Performance variables controlled to dampen hand vibration

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Abstract
The human has to reduce the hand jerk and maintain the cup angle constant so as to carry a cup with water without spilling it. We examined whether these variables were independently controlled. We measured the task in which subjects had to separately control the hand jerk or the cup angle by LED feedback. Our results showed that the human can independently control both the hand jerk and the cup angle. These results suggest that the human has to simultaneously control these independent variables to carry a cup with water.

Keywords — dampening vibration, jerk, walking

1 Introduction
It is considered that the human reduces the variance of some variables (performance variables) which should control to achieve a task by coordinating redundant multi-joints. We examined one of dexterous tasks carrying a cup with water without spilling it. In the former study [1], we found that the human reduced the hand jerk and maintain the cup angle constant to achieve the task by joint coordination. In addition, we implicitly hypothesized that these performance variables (hand jerk and cup angle) were independently controlled because the hand jerk and the cup angle are physically independent. It is however possible that controlling one performance variable results in the control of another performance variable, e.g. hand jerk might be reduced by maintaining the cup angle constant.

In the present study, we examined whether the hand jerk and the cup angle (which are the performance variables) are independently controlled. We set up the task in which these variables must be separately controlled by LED feedback, and compared the values of the hand jerk and the variance of the cup angle. To compare these tasks, we also measured the task carrying a cup with water and with stones.

2 Methods
2.1 Procedure
Four healthy right-handed male subjects participated in the experiments. The subjects walked on a motorized treadmill (PW22, Hitachi information & Communication Engineering, Ltd.) at a speed of 0.56 m/s (2.5 km/h) for three minutes (Fig. 1). They held a cup tightly with their right hand. Metronome beeps (1.5 Hz) were provided to guide the walking of the subjects. The subjects performed six conditioned tasks: 1. carrying a cup with water without spilling it [WW task]; 2. carrying a cup with stones instead of water [WS task]; 3. controlling the cup angle instructed by LED [AC task] (threshold: ±0.05 [rad]); 4. controlling the cup angle instructed by LED [AC2 task] (threshold: ±0.03 [rad]); 5. controlling the hand jerk instructed by LED [JC task] (threshold: ±5 [m/s²]); 6. controlling the hand jerk instructed by LED [JC2 task] (threshold: ±4 [m/s²]). Three LEDs were lightened up by threshold condition. In the AC task, if the change of cup angle from starting position was over the threshold, the one red LED was lighted up corresponding to ±. If it was kept within the threshold, the green LED was lighted up. In the JC task, if the peak of hand jerk last one second from current time was over the threshold, the one red LED was lighted up, and if it was not, the green LED was lighted up. The subjects were instructed at each tasks as follows: In the WW task, to walk without spilling water; In the WS task, to walk gazing a green LED; In the AC and JC tasks, to keep lighting up the green LED. The subjects practiced walking on the treadmill for the AC task and the JC task for three minutes before the experiments. Two subjects performed the task in order from 1 to 6, the other two subjects performed in the reverse order.

2.2 Data collection
We used a three-dimensional position measurement system to record kinematics at 100 Hz (OPTOTRAK CERTUS, Northern Digital Inc.). Infrared-ray markers were placed on the subject’s malleolus, the center of gyration of the articulatio coxae, the shoulder, the elbow, the wrist, the root of the digitus medius, and the side of the cup. We used AD/DA board (ADA16-32/2(PCI)F, CONTEC) to control LED.

2.3 Data analysis
The position data were filtered with a second-order Butterworth low-pass filter with a 10 Hz cut-off frequency. We obtained the jerk of each body part by calculating the third differential of the measured po-
sition. The differentiated data were also low-pass filtered. In the JC task, we used the same process of differential and filter for hand position in real time, we fed back the hand jerk in real time. The onset of the walking cycle was defined as the point when the horizontal velocity of the malleolus was over $-0.6 \text{ m/s}$. All kinematics data were divided by onset (one stride).

2.4 Statistical analysis

A one-way repeated measures analysis of variance (ANOVA) was performed to examine the effect of task with respect to the sum of squared hand jerk. The Tukey-Kramer method was used for a post-hoc test ($\alpha = 0.05$). Moreover, a two-way ANOVA was performed to examine the effect of task and each body part with respect to the sum of squared jerk.

3 Results

Fig. 2 shows the sum of squared hand jerk of a typical subject. The horizontal axis denotes the tasks, and the vertical axis denotes the sum of squared hand jerk for one stride. The hand jerk in the AC task was larger than that in the WW task, and that in the JC task was almost same as that in the WW task ($P < 0.05$). Moreover, the hand jerk was decreased by the strict threshold.

Fig. 3 shows the sum of squared jerk of each body part of the typical subject. The horizontal axis denotes the body parts. The jerk of each body part indicated the similar tendency as the hand jerk, and dampened from hip to hand ($P < 0.05$), which indicates that the hand jerk was dampened by using whole body.

Fig. 4 shows the variance of the cup angle of the typical subject. Variance of the cup angle in the AC task was same as that in the WW task. In contrast, the variance of the cup angle in the WS and JC tasks was larger than that in the WW task.

The other three subjects showed the same tendency.

4 Discussion

In the AC task, the variance of the cup angle was reduced as that in the WW task, but the hand jerk was not reduced. It is likely that the hand jerk in the AC task was smaller than that in the WS task because the subjects might carefully watch the LED feedback. In the JC task, the hand jerk was reduced as that in the WW task, but the variance of the cup angle was not reduced. These results showed that the human can separately control the hand jerk and the cup angle, and suggest that the human simultaneously controls these independent variables to carry a cup with water without spilling it.

In our former study [2], controlling the hand jerk was not affected but controlling the cup angle was difficult by visual blocking. Considering the results of our former and present studies, it is likely that the control system of the hand jerk and the cup angle are independently existent. Cup angle would be controlled using visual information, and the hand jerk would be controlled by using somatosensory information and so on. In the task carrying a cup with water without spilling it, the human would adopt both control strategies. We think that the human can adopt above strategy to achieve the dexterous task because they have redundant multi-joints.

References
