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Alphabet Letter Display via Imitated Writing Motion

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***Abstract*— In this paper we report a method to transmit symbolic information to untrained users with only their hands. Our simple concept is presenting three-dimensional letter trajectories to the readers' hand via a stylus which is electronically manipulated. Despite its simplicity, experimental participants were able to read 14mm-height lower-case alphabets displayed at a pace of one letter per second with the accuracy rate of 71% with their first trials, which was improved to 91% after 5-minute training. These results showed small individual differences among participants. Our findings include the fact that this accuracy is retained even when the letters are downsized to 7 mm. Our method can be applied to such handy devices that would allow us reading texts in our pockets in a situation where no visual and auditory modalities are available.**

I. INTRODUCTION

Researches on conveying symbolic [1] or graphical information [2] via our hands to us have a long history. These are categorized into 'visual-tactile substitution' systems, which have been used mainly for blind people. On the other hand, only a few researches reported on the reading ability of the sighted: by touching embossed letters [3, 4], tracing trajectories of engraved letters with a stylus [5], writing letters on their palms [6, 7, 8], and guiding their fingers along letter trajectories [9]. Although these results clarifies some features of the hand reading ability, they do not discuss the possibility of practical information conveyance. Thus, hands have been considered unsuitable medium to read characters for the sighted people.

In this paper we report a method which enables the sighted adults to read lower-case alphabets as small as a single key of standard computer keyboards at a normal writing speed with a simple method. The simple method we try here is presenting 3D trajectories of pen writing including up-and-down motion. The device consists of two simple components: two-dimensional linear actuators and an on-off two way solenoid, whose details are described in the next section. In the following of the paper, we describe the experimental evaluation of the device from the perspective of practical symbolic information conveyance.

II. CHARACTER DISPLAY SYSTEM

Figure 1 shows the schematic diagram of our setting. An on–off two-way solenoid actuator, which moves vertically, was attached to the two-dimensional horizontally moving stage. Horizontal motions represented trajectory of letters,

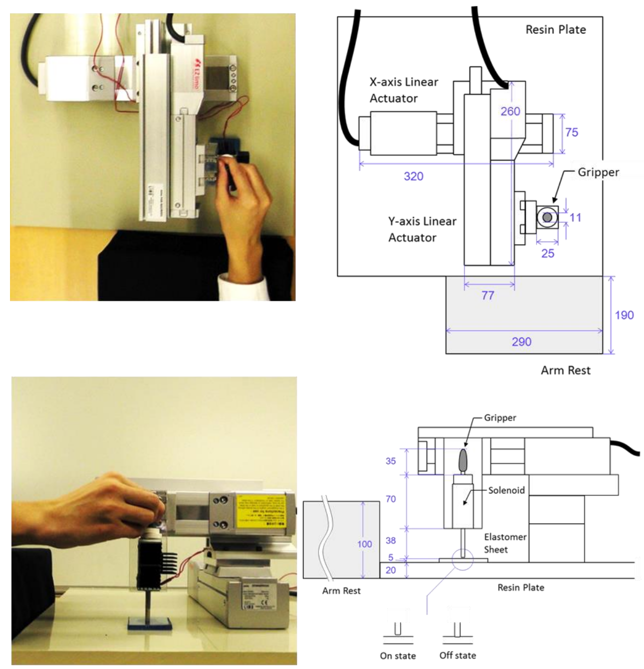

Figure 1. Experimental Device: Top view (top figures) and side view (bottom figures). It is composed of a 2-dimensional linear actuator using stepping motors for the horizontal motion and an on-off state solenoid attached on the actuator for the vertical motion. Participants held the gripper, upper tip of the solenoid covered with rubber.

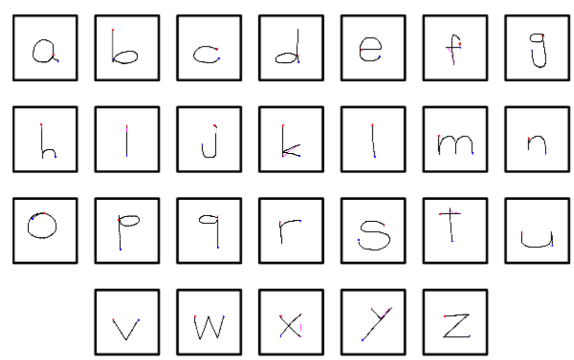

Figure 2. Displayed letter trajectories. Red points indicate the starting point in each trajectory terminated at blue points. The stylus tip is supposed to be on the paper along the bald black lines and to be lifted up over fine purple lines. All letters are depicted in the same scaling.

