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DEVELOPMENT OF TERMINAL DEVICE WITH TACTILE FEEDBACK

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ABSTRACT:

The purpose of this study was to identify the effectiveness of tactile feedback with terminal devices. For this purpose, a device was produced to control feedback frequency dynamically using solenoid magnets and permanent magnet. The feedback frequency could be controlled with a computer. In the first experiment, the subjects were asked to performed tasks to select targets from a list under without and with feedback conditions. The result shows that excessive tactile feedback gives rise to stress. In the second experiment, the subjects carried out the same task under different tactile feedback conditions: without feedback, with constant tactile feedback and with frequency controlled tactile feedback. The results show that the feeling about the device under frequency controlled tactile feedback was significantly better than that under the other feedback conditions. Finally, it was confirmed that tactile feedback makes it easier to handle fine adjustment operations.

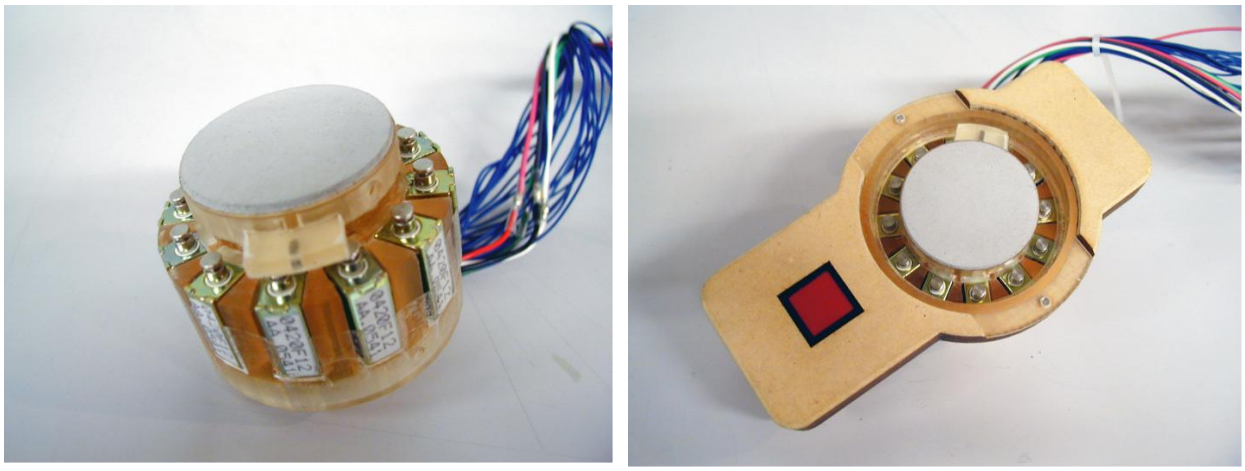
1. INTRODUCTION

There are many studies to transmit information using tactile stimulus (Wood 1998). However, not so much attention has been given to tactile feedback to use for terminal device (Akamatsu *et al*). Feedback information using tactile stimulus is important to make sure one's action and operation. Tactile feedbacks are used in many products as a user interface. Although almost of them used in products are produced with the help of elastic materials such as plate spring or coil spring. Therefore it is difficult to control its feedback frequency. This study was carried out on the hypothesis that controlled tactile feedback frequency to improve the usability of information device. The purpose of this study was to reveal the effect of tactile feedback with controlled its frequency on subjective feeling and task performance.

2. EXPERIMENTAL

2. 1. Device to produce tactile feedback

Figure 1 shows a device designed to control feedback frequency. Tactile feedback is produced by a magnetic force. The device is composed of solenoid magnets and permanent magnets, with twelve solenoid magnets fitted around the cylindrical casing, and permanent magnets attached to the edge of the wheel. These parts were held together with UV-curable resin. Feedback frequency was controlled using a development software kit (LabVIEW 7.1) manufactured by National Instruments Corp. Each subject was able to adjust the feedback frequency to his/her preference.



(a) Structure of terminal device (b) Terminal device used in this experiment

Figure 1: Terminal device to produce tactile feedback

2.2 Exploratory experiment

The task window of the exploratory experiment is shown in Fig. 2. The target was a song title. The subjects were required to select the target song title from the list. They scrolled up or down the list using the rotating wheel of the device. In order to identify the effect of the tactile feedback, the subjects performed the tasks without and with feedback. Ten subjects participated in the experiment. All of them were graduate or undergraduate students of Chiba University. The subjects aged from 21 to24 years. The subjects' impressions of the operation are shown in Table 1. The information suggests that tactile feedback makes it easier to handle fine adjustment and gives a sense of operational stability. However, it also suggests excess feedback rise to stress.

