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Transfer Information Enhancement with a 2-D Tactile Stimulator Array for Acoustic Vision Substitute System

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***Abstract*—Existing vision substitute systems provide insufficient information as a navigation system. To present spatial information in detail, we propose a stimulation method for transfer information enhancement by using a 2-D tactile stimulator array. Stimulators are divided into several groups. Since each stimulator group is activated alternately, the interval of stimulators can be shortened to less than the two-point discrimination threshold. In the case that stimulators are divided into two and four groups, the number of stimulators increase to twice and four times of that in the case of the two-point discrimination threshold. We examine and confirm this method experimentally.**

I. Introduction

MANY researchers have investigated into human machine information transfer method through tactile excitation. Especially, 2-D stimulator array is often used for vision substitute system [1-4]. Previous works have directed to convert visual image to vibrotactile or electrotactile excitation. Since excitation intensity does not correspond to the range of target in these methods, it is difficult to use them in the condition of existing plural targets with different ranges.

We have proposed an acoustic vision substitute system based on a hybrid array-reflector configuration which realizes high time and spatial resolutions with modest computational load [5]. Fig. 1 shows the schematic view of the vision substitute system. In this system a broad transmit beam is radiated over the entire measuring area. The reflected echo is first focused by a concave reflector, and then received by the 2-D sensor array. Images are reconstructed from widely distributed signal received on the array by using numerical back projection.

We suppose that the spatial information, measured by the acoustic sensor, are presented by the stimulation device put on the forehead. In this method the forward direction of the face corresponds to the center direction of the measurement area. Therefore it is easy for late totally blind to be accustomed to this system. For the purpose that each stimulator transfers different information individually, stimulators of the array are spaced at an interval of two-point discrimination threshold. This restricts the number of stimulators which transfer information through a certain area. In this paper we propose a method to increase transfer information. This method employs a 2-D stimulator array whose stimulators are spaced at an interval of less than the length of simultaneous two-point discrimination threshold to increase the number of stimulators. Since two stimulators adjoined by each other work with a certain stimulus onset asynchrony, they can transfer different information individually. We investigate this method experimentally, and confirm its effectiveness.

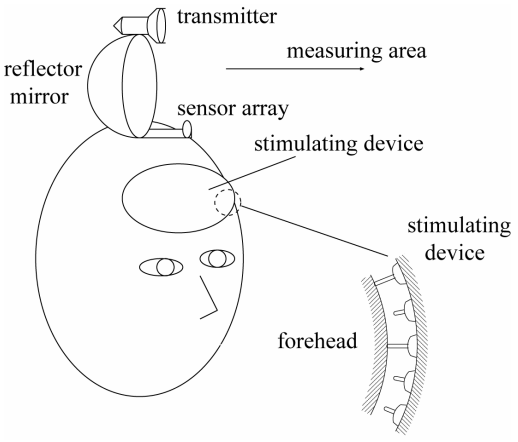

Fig. 1. Schematic view of the acoustic vision substitute system.

II. Methods

A. Alternating stimulation method

This system uses a 2-D stimulator array as a stimulating device. The stimulator spacing should be more than the two-point discrimination threshold for the purpose that each stimulator transfers difference information by each other to the user. Since this restricts the number of stimulators consisting a 2-D stimulator array, it is difficult to transfer enough information to a user for the vision substitute system. Then we propose the alternating stimulation method to gain transfer information by increasing the number of stimulators. In this method stimulators of a 2-D array are divided into several groups. Fig. 2 shows divide examples of stimulators into two and four groups. Stimulators which belong to a group move synchronously, and each stimulator group is

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activated alternately. Stimulators within a group are spaced at an interval of two-point discrimination threshold. The interval of two stimulators which are adjoined by each other is less than the interval of the two-point discrimination threshold. Since they belong to different groups, there is a stimulus onset asynchrony (SOA) between the two stimulations. In this case two stimulations are perceived individually under the condition that stimulator spacing is about 1/3 of the two-point discrimination threshold [6]. In the case of two examples shown in Fig. 2, the intervals of stimulators adjoined by each other are 0.71 and 0.5 of the two-point discrimination threshold. Therefore if stimulator spacing of the same group is set to the two-point discrimination threshold, stimulations can transfer different information individually. This means that the number of stimulators can be increased to 2 or 4 of a 2-D array spaced at an interval of the two-point discrimination threshold.Then the spatial information presented in this method is improved to 2 or 4 times of that in the previous one.

