of signals from iBeacon signal transmitters in an environment with no obstacles. We have installed an iBeacon signal transmitter at the one end of a straight-line corridor (50 m) in the university's reinforced concrete building and have searched for the locations where no signals are received by moving the same iPhone as used in Research Task 1 (experimental device) away from the installed iBeacon signal transmitter at intervals of 1 m at a height of 1.5 m. We have measured the reception of signals five times at each distance. We have turned off the iBeacon signal transmitter at each measurement to check that the Friendly VOCA has received no location information before turning it on again for the following measurement.

The results of the preliminary experiment show that signals from the iBeacon signal transmitter have been received at the other end of the straight-line corridor 50 m away from the iBeacon signal transmitter in all five measurements. This proves that the iBeacon signal transmitter used in the experiment can transmit signals as far as 50 m or more under obstacle-free conditions.

4.3. Preliminary Experiment 2

To study how to install iBeacon signal transmitters for children/persons with speech disabilities to use the Friendly VOCA, we have checked the reception of signals in the environment where some obstacles are present. We have conducted the experiment in the same building and corridor as used in Preliminary Experiment 1. In Preliminary Experiment 2, however, we have installed an iBeacon signal transmitter outside the concrete wall; there is an aluminum sash sliding door (with glass windows). Under such experimental conditions, we have searched for locations where no signals from the installed iBeacon signal transmitter are received by moving the iPhone as an experimental device away from the iBeacon signal transmitter at intervals of 1 m at a height of 1.5 m using the same procedure as in Preliminary Experiment 1. We have measured the reception of signals five times at each distance.

The experimental results show that signals have been received in all five measurements at the location 3 m away from the iBeacon signal transmitter; no signals have been received in any of the five measurements at the location 4 m away from the iBeacon transmitter. This seems to suggest that the signals transmitted by the iBeacon signal transmitter used in the experiment can be received at a range of 3–4 m where concrete walls are present.

4.4. Method and Procedures

We have used an Apple iPad mini 4 (WiFi only, with Bluetooth 4.2) with iOS version 9.3.5 as an experimental device. We have used 13 units of Aplix-made beacons for general application (My Beacon MB004AC) as iBeacon signal transmitters. The specifications of the experimental device specify Bluetooth 4.1 and measured power -61 dBm.

The iPad mini 4 as an experimental device is installed with the Friendly VOCA, in which the UUIDSs of all 10 iBeacon signal transmitters are registered. In addition, VOCA interfaces are registered to be displayed corresponding to the UUIDs (messages and corresponding voices).

We have installed experimental iBeacon signal transmitters in 13 lecture rooms of the university. The 13 lecture rooms are located in three different buildings: seven lecture rooms in Building A (one on the first floor, three on the second floor, two on the third floor, one on the fourth floor), five lecture rooms in Building B (three on the first floor, two on the second floor), and one lecture room in Building C (on the first floor). Based on the results of the preliminary experiment, the iBeacon signal transmitters are installed 4 m or more apart in a straight-line distance on both sides of the concrete wall. The participants, carrying an iPad mini 4 as an experimental device and securing enough distance from each iBeacon signal transmitter, move into specific lecture rooms to load positional information after checking that the Friendly VOCA has not acquired the UUIDs of any iBeacon signal transmitters. They checked whether their experimental device can acquire the UUIDs of the iBeacon signal transmitters installed in the said lecture rooms and display the preregistered VOCA interfaces. They took the measurements five times for each iBeacon signal transmitter.

4.5. Results and Consideration

They have loaded the UUIDs 65 times. VOCA interfaces corresponding to the iBeacon signal transmitters have been displayed 46 times, making the correct answer rate 70.8%.

The correct answer rate of the iBeacon system is lower than that of the GPS system. Erroneous VOCA interfaces are displayed in some trials where the displayed

VOCA interfaces correspond to the iBeacon signal transmitters installed in adjacent lecture rooms on the other side of the concrete wall. On the other hand, their device has never acquired the UUIDs of the iBeacon signal transmitters installed in the lecture rooms of other buildings. This seems to suggest that erroneous displays of VOCA interfaces may be attributable to the distance between iBeacon signal transmitters. As signals from the iBeacon signal transmitters used in the experiments are found receivable at a distance of 50 m if there are no obstacles, if iBeacon signal transmitters are installed in adjacent rooms, the experimental device may acquire signals from other iBeacon signal transmitters due to the room's physical environmental factors and display other VOCA interfaces than those of the intended rooms. In the future, we will review the algorithms for the iBeacon system of the Friendly VOCA as well as various problems with the iBeacon signal transmitters, such as adjustments of signal intensities transmitted by iBeacon signal transmitters and installations of iBeacon signal transmitters at locations and distances where they do not interfere with each other.

5. Future Issues and Views

Friendly VOCA is now at the point where its development and evaluation experiments have been completed as described in this paper and we could technically transfer it for marketization. Its merchantability, however, will require some modifications such as improvements in its general user interface and usability. In previous research and development, we asked children/persons with speech disabilities to evaluate our developed devices, and so we plan to invite children/persons with speech disabilities as research cooperators for further evaluation in the future.

In particular, VOCA interface switching functions using the iBeacon system crucially need to be adjusted or improved in both the App and iBeacon signal transmitters. As the use of iBeacon devices without a certification of conformance to technical standards could violate the Japanese Radio Wave Law and related laws, in this study we have used Aplix-made devices that have already obtained a certification of conformance to technical standards as iBeacon signal transmitters. At the point when the development of Friendly VOCA was completed, the iOS specifications were such that the iOS devices could not receive the UUIDs of iBeacon signal transmitters and display the lists of messages from which to select and register desired ones, and so end users had to input 16 bytes of UUIDs by themselves. In the future, we will select iBeacon signal transmitters that can facilitate the registry of UUIDs and use iBeacon information and make further improvements to the App itself.

Acknowledgements

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Main Works:

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- The Japanese Association of Special Education
- The Japanese Psychological Association