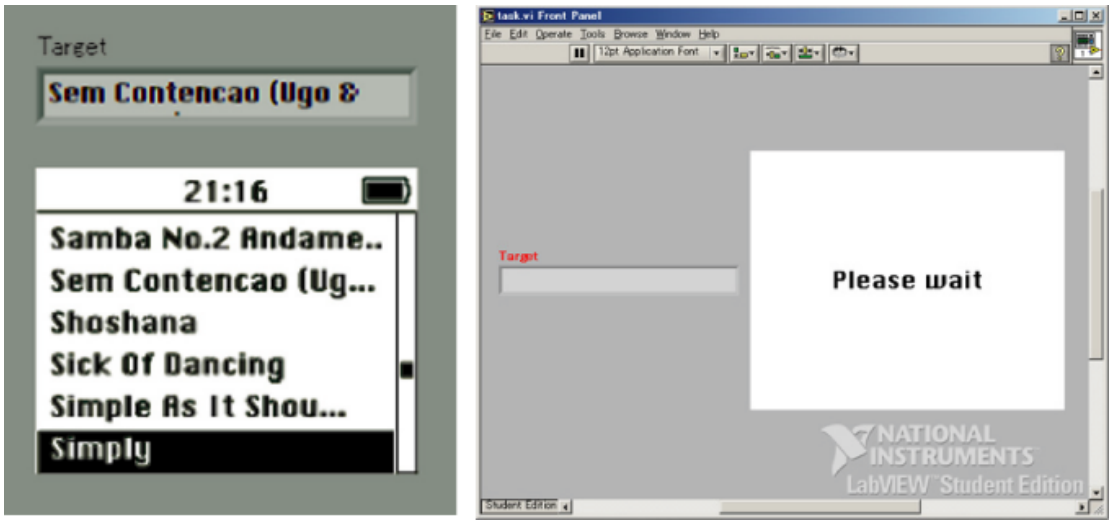


Figure 2: Task Window
Left: Task window for exploratory experiment, Right: Task window to measure task performance

Table 1: Operating impression without and with tactile feedback.

Condition	Positive impression	Negative impression
Without Tactile Feedback	It is scilent and comfortable. It is not feel so tired.	Something is missing. It is not interesting. It is difficult to control. It is uneasy to control.
With Tactile Feedback	It is amusing. It is easy to control. Feedbacks give me a sense of stability for operation.	I can not ignore its sounds. I am very tired. Too many feedbacks give me stress.

2. 3. Method

2.3.1. Program to control feedback frequency

The results of the exploratory experiment suggests that excessive feedback at high operational speed may give subjects some stress. Therefore, a program was developed to control the feedback frequency at each control speed. Figure 3 shows the graphic user interface of the program. The operational speed was measured in degree per second. The feedback frequency per rotation could be changed from 0 to 12.

2.3.2. Procedure

In the first 20 trials, the subjects performed as the one in the exploratory experiment without and with tactile feedback. Also, they were required to choose a suitable feedback frequency per rotation at each control speed. Subsequently, the subjects performed the task under the following three conditions: without feedback, with constant feedback, and with frequency controlled feedback. The total number of trials taken by each subject was 90. Twenty subjects participated in the experiment.

2.3.3. Measurement of subjective evaluations and task performances

The subjects evaluated the operational feel of the device under the three different feedback conditions using SD scales. Measurements were taken on the task-elapsed time, the moving distance to target selection, and the number of passing target as task performance indexes.