while the vertical motions imitated the contact of a pen tip to paper (in the actual experiment a resin plate was placed under the solenoid instead of paper). We used a pair of linear actuators driven with stepping motors (model EZS3D005-A, EZS6D005-A, product of Oriental Motor Co., Ltd.) jointed perpendicularly to each other. An on–off two-way solenoid (model 8.M14-02-62-12 VCC-100%, product of Mecalectro) was attached on the stage of the linear actuators with its lower tip pointing the resin plate. Both the linear actuators and the

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solenoid were electronically controlled by the computer via a micro-controller board (Arduino Mega 2560, product of Arduino), resulting in three-dimensional movement of the tip of the solenoid. Participants held the gripper, the upper side of the solenoid stylus, during the experiments with their arms on the arm rest, while vertical on-off movement of the stylus as well as lateral movement along the letter trajectory was reproduced. The maximum range of the device movement was 50 mm x 50 mm horizontally and 1mm vertically. Trajectories of lower-case alphabets were recorded by actual drawings by the authors on a graphics tablet (model PTH-850KO, product of WACOM). The extracted trajectories are shown in figure 2.

III. Experiments

A. Methods and Procedures

We conducted two experiments where the participants were asked to identify the presented letters. Participants were told in advance that the presented letters were randomly chosen out of 26 lower-case alphabets. For each trial a letter was displayed only once with no repetitions. Participants answered verbally what letter was displayed. Curtains and headsets were used in the experiments for nullifying visual and auditory cues. There was no time limit for the participants' responses. We tested 20 naïve participants, including 8 female and 12 male. Their ages ranged from 23 to 53. In all experiment sets, every alphabet was displayed twice in random sequences, 52 trials in all. Participants did not know the number of trials in every experiment set.

The participants initially identified 14mm-height letters displayed at a pace of one letter per second. Then a short-time training of the system was executed before the second identification tasks. The training aimed for getting participants accustomed to the presented letter strokes. In the training the participants guessed displayed letters. Each letter was chosen by the experimenters and the participants were informed of the correct for every single guess. This procedure lasted for 5 minutes for each participant. After this training, participants were engaged in identification tasks under the experimental condition identical to the first trial (14mm/1000ms) at first. Subsequently, they were engaged in the other three task sets (7mm/1000ms, 14mm/500ms and 7mm/500ms) with randomized order.

B. Results

The first experiment showed that naïve participants were able to identify displayed letters by their average accuracy rate of 71% (SD = 11.2%) on their first trials (Figure 3). The second experiments showed the effect of the 5-minute trainings. It raised the accuracy rate up to 91% (SD=6.7%). The paired t-test proved that the 5-minute training brought significant ($p < 10^{-8}$) difference. By applying two-way analysis of variance, we verified that both of letter height ($p < 10^{-4}$) and writing speed ($p < 10^{-15}$) had significant effect over the accuracy rate while their interaction did not ($p > 0.05$). Under all of the experimental conditions, it was concluded that there was no significant difference between male and female participants by the t-test ($p > 0.05$).

The achievable reading speeds corresponding to our experiments are 60 letter per minute (with a pace of 1000ms/letter) and 120 letter per minute (with a pace of 500ms/letter) excluding the time for answer. The former one,

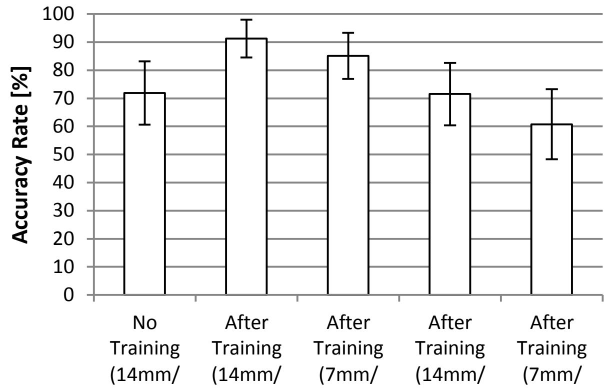

Figure 2. Accuracy rate graphs with standard deviation bars under the five experimental conduitions.

which guaranteed accurate symbolic communications, is almost the half of the typical adult handwriting speed: 130 letters per minutes [10].

IV. Future Perspective

The significant contribution of the research would be that it opens a new field of human computer interface beyond the conventional limitation of visual and auditory modalities. We expect that the communication rate of our method will be much improved by users' practices and technical modification of the interface design. The method can be embedded in various devices in principle. Our next interest includes whether a handheld devices is able to convey symbolic information in a similar way, which will allow us to read texts even in our pockets.

Acknowledgment

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