HUMAN-COMPUTER INTERFACE SYSTEM USING ORAL FUNCTIONS

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Abstract: We developed two kinds of interfaces having two independent inputs based on mandibular movement for position control, and a 'press-type' switch input operated by tongue movements. The main components of both interfaces are an acryl board, a slide-type potentiometer, and a 'press-type' switch. In type I, the interface is fixed between the upper and lower lips. In type II, a mouth piece is used and fixed to the upper jaw. Using these interfaces, we developed a PC-based Japanese language input system. The user follows operating instructions shown on the PC display to use this interface. The display consists of a two dimensional matrix showing the elements of the 50 syllables of the Japanese language and elements of a variety of signs. Operation involves the user looking at character patterns displayed on the PC screen and selecting elements from the two dimensional matrix by making a 'biting' movement. The final selection of a character element is made by pushing a switch with the tip of the tongue. Four subjects carried out the input experiments over a period of fourteen days. Results indicated that the time required to input a single syllable was between 3 and 4 seconds.

Introduction

Conventional computer input systems make extensive use of keyboards, the mouse and track balls. Furthermore, more recently, 'tablet' based input systems are becoming increasingly popular for multimedia applications as intuitive and direct human-machine interfaces. However, these aforementioned methods have severe limitations in cases where upper limbs cannot be used due to paralysis or injury. In order to solve such problems, input systems using the remaining moving parts of the body have been proposed. For example, there have been studies on the development of input systems employing eye, tongue, jaw and lip movements as part of an active daily life (ADL) for people suffering from cervical spinal injuries.

In this research, we focused on oral functions, and developed a human interface combining mandibular and tongue movements. The mandibular and tongue movements are known to be highly coordinated during short utterances, mastication and swallowing[1]-[7]. In particular, there are several examples on the use of tongue movements for the control and operation of electric wheel chairs[8] and other forms of equipment[9]. It is thought that it should be possible to construct an interface based on such movements.

In this paper, we describe the structure and operational principles of two kinds of interfaces having two independent inputs based on mandibular movement for position control, and a 'press-type' switch input operated by tongue movements. Further, we developed a Japanese language input system based on this interface platform that was tested over a period of 14 days. Our results showed that these interfaces are an effective means of constructing a human-computer interface for the aforementioned applications.

Structure and operating method of interface employing oral functions

Two kinds of interfaces were developed in this research. The main components of the interfaces are an acryl board, a slide-type potentiometer and a 'press-type' switch. Fig. 1 is a schematic illustration of the concept and components of the interfaces. Two input channels are employed in these interfaces, where 1) the mandibular movements are used to move the slide of the potentiometer, and 2) the tongue is used to press the switch. In type I, the interface is fixed between the upper and lower lips. In type II, a mouth piece made from an ethylene vinyl acetate copolymer resin (EVA resin) is used and fixed to the upper jaw. The mouthpiece is thermally molded to precisely fit the user's oral cavity. A stainless steel spring with a spring constant of 0.151N/mm and initial tension of 0.471N is attached to the sliding part of the potentiometer, which returns to its initial state (position zero) in the absence of an external force. The sliding part of the potentiometer has a maximum stoke length of 13mm. The switch operates when an external force of 1.27N is applied. It should be noted that when the mouthpiece was placed into the oral cavity, it was covered with a 0.05 mm thick polyethylene sheet for waterproofing and to prevent short circuits.

Both interfaces were fitted to a 23-year-old male, a 22-year-old male, and a 22-year-old female. In answer to questions about the interfaces, all the subjects stated that the equipment did not move during use and that it was possible to attain stable operation. Further, the subjects also confirmed that the inside of the mouth did not become dry with either interface.

