A Preliminary Analysis of Movement Times and Subjective Evaluations for a Visually-Controlled Foot-Tapping Task on Touch Pad Device

Angel O. K. Chan, Alan H. S. Chan, Annie W. Y. Ng, and B. L. Luk

***Abstract*—This study investigated the effects of foot-side, sex, and index of difficulty (ID) on lateral and visually controlled foot-movement time with a reciprocal foot-tapping task on touch pad device in sitting posture. Perceived difficulty level of subjects in different tapping conditions was also examined. Nineteen male and nineteen female right-foot dominant university students (aged 20 to 24) voluntarily participated in the experiment. The results indicated that sex and foot-side did not significantly affect foot-movement time, while the effect of ID was significant. It was also found that the ID reflects accurately the difficulty level perceived by subjects. The lowest ID (1 bit) was recognized as the easiest condition while the highest ID (4.5 bits) was the most difficult one. Possible applications of the results are useful for the design of foot controls for person-machine interfaces.**

***Index Terms*—foot tapping, foot movement, touch pad device, visually-controlled**

I. Introduction

Previous research indicated that foot operated controls could reduce hand and wrist strains, and be used as substitutes for hand operated controls for people without normal use of hands [1]. Foot controls are often used in human machine interfaces for system activation and information transmission, for example, stage lighting foot switch systems, foot-controlled computer mice, and foot-activated touch pads for operating front and rear screen wipers. There has been an increasing interest and number of applications of foot controls in industry. van Veelen *et al.* [2] designed foot pedals for medical and surgery operations with consideration of ergonomic guidelines. Pakkanen and Raisamo [3] investigated the performance of foot-operated trackball on selection, moving, and scrolling tasks in a computer environment. Rovers and van Essen [4] improved teleoperator system performance with the use of foot controls for interaction during communication in computer networks.

Foot operated controls, usually arranged in the transverse orientation and in front of the operators, require high speed and accurate lateral foot-tapping motions. A review on the current state of knowledge about foot movement had been conducted [5]. It was found that some of the reported work on visually-controlled foot tapping has been done [6]–[9]. The foot tapping with conventional hard keys such as pedal, wooden block, and metal sheet were tested extensively, whereas the foot-tapping performance with touch pad interface had never been studied. The variation of visually-controlled foot-movement time with user factors of gender and foot-side had not been extensively examined. Also, subjective assessment of overall usability of foot interaction with a touch pad device was not performed. Given the prevalent use of foot controls in various human tasks, there is a genuine need for further investigation of foot-tapping movement times. The movement times for reciprocal, lateral, and visually-controlled foot tapping at different movement amplitudes were examined to investigate the effects of sex and foot-side on such movements. The perceived difficulty level in foot tapping with various testing conditions was also studied. The results would be useful to engineers and industrial designers for the design of foot-operated controls in a diverse range of industrial applications.

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II. Method

A. Participants

Nineteen male and nineteen female right-foot dominant university students voluntarily participated in this study. Their ages ranged from 20 to 24 years. The dominant foot was specified by each participant with self-reporting of foot preference for skilled activities like kicking a ball placed directly in front of them [10]. To simulate the real work situation, participants were required to wear their shoes during testing.

B. Apparatus

A specially designed single-color LED display and touch panel of 960 x 480mm, two RISC-based microprocessor boards for controlling the LED display and touch panel (Fig. 1), Visual Basic 6.0 and a personal computer were used to generate a pair of rectangular targets and to capture participants' responses. A pair of rectangular targets with fixed size of 60mm x 160mm was shown on the LED lighting touch board. In alternating tapping and pointing tasks with visually controlled movements, the difficulty of hand or foot movements has been evaluated with an index of difficulty (ID) which considers movement amplitude and target width.

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The ID is defined as $\log_2[2A/W]$ where A is the amplitude of movement and W is the target width [8]. Tests with eight different IDs were conducted, viz. 1, 1.5, 2, 2.5, 3, 3.5, 4, and 4.5 bits. Thus, the corresponding movement amplitudes (i.e. center-to-center distances between targets) were set to 60, 85, 120, 170, 240, 339, 480, and 679 mm. A chair with armrests was provided to participants for performing the reciprocal foot-tapping task in the sitting posture. The chair did not restrict lateral leg movements of the participants.

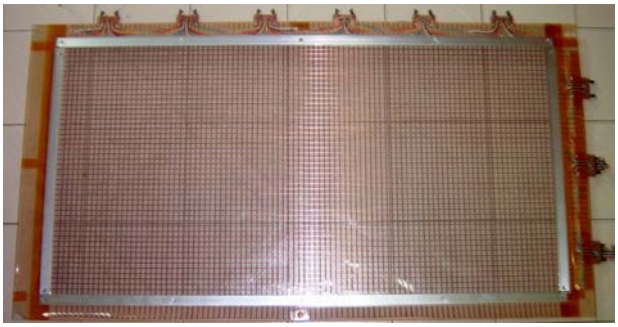

Fig.1: The touch-pad device used in the experiment

C. *Procedure*

The eight different ID conditions were tested for each foot side for all participants in a random sequence. For each condition, the pair of targets was located in front of the participants and placed symmetrically on either side of the participants' sagittal plane. Participants were asked to tap the two targets reciprocally for 20 cycles as fast as they could. Before the commencement of the test, participants were allowed to adjust their distance from the target freely until they could make comfortable movements, and to practise a few cycles of tapping. The foot-movement time for completing all 20 tapping cycles in a condition was recorded for further analysis. At the end of each test condition, participants were asked to indicate their perceived level of difficulty of the tapping task on a 9-point scale (0 = very difficult; 8 = very easy).

