Brief Report

Does Slight Vibration Noise Affect Operation Accuracy of the Control Device? – Pilot Study –

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1. Introduction

For elderly people whose motor functions have degraded, it is important to find suitable methods for improving functions such as operation accuracy in order to maintain their quality of life. Their degraded motor functions often give rise to poorly controlled operation or movement. It is assumed that their somatosensory (muscle spindles and tendons) functions have degraded in addition to their muscular contraction functions.

To improve these operational functions, we have studied the somatosensory characteristics of the motor control system. It is known that afferent signals from muscle spindles are enhanced by applying subthreshold noise (vibrations).[1] This result suggests that muscle spindle sensitivity might be enhanced by a suitable level of noise due to the stochastic resonance.[2] Therefore, it is possible that the accuracy of operation can be improved by applying suitable noise.

It is generally thought that vibrations have a negative influence on the operation. However, depending on the vibration settings, it may produce beneficial effects for operation accuracy. To confirm this possibility, different types of vibrations were applied to a control device and operation accuracy was evaluated.

2. Method

The experimental apparatus (a driving simulator) is shown in **Fig. 1**. A computer display and a conventional steering wheel were located in front of the subject. The subject took a suitable driving position and grasped the steering wheel at the 10 and 2 o'clock positions with both hands. Six healthy males and females (aged 22 to 59 years) participated as subjects. Informed consent was obtained from each subject before each experiment.

The vibrations consisted of sine waves at four different frequencies of 5, 10, 20 and 30 Hz, and four different amplitudes of 0.05 (barely detectable), 0.1, 0.15 and 0.2 Nm (clearly detectable). The no-vibration condition (none) was set as a control, to give a total of 17 conditions. Each vibration stimulus was applied along the rotational direction of the steering wheel. The sequence of vibration conditions was randomized for each subject.

The experimental task was a tracking operation (see **Fig. 2**). The target cursor moved between the left and right sides of the display, and the rotation angle of the steering wheel was – 60 to 60 deg. The angular velocity of the target cursor was 20 deg/s. The subject attempted to overlap the control cursor and the target cursor by operating the steering wheel for 120 s. Tracking errors in the rotation angle between – 45 and 45 deg (in this range, the operations were kept with steady velocity) were measured at a 60 Hz sampling rate as an index of operation accuracy.

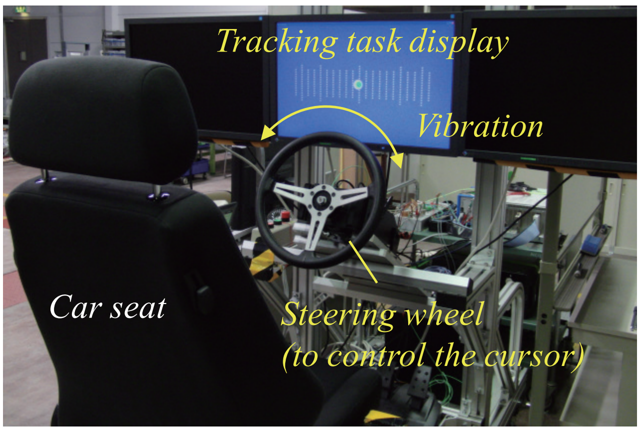

Fig. 1 Experimental apparatus (driving simulator).

The average tracking error for each vibration condition was analyzed by an analysis of variance (ANOVA), and the statistical significance level was set to less than 5%.

3. Results

A statistical analysis of the average tracking error showed that the frequency of vibrations was a significant factor. On the other hand, the amplitude of vibrations was not a significant factor. The average tracking error for each frequency condition is shown in **Fig. 3**. The average tracking error for the 20 Hz condition is significantly less than that for the control condition (no-vibration, $p<0.01$). Although the average tracking error for the 30 Hz condition is also less than that for the control condition, the difference is not significant. These results suggest that operation accuracy can be improved by applying a suitable frequency vibration.

Based on these results, we now consider the physiological effect of vibration. Frequencies of 20-30 Hz are close to the resonance frequency of the forearm and elbow region. Some of the protagonist muscles for this type of steering control are located in the forearm. Therefore, slight vibrations at 20-30 Hz from the control device would stimulate not only these protagonist muscles but also their muscle spindles. The sensitivity of the muscle spindles would then be improved due to the stochastic resonance.[1] As a result, the control device could be operated more accurately, and the tracking errors were reduced by vibration at 20 Hz.

4. Conclusion

The results of this study suggest that a slight vibration at a suitable frequency can improve operation accuracy. Moreover, this frequency should be close to the resonance frequency of the part of the arm in which the protagonist muscles are located. We consider that this effect is caused by the stochastic resonance in the muscle spindle.

However, these results were obtained from limited conditions and subjects. To clarify this phenomenon and its mechanism, we have been accumulating experimental results using other devices and conditions.[3,4]

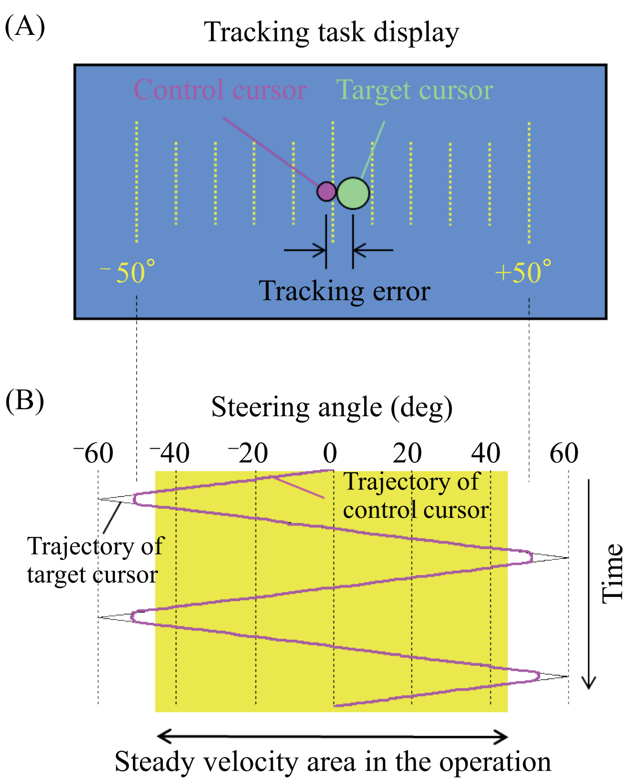

Fig. 2 Tracking task on the display (A) and example of tracking procedure (B).

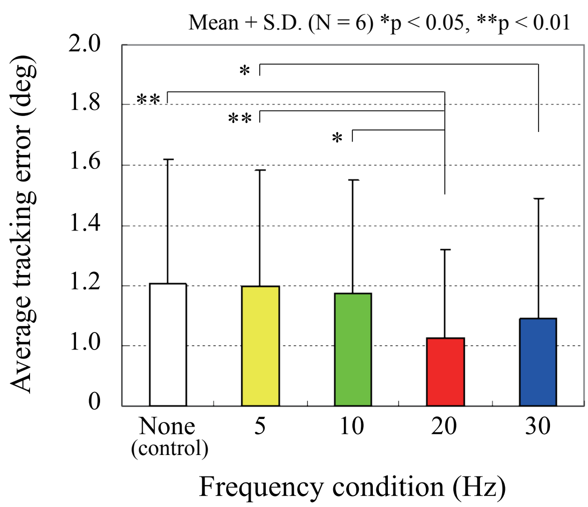

Fig. 3 Comparison of average tracking error for different frequency conditions.

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