 ISSN: 1727-1983

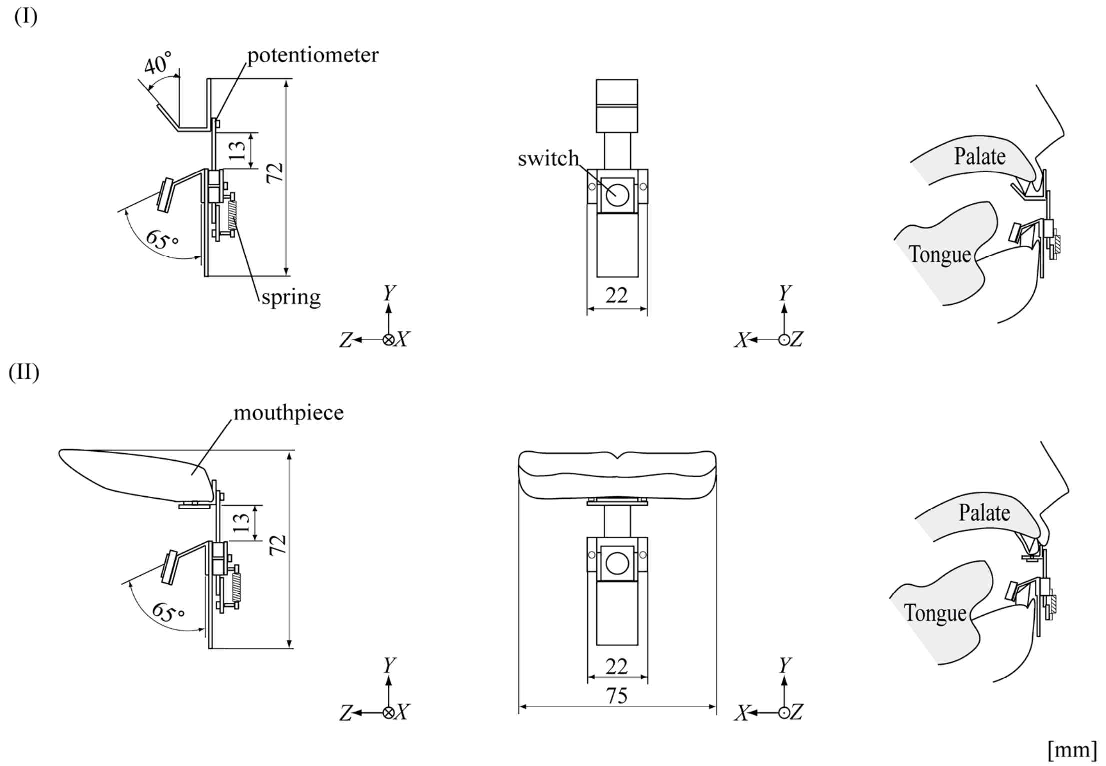

Figure 1: Schematic Illustration of Two Types of Interfaces using Oral Functions

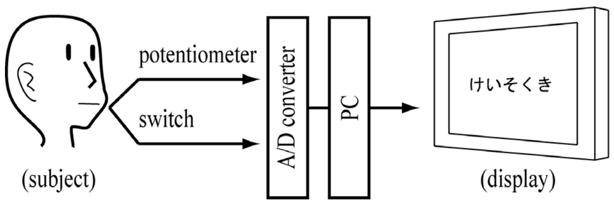

Figure 2: Main Components of the Japanese Language Input System

Japanese language input system

Using these interfaces, we developed a personal computer (PC) based Japanese language input system as schematically shown in Fig.2. The mandibular and tongue movement input signals were digitized and inputted into a PC. The A/D conversion condition was 12bit - 100Hz. The user follows operating instructions shown on the PC display to use this interface.

The operation display is shown in Fig.3. The display consists of a two dimensional matrix showing the elements of the 50 syllables of the Japanese language and elements of a variety of signs. The user first selects an element of the y-axis via mandibular movements then uses the switch to make the final choice of element. After this, mandibular movements are once again used to select an x-axis element followed by the press-switch to confirm the final choice. By applying a force to the sliding part, the selection element moves in the directions of the arrows that are shown in the diagram. The user can visually confirm which element has been selected by looking at the appropriate flashing pilot lamps. A character can be deleted by pressing the switch when the state of the potentiometer is at position 'zero'.

Methodology of input experiment

In order to evaluate the effectiveness of the Japanese language input system developed in this study, we carried out an experiment identical to the actual input operation. That is, the time taken for the subjects to complete the input of five sounds chosen from the collection of problem letters/words was measured and the signals due to mandibular and tongue inputs and press switch inputs were recorded. The subjects were a 24-year-old male (Subject 1), a 23-year-old male (Subject 2), a 22-year-old female and a 22-year-male (Subjects 3 and 4) none of whom had a history of medical treatment of the oral functions. Three experiments were conducted per day over a period of 14 days. The problem letters/words were selected randomly from the following list.