III. Results

Table 1 shows the mean movement times (in ms) from one target to another for the factors of sex, right or left foot, and ID. Males (656ms) performed faster than females (705ms), and left foot (674ms) had better performance than right foot (687ms) in the foot-tapping task. The higher the ID values, the longer the movement times were obtained. A mixed analysis of variance on transformed movement times was then performed with the between-subjects factor of sex and the within-subjects factors of foot-side and ID. The factor of ID was significant [$F_{(7, 252)} = 24.619$, $p < 0.001$], but sex and foot-side were not significant. Foot-movement times were plotted against IDs (Fig. 2) and it was shown that foot-movement time increased generally with an increase of ID value.

Similar to that of movement time, the perceived difficulty in foot tapping generally increased with increase of ID value. The lowest ID = 1 bit (mean =2.34) was identified as the easiest condition while the highest ID = 4.5 bits (mean = 7.71) was the most difficult one. The result of a Friedman test showed that there were significant differences of the perceived level of difficulty amongst the eight ID conditions ($p < 0.001$).

The relationship between movement time and perceived level of difficulty was also examined. Correlation analysis found that such a relationship was positively significant ($p < 0.001$).

Table 1: Movement times by sex, foot-side, and index of difficulty (ID)

	Level	Movement time (ms)	
		Mean	Standard deviation
Sex	Female	705	149
	Male	656	203
Foot-side	Right	687	206
	Left	674	182
ID (bit)	1	496	22
	1.5	448	22
	2	544	36
	2.5	544	23
	3	628	30
	3.5	777	31
	4	988	32
	4.5	1002	40

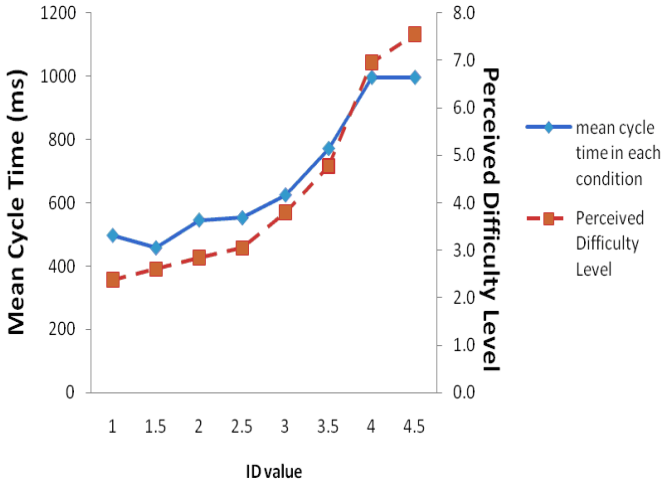

Fig. 2: Mean cycle time and perceived difficulty level for different ID conditions

IV. Discussion

The results of this study showed that sex and foot side factors had no significant effects on lateral foot-movement time. Human muscle consists of connective tissues, muscle fibers, and nerve elements [11], and the quality of a muscle fiber in exerting force is independent of sex [12]. It was thus not surprising that males and females showed similar magnitudes of movement time in this foot-tapping task. In past research, equal tapping speeds for men and women were reported with motions of fingers [13] and hands [14]. Both feet and legs of

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normal people have similar developmental histories, face equal demands on strength and balance, and experience comparable practice at complex movements such as running and jumping in daily life [15]. Therefore, the non significant difference in movement times found between left and right feet was expected.

In this experiment, ID and perceived difficulty on foot-movement time was found to have positive relationship. It was also noted that the ID value somewhat reflected the perceived difficulty in foot tapping. The findings here indicated that foot tapping became more difficult (in terms of ID and perceived difficulty level) for larger movement amplitude and required longer movement time. Therefore, designers should attempt to minimize the distance between tapping, given the practical and safety constrains involved.

Notwithstanding the usefulness of the results for the design of foot controls, there were limitations in the experimental design in this study. All participants were right-foot dominant and aged from 20 to 24 years. The findings would be more representative if subjects who were left-foot dominant and from other age groups were included. Future research studies on foot tapping may consider addressing the above-mentioned limitations in the design of methodology.

V. Conclusion

This study examined visually controlled foot-movement time for sex, right/left foot, and index of difficulty (ID) on a reciprocal foot-tapping task in sitting posture. Perceived difficulty level in foot tapping was also investigated. Results showed that ID significantly affected movement time, whereas the effects of foot-side and sex did not. It was also found that the ID reflected acceptable index of perceived difficulty level. The foot tapping was perceived easier for low ID value. Implications of the results would be useful for the design of foot operated controls in particular the touch pads for various person-machine interfaces.

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