Pattern Recognition of Dorsal Mounted Linear Vibrotactile Array

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Abstract— **This paper reports on the findings of a human study assessing the pattern recognition performance when using a dorsal mounted, linear vibrotactile array. These tactile patterns are correlated to three variables: size, speed, and direction. The subjects were trained to identify these vibrotactile responses and then subsequently tested with a series of random sequences. Results from the size, direction and speed experiments reflect that subjects were able to accurately detect the respective variable through the array in 61.5%, 90.5% and 92% of the tests.**

I. INTRODUCTION

According to the American Census survey conducted in 2015, an estimated 7.3 million people in the United States are diagnosed with visual disability [1]. The most common causes of vision loss are due to macular degeneration, glaucoma, detached retina, and diabetic retinopathy [2]. Due to such a large population of individuals affected by such diseases, it is important to have some visual supplements. Most people with severe cases of the aforementioned diseases use the white cane and auditory feedback to get a sense of their surroundings. There are also audio devices that provide information about an individual's surroundings. These devices, however, could still lead to an individual being unaware of the size or speed of an approaching object. Chabot et al. [3] had explored the use of tactile patterns to relay such parameters on the ventral side of the abdomen. This work assesses the pattern recognition performance of subjects using a lumbar mounted linear array varying size, speed, and direction of an active stimulator group. Based upon prior work on the abdomen by Cholewiak [4], it is hypothesized that a dorsal mounted array should have a similar performance to a ventral mounted array. The results, if positive, would emphasize an alternative, potentially less intrusive location for some individuals with tactile communication devices.

II. METHODS

A. *Subjects*

Ten subjects were recruited for the IRB sanctioned human study. Participants were solicited from the university engineering department by email and were not compensated for their time.

B. *Vibrotactile Belt*

A support belt composed of nylon was used in this experiment. Fifteen pockets were sewn on the inner lining to hold each vibrotactile stimulator in place. The stimulators were placed approximately 2.5 cm center to center, which was effective distance for similar patterns as demonstrated by Chabot et al. [3]. All vibrotactile stimulators (Yuesui, B1034.FL45-00- 015), were controlled by a PIC microprocessor (Microchip, PIC18F4520). The training and test array tactile sequences were programmed into the microcontroller.

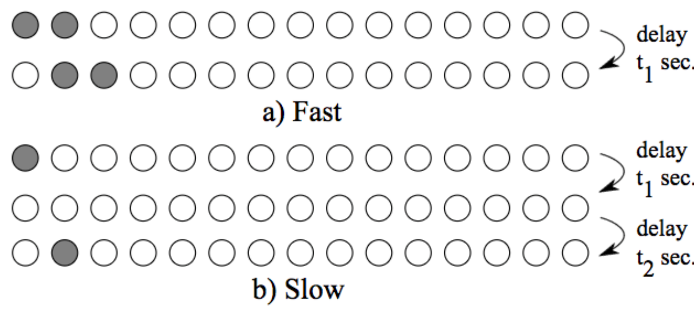

Fig. 1 - Tactile sequences are shown for fast speed (a) and slow speed (b) reflecting two timing parameters: t1 and t2. **Circles represent individual vibrotactile elements. Shaded circles illustrate active elements.** Time t1 denotes the time a stimulator is active, while t2 denotes off-time between patterns

C. *Test Procedure*

The human study was decomposed into three sections: size, direction, and speed testing. Each of the sections was preceded by a training period. Each test involved twenty sequences with a four-second pause after each sequence to allow for responses. The same randomized test sequence was presented to all participants in the same order. For the size variable, every individual was given a small, medium, and then large active stimulator group. Training each subject involved activating these amounts of motors across the right, left, and then middle portion of the belt. Following this training, each subject received the same twenty sets of stimuli with varied location and size. For each of these sequences the individuals were asked by the investigator to report the group size observed. Upon pressing a push button on the electronics, the next training sequence started to present sequences illustrating left and right moving groups. Motors were sequenced on and then back off from right to left (denoted as left moving), and left to right (denoted right moving). The two sequences were repeated once to reinforce the connection between the pattern and desired response. Subjects were asked to provide a response of left or right moving. The final training period focused on the speed parameter. Two speeds were presented: slow and fast moving. Similarly, the responses requested for the test were slow or fast.