(a) /ko/n/ni/chi/ha/
(b) /sa/yo/u/na/ra/
(c) /ke/i/so/ku/ki/
(d) /o/ha/yo/u/./
(e) /ma/ta/a/shi/ta/
(f) /o/i/shi/i/./
(g) /ni/ho/n/ko/ku/
(h) /a/i/shi/te/ru/

The procedure for the first experiment was as follows:

1) The subject was given oral instructions about the functions of the input system.
2) The problem letters/words were presented to the subject.
3) The subject was asked to fit the interface (type I) into his/her mouth.
4) Signal recording was initiated at the same time the subject was told to start the experiment.
5) The recording was stopped after checking the end of the input.
6) The subject was asked to fit the interface (type II) into his/her mouth.
7) Signal recording was initiated at the same time the subject was told to start the experiment.
8) The recording was stopped after checking the end of the input.

In cases when an erroneous input was made, the subject was instructed to make the appropriate corrections. The subject was not told about the problem letters/words, and was not allowed to practice beforehand.

Experimental results

Fig. 4 shows the results for the input time of the subjects. Repetition of the experiments was found to slightly reduce input time. The time required to input a single syllable was found to be between 3 and 4 seconds. In the case of Subject 4, the overall input time was fastest for the type II interface. A possible reason for this observation is thought to be that long-term, stable operation was possible because of the good adhesion of the mouthpiece inside the oral cavity. The other subjects also stated that the type II interface fit well inside the oral cavity.

Fig. 5 shows the record of the input signals from the mandibular movements and press-type switch. The problem letters/words was /ke/i/so/ku/ki/. It was observed that Subject 3 frequently used mandibular movements to select elements. However, Subject 4 was found to be very careful about selecting target elements.