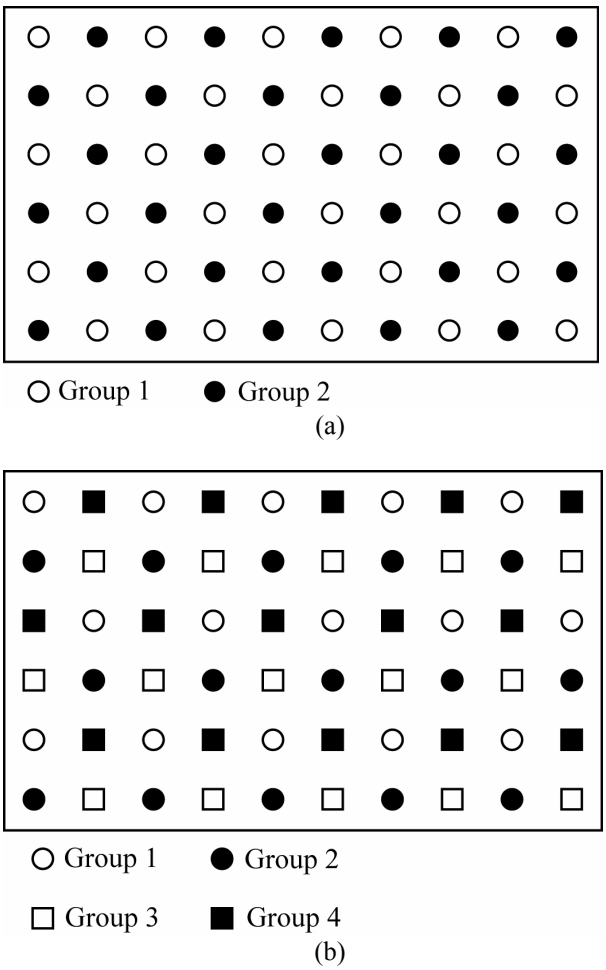

Fig. 2. Division of stimulators which are components of a 2-D array stimulating device put on the forehead. Stimulators are divided into (a) two and (b) four groups. Stimulators which belong to a group move synchronously, and stimulator groups are activated alternately.

B. Overview of the experiment

We examine the alternating stimulation method experimentally by using a 2-D solenoid array consisting of a 2 × 4 arrangement with two dummy solenoids put at the left and right side of the array, as shown in Fig. 3. The stimulator array is put on the forehead because a user can use hands and auditory freely. In the case of employing the simultaneous stimulation method, active stimulators work synchronously. In the case of employing the alternating stimulation method, stimulators of a 2-D array are divided into two groups, as shown in Fig. 4. The left side dummy solenoid belongs to group 1 and the right side one belongs to group 2. Each stimulation group is activated alternately. We compare the perceive stimulus quality of the alternating stimulation to that of simultaneous stimulation.

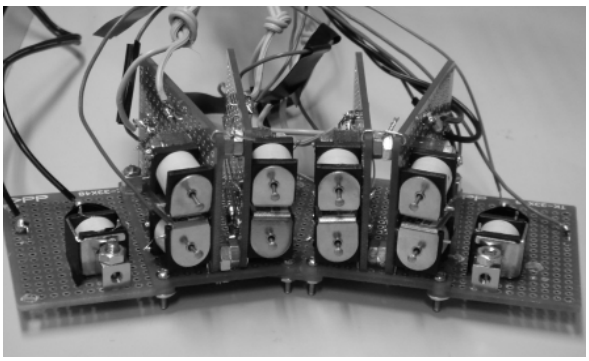

Fig. 3. Solenoid array put on the forehead of participants. 2 × 4 solenoids placed at the center of the array are stimulators. Two solenoids placed at the both sides always generate sound and vibration, to prevent participants to distinguish tactile patterns by sound.

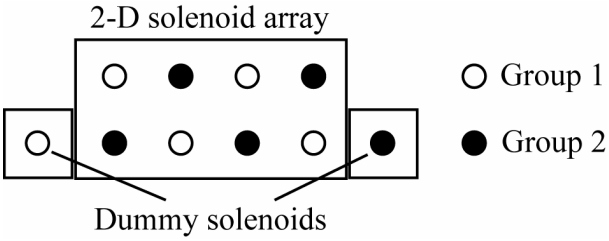

Fig. 4. The arrangement of stimulators divided into two groups in the case of employing the alternating stimulation method.