A push button was provided to the test conductor to trigger the execution of the next training or test phase. In between segments, the push button was required to progress.

D. *Tactile Patterns*

For the three tests performed, different tactile sequences are presented. The size test reflects a change in the active stimulator group size denoted by small, medium, and large, which corresponds to 1, 2, or 4 stimulators, respectively. The direction test varied moving the active group left or right. The rate of change of this pattern corresponds to the slow sequence in Fig. 1, which defined t1 and t2 as 1 second. Each direction sequence spanned 4 sequential motors. The speed test created a slow or fast moving group (see Fig. 1). The slow delay had each motor turn on for one second and then off for one second before the next started. The fast moving sequence had each motor stay on for two seconds while overlapping the next motor in the sequence.

III. RESULTS

The same ten participants were used for all three tests. The results of each test are presented in confusion matrices Tables 1, 2, and 3 for the size, direction, and speed test, respectively. Additionally, the accuracy of each individual subject is shown in Fig. 2. The mean scores for size, direction, and speed tests are 61.5%, 90.5%, and 92%, respectively. In total, 8 responses were left blank with 6 occurring in the size test and 2 occurring in the direction test.

TABLE 1
Size Test Confusion Matrix

		Responses			Correct %
		Small	Medium	Large	
Answers	Small	48	15	4	68.5
	Medium	12	28	18	46.6
	Large	3	20	47	67.1

TABLE 2
Direction Test Confusion Matrix

		Responses		Correct %
		Left	Right	
Answers	Left	90	10	90
	Right	9	91	91

TABLE 3
Speed Test Confusion Matrix

		Responses		Correct %
		Slow	Fast	
Answers	Slow	95	5	95
	Fast	11	89	89

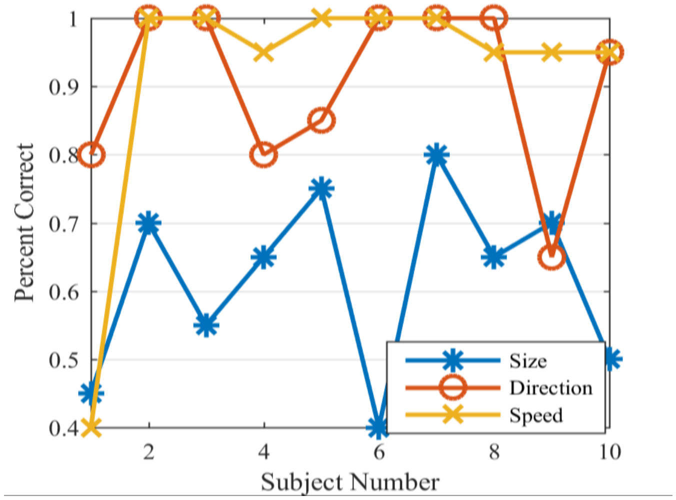

Fig. 2 - Subject Accuracy is shown over all three tests.

IV. DISCUSSION

Vibrotactile arrays provide an inexpensive and low discomfort for use as a tactile communication device. This study reflects a high accuracy in determining patterns, which would be useful in conveying size, speed, and direction. While the size reported by the users was often wrong, the subject was biased toward the correct answer. For example, when the size was small, the subject rarely reported a large size. When used in a real-time feedback device, such as for visual sensory substitution, knowing when objects are approaching or growing in size could be more important than properly judging the absolute size. It is also important to note that the first subject had results indicative of an outlier due to material obstructing the vibrotactile array. The recalculated mean scores, excluding those results, become 63.3%, 92.7%, and 97.8% for size, direction, and speed respectively.

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