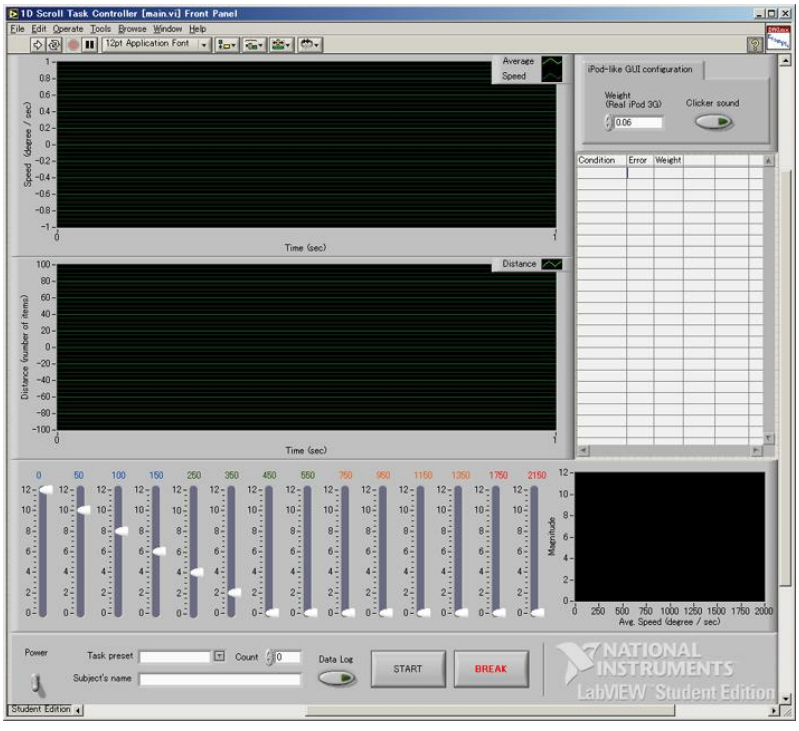


Figure 3 Control window to change the tactile feedback frequency.

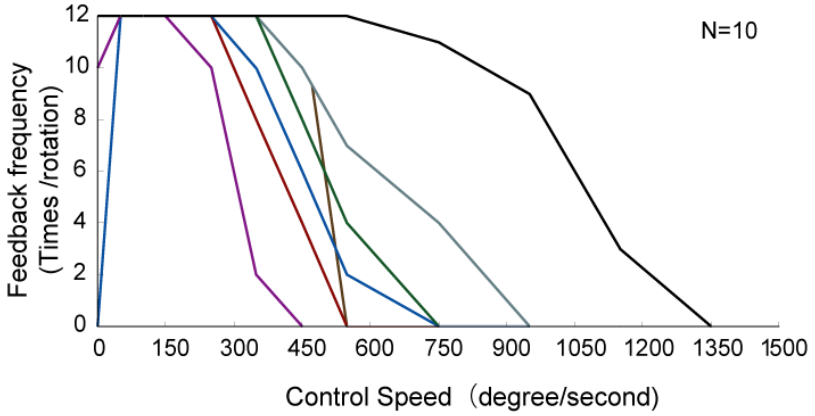
3. RESULTS AND DISCUSSION

3.1. Relationship between operating speed and feedback frequency

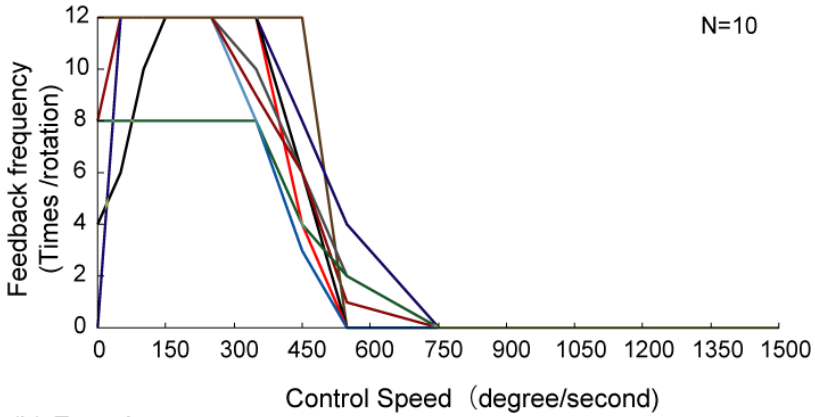
The feedback frequency per rotation was decided on by the subjects according to their preferences. Figure1 shows the relationship between operational speed and feedback frequency of all subjects. The top graph in Fig.4 shows the relationship of the male subjects, and the one below shows that of the female subjects. Most of the subjects tended to require tactile feedback at low control speed, and tended to dislike feedback at high control speed. These graphs suggest that the male subjects tended to tolerate tactile feedback at high control speed more than the female subjects.

3.2. Effect of tactile feedback on subjective feeling.

Figure 5 states of the result of subjective feeling under different tactile feedback conditions. Statistical significance was determined by analysis of variance (ANOVA). Significant main effect



(a) Male



(b) Female

Figure 4 Relationship between control speed and feedback frequency

was found in tactile feedback conditions at 1% ($p<.001$). Also the results of a Bonferroni multiple comparison test are shown in Fig. 5 and 6. The feeling under the frequency controlled tactile feedback condition was significantly better than that under the other feedback conditions.