C. Vibrotactile stimuli

In this study, we use a solenoid array as a stimulating device. Each solenoid has a round-topped vibrating rod, as shown in Fig. 5. The tops are spaced at an interval of 1.3 cm vertically and 1.5 cm horizontally. A participant puts the array on the forehead and replies the tactile pattern presented by the array. Rectangular pulses are delivered to activate solenoids, which contain two dummy solenoids. The voltage delivered to solenoids is 3 V and the pressure of them is 1 to 2.5 gf.

Fig. 6 shows the waveforms used in this experiment. The interval of pulse onsets is 33.3 ms (pulse repetition rate is 30 Hz) and pulse width is half of the interval. The burst onset is separated by 800 ms and each burst contains 6 pulses.

Phantom sensation occurs in a certain condition of SOA, stimulator spacing and stimulation pressure. In this case two stimulators which are adjoined by each other can not transfer different information individually. To prevent phantom sensation, in the alternating stimulation trials we set the SOA and the duration of stimulation as 400 ms and 200 ms, respectively. Furthermore, we set both types of trials have the same power consumption as follows.

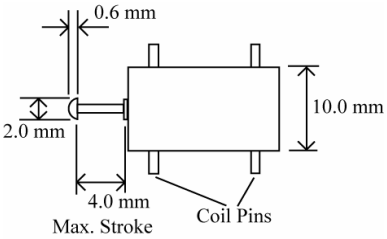

Fig. 5. Schema of a solenoid which is a component of the 2-D stimulator array put on the forehead.

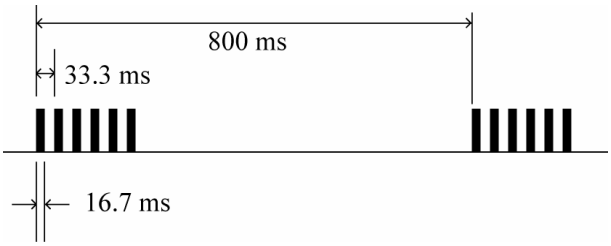

Fig. 6. Stimulus waveform in the simultaneous stimulation trials. Pulse repetition rate is 30 Hz and pulse width is half of the pulse onset interval. Each burst has 6 pulses and burst onset interval is 800 ms.

In the trials of simultaneous stimulation, the waveform of Fig. 6 is delivered to all active solenoids. In order to stimulate Meissner body, each active stimulator receives pulses whose repetition rate is 30 Hz. Tactile patterns used in these trials are 1-point stimulations and 4-point square stimulations, as shown in Fig. 7. The 1-point stimulations are presented at one of the 8 positions. The 4-points stimulations are presented simultaneously at one of the three positions; left, middle, and right. In the trials of alternating stimulation, the waveforms of Fig. 8-(1) and 8-(2) are delivered to active solenoids of group 1 and group 2, respectively. Tactile patterns used in these trials are same as those in the simultaneous trials. Each 4-points square stimulation is presented by two pairs of stimulators which are activated alternately, as shown in Fig. 9.

A presentation time of each pattern is 5 s, which contains 6 bursts of delivered voltage to solenoids. The interval of two presentation time is 5 s, and at that time a participant answers the presented pattern.

D. Participants

Six young, healthy males (22-30 years old) participated in this experiment. Each participant provided informed consent and wiped the forehead before the start of the experiment. All the participants undertook this experiment.

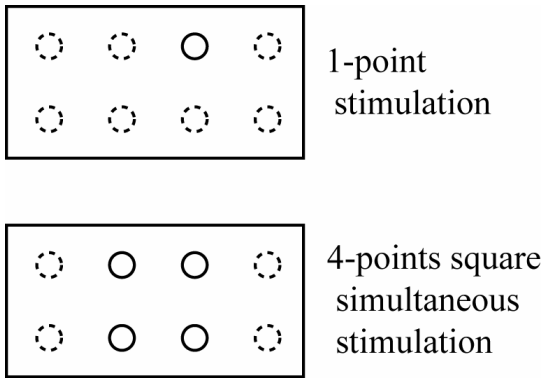

Fig. 7. Tactile patterns in the simultaneous stimulation trials. The 1-point stimulations are presented at one of the 8 positions. The 4-points stimulations are presented simultaneously at one of the three positions; left, middle, and right.