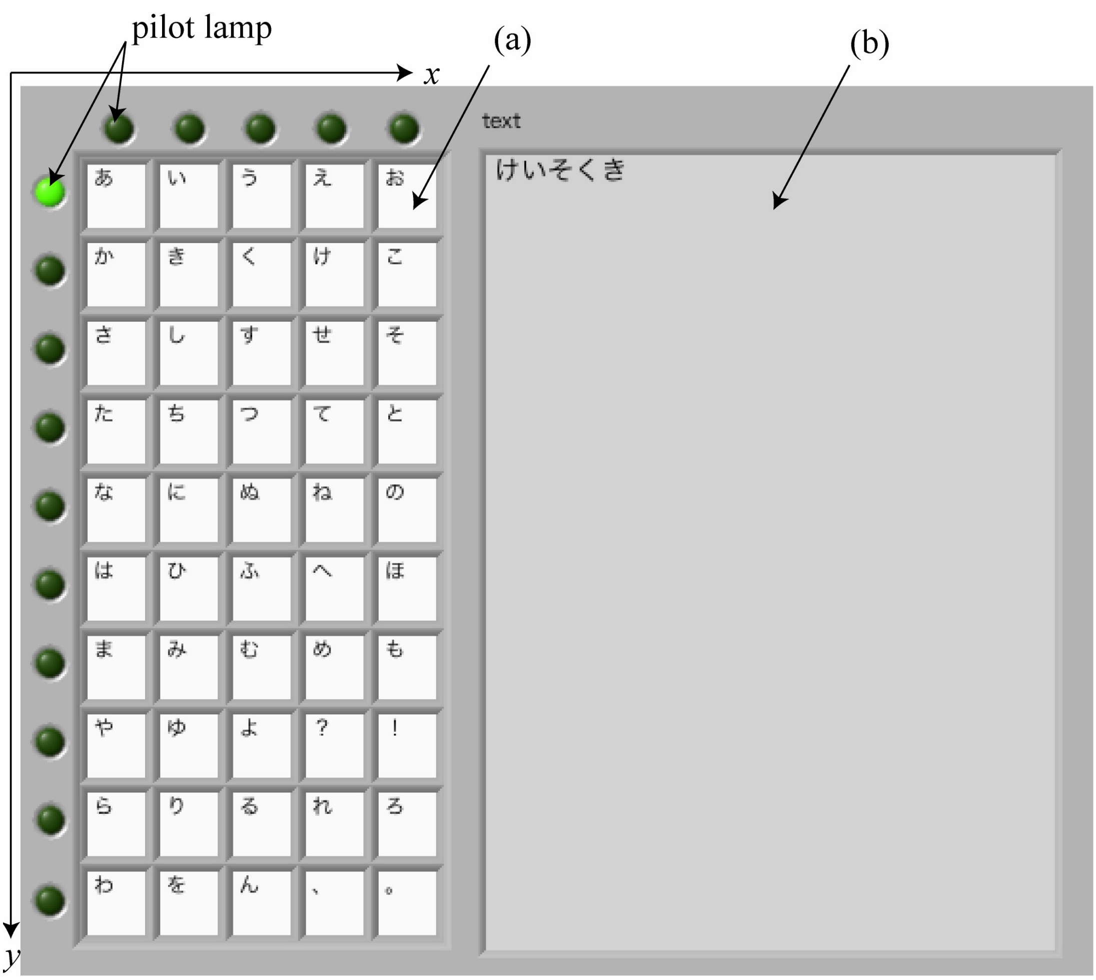

Figure 3: Operation Display of the Japanese Language Input System

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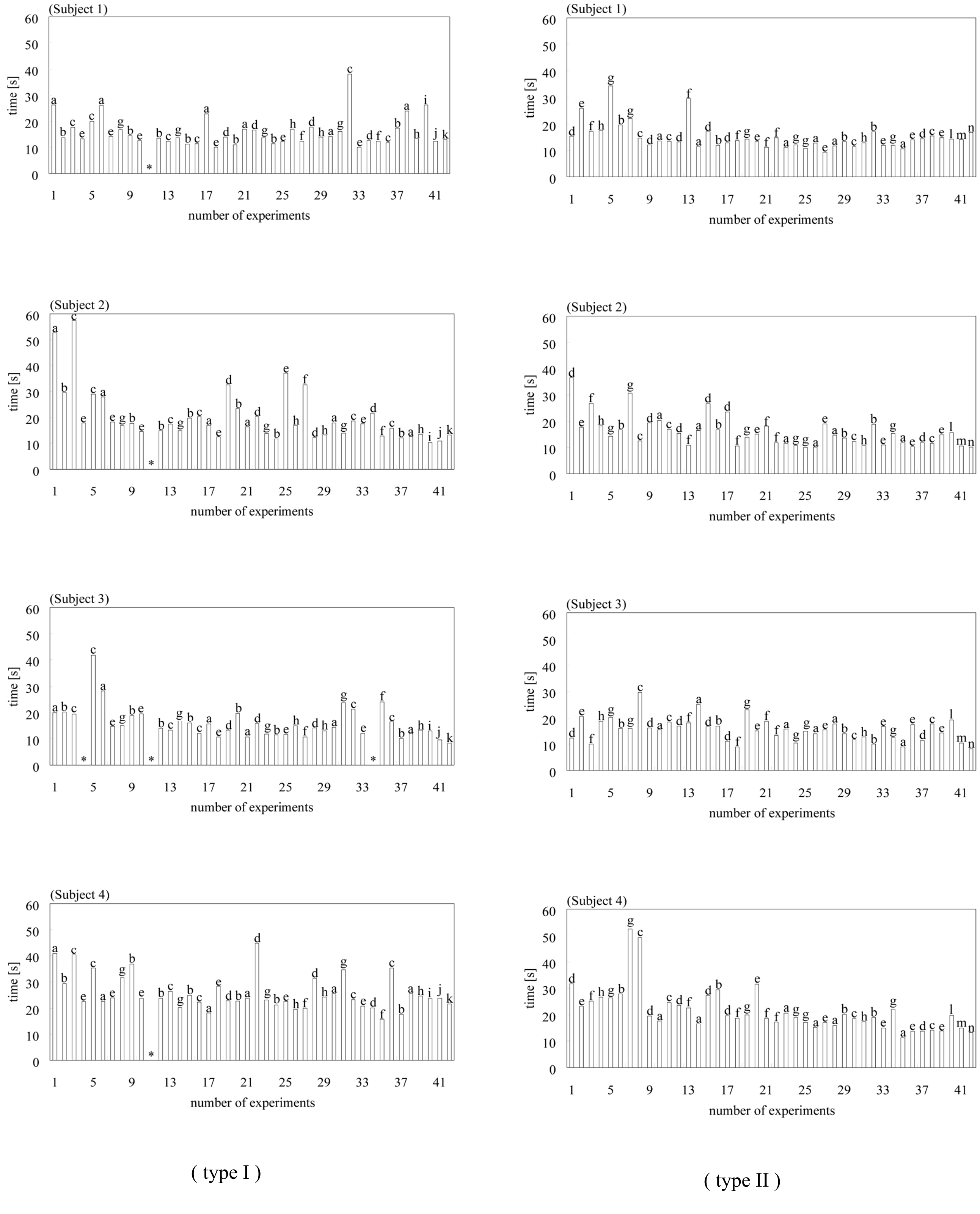

Figure 4: Time Required for Input (*: Failure of Measurement)