3.3. Effect of tactile feedback on task performance

The result of ANOVA shows there were no significant differences in the task-elapsed time and the moving distances for target selection between feedback conditions ($p>.05$). On the other hand, significant difference was found in passing times of target between the feedback conditions ($p<.01$). Figure 6 indicates the relationship between the feedback conditions and the passing times of

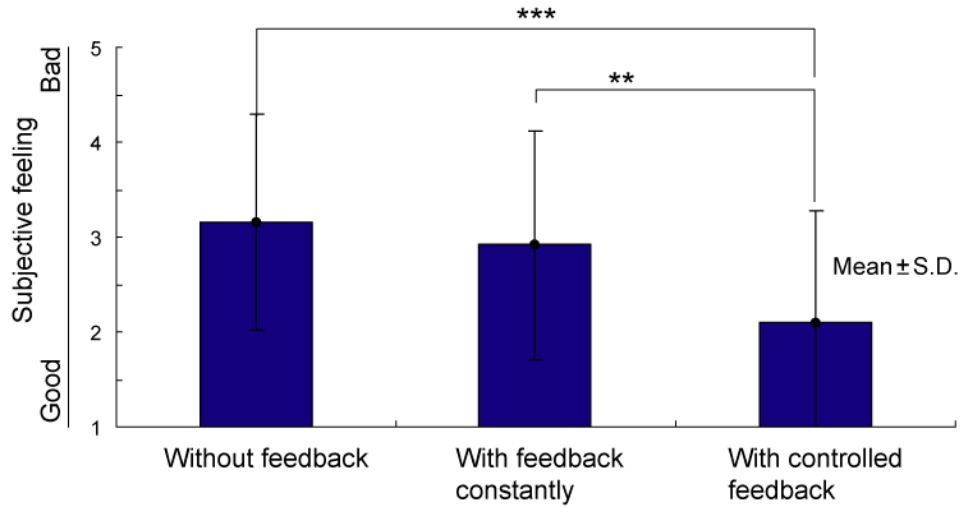


Figure 5 Effect of tactile feedback on subjective feeling **: $p<0.01$ ***: $p<0.001$

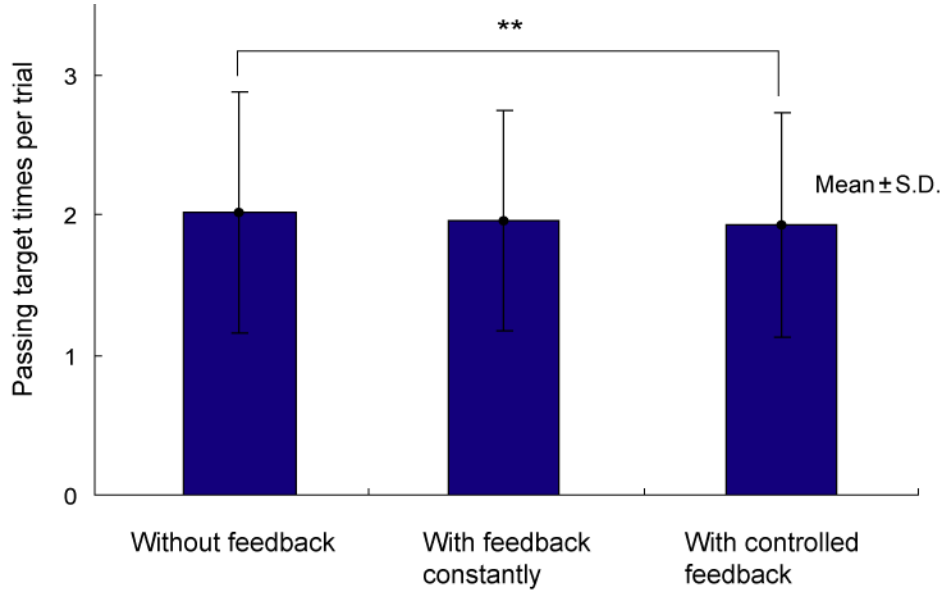


Figure 6 Effect of tactile feedback on passing target times **: $p<0.01$

target per trial. The figure was considered as an index to indicate the difficulty of fine adjusting. The results of the Bonferroni multiple comparison test shows there was significant difference in the passing times between the without feedback condition and the with frequency controlled tactile feedback condition ($p<.01$). It was verified that tactile feedback helps fine adjusting.

4. CONCLUSION

This study aimed to reveal the effects of tactile feedback on subjective feeling and task performance. For this purpose, a feedback device was designed and a program was used to control its feedback frequency. Subsequently, the subjective feeling about the device and the task performance was evaluated under different feedback conditions. The results obtained are summarized as follows.

(1) It was suggested the too much tactile feedback would give us stress
(2) Most of the subjects tended to require tactile feedback at low control speed.
(3) The subjective feeling under the controlled tactile feedback condition was significantly better than that under the without feedback or the with constant tactile feedback condition.
(4) It was verified that tactile feedback helps to fine adjusting

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