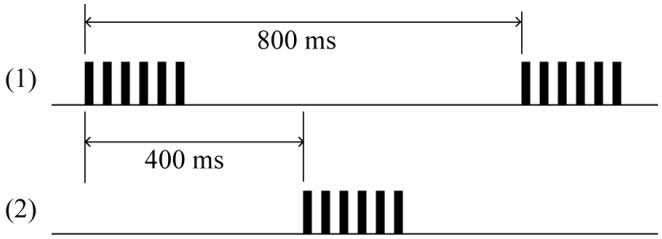

Fig. 8. Stimulus waveform in the alternating stimulation trials. Waveform (1) and (2) are delivered to active solenoids of group1 and 2, respectively. Stimulus onset asynchrony between two groups is 400ms.

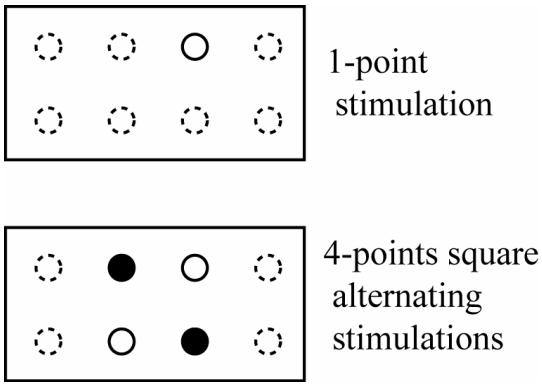

Fig. 9. Tactile patterns in the alternating stimulation trials. The 4-points stimulations consist of two stimulation groups.

E. Main experiment

The experiment consists of two practice trials followed by two experimental trials. Each practice trial consists of 16 1-point stimulations and 6 4-points stimulations. Participants are informed about presented patterns and practice to be accustomed to these trials. The first practice trial employs simultaneous stimulation, and the second trial alternating stimulations. Each experimental trial consists of 12 1-point stimulations and 12 4-points stimulations. The arrangement on the array and the order of these tactile patterns are random.

Participants answer the presented pattern in the experimental trials. First experimental trial employs simultaneous stimulation and second trial two synchronous stimulations, similar to practice trials.

III. Result

Table 1 shows the average and standard deviation of the possibility that answer is correct in the case of tactile pattern being 1-point stimulation. This result proves reproductivity of this experiment.

To revise the possibility that the answer is correct in the case of tactile pattern being 4-points square stimulation, we deal with this result statistically as follows. The reason that 1-point stimulation is not perceived is mainly bad contact between a stimulator and the forehead. To allow this possibility we estimate the number that 4-points square stimulation becomes 1-poit stimulation because of bad contact between stimulators and the forehead. After this revision, we calculate the possibility that the answer is correct in the case of tactile pattern being 4-point square stimulation, as shown in Table 2.

This result shows the effectiveness of the proposed alternating stimulation method for transfer information enhancement with $p < 0.05$. We introduce the assumption that the possibility follows normal distribution and use t-examination.

TABLE I
AVERAGE AND STANDARD DEVIATION OF THE POSSIBILITY THAT THE ANSWER IS CORRECT IN THE CASE OF TACTILE PATTERN BEING 1-POINT STIMULATION.

	Average	Standard deviation
Simultaneous stimulation	0.843	0.122
Alternating stimulation	0.846	0.134

TABLE II
AVERAGE AND STANDARD DEVIATION OF THE POSSIBILITY THAT THE ANSWER IS CORRECT IN THE CASE OF TACTILE PATTERN BEING 4-POINTS SQUARE STIMULATION.

	Average	Standard deviation
Simultaneous stimulation	0.638	0.136
Alternating stimulation	0.839	0.209

IV. Conclusion

For the stimulating device of the acoustic vision substitute system, we propose an information transfer method by using a 2-D stimulator array. Stimulators are divided into several groups, and each stimulator group is activated alternately. Since two stimulators which are adjoined by each other belong to different groups, there is a certain SOA between these two stimulations. In this case two stimulations are perceived individually under the condition that stimulator spacing is about 1/3 of the two-point discrimination threshold. In the case that stimulators are divided into two and four groups, the intervals of stimulators adjoined by each other are 0.71 and 0.5 of the two-point discrimination threshold, respectively. Therefore if stimulator spacing of the same group is two-point discrimination threshold, stimulations can transfer different information individually. This means that the number of stimulators can be increased to 2 or 4 of a 2-D array spaced at an interval of the two-point discrimination threshold. Then the spatial information presented in this method is improved to 2 or 4 times of that in the previous one. Furthermore we compare the alternate stimulation method to the simultaneous stimulation experimentally, and confirm this method is useful to gain transfer information to a user.

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