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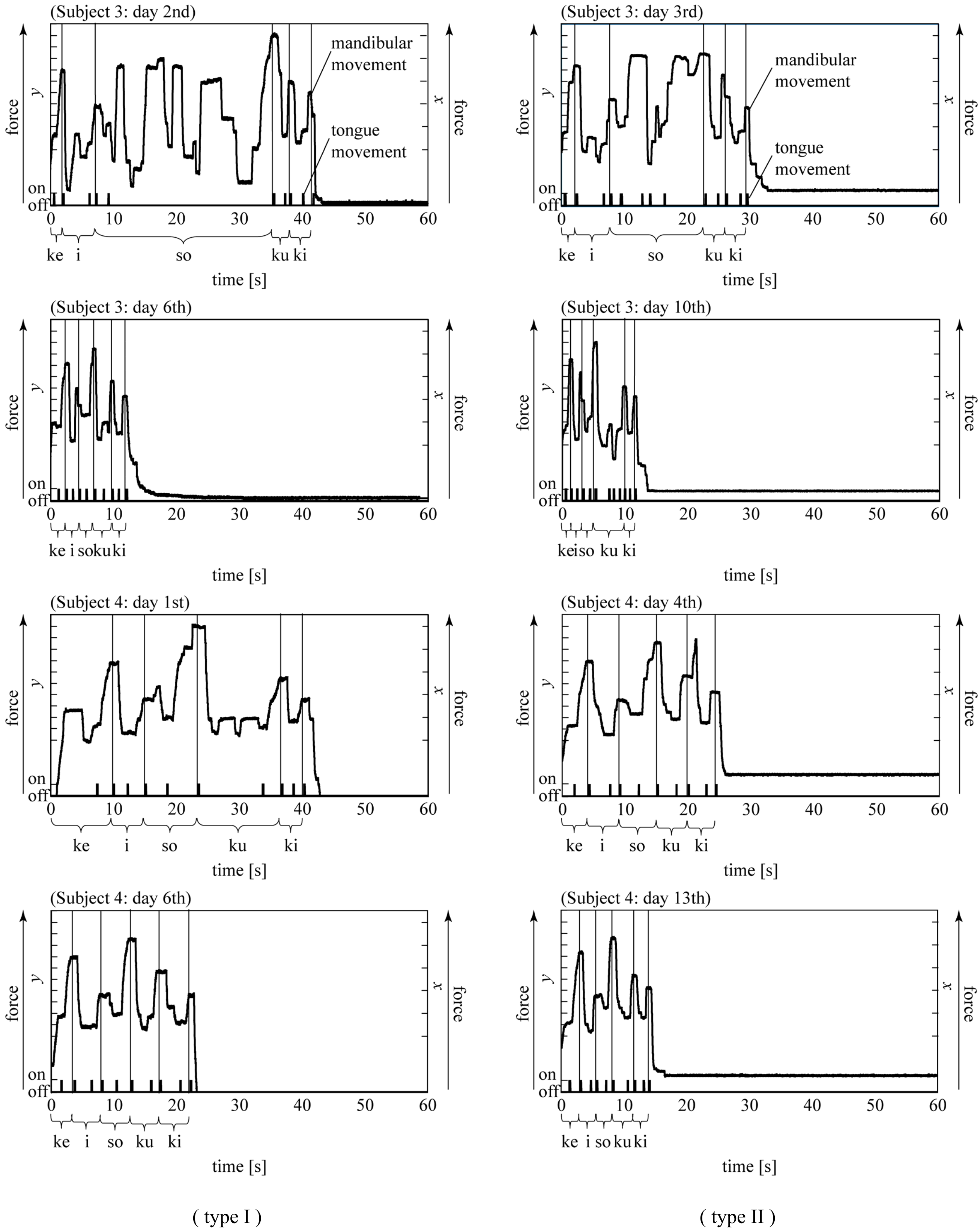

Figure 5: Recordings of Input Signals

These results are speculated to be due to differences in the ability of a particular subject to learn and progress. Further studies are required to quantify the results.

Summary

In this research, we used oral functions for the development of a human-computer interface which was used to construct a Japanese language input system. Experimental results showed that the time required to input one syllable was less than 5 seconds. This result is similar to that of conventional eye-gaze input methods[10], and shows the effectiveness of our new system. It is possible to use this system for English as well as other languages.

Acknowledgments

This research was partly supported by the Ministry of Education, Culture, Sports, Science and Technology in Japan under the Grant-in-Aid Scientific Research No.17700465.

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ISSN: 1727-1983