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指の摩擦特性に及ぼす知覚刺激の影響

Effect of Perceptual Stimuli on Friction Behavior of Finger

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1. Introduction

In this study, we aim to provide a pseudo-haptic effect for finger sliding through an unpredicted visual stimulus. According to research, when multiple senses converge, vision often plays a dominant role[1]. Visuo-haptic illusions are therefore occasionally used to enhance the sensations of stiffness, friction, and shape recognition[1, 2] in virtual reality. Researchers induced perception by giving virtual objects a faster movement, a larger (or smaller) volume, etc. compared to actual situations. However, not much relevant research has been seen in the field of touch screens.

For this experiment, we use the visual stimuli of time-delay. Instead of staying sync with the finger sliding trajectory as participants suppose it to, we let the cursor in the tablet lag the finger for a certain time when moving. We investigate the physiological feedback of the sliding finger to explore how this visual stimulus affects the finger friction behavior. For each of the different delay times, we look into the changing in sliding speed and applied normal load. The quantification of such changes will help to establish a correlation between the visual stimulus and the kinematic and mechanical feedback of the finger, providing clues for the future implementation of simulations of desired tactile sensations.

2. Experiment

2.1 Preparation of test specimen

In this study, commercially available glass plate (EAGLE XG® alkaline-earth boroaluminosilicate, 40×120×0.7mm) was used as test specimen. The contact angle of distilled water on the surface of the specimens was measured in an ambient environment with a contact-angle goniometer (DMo-501, Kyowa Interface Science). The contact angle of distilled water was 34° for the glass surface. It should be noted that the glass substrates are transparent.

2.2 Finger friction measurement under the experience of visual stimuli

2.2.1 Application software for visual stimuli

Finger 1 shows a schematic illustration of the laboratory-made software loaded on the tablet (MS Surface Pro 7+). There are a pair of circular cursors (Radius: 15mm) arranged on the screen, The two slides up and down are considered as one set. For reference, in each set, either up or down will have one cursor that moves in sync with the finger (Normal mode, delay time 0s) and the other cursor moves with a certain time interval after the finger movement (Time-delay mode, delay time:0.03-0.30s). The initial position of the cursor always appears at the start of the indicator bar.

The distribution of normal mode, time-delay mode, and the delay time of time-delay mode was set in advance pseudo-randomly with 10 sets of 20 slides as a trial (Table 1 as an example). 10 delay-times evenly distributed in the range, the immediately followed trial has the reverse order in the set, the rest identical.

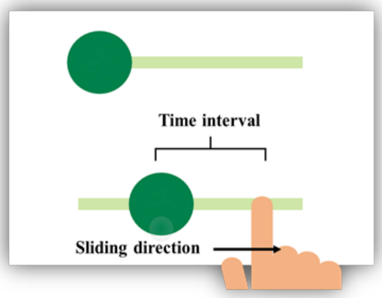

Fig. 1 Illustration for lab-made software

Table 1 Example of delay times in one trail

	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7	Set 8	Set 9	Set 10
Cursor 1(s)	0.06	0.27	0.15	0.24	0	0	0	0.21	0.06	0
Cursor 2(s)	0	0	0	0	0.30	0.03	0.12	0	0	0.18

2.2.2 Procedure of friction measurement

Figure 2 shows the apparatus consisted of a flat aluminum alloy plates and a 3-component force sensor (LSM-B-20NSA1, Kyowa Electronic Instruments) beneath; the sensor was connected to a computer. The x, y, and z component forces, F_x, F_y, and F_z, were simultaneously measured during the finger sliding process. The horizontal friction force F was calculated as the resultant force of F_x and F_y, whereas the F_z was the normal load perpendicular to the flat plate surface. Then, the friction coefficient was obtained by dividing F by F_z. The tablet loaded with the software was placed on the tribometer not only to present visual stimuli but also to collect kinematic information such as the position of the finger and the cursor at each specific moment. Two pieces of the glass substrate, as mentioned in 2.1, were attached to the tablet with adhesive tape above the sliding position.

Before the friction measurement, the glass substrates were ultrasonically cleaned with acetone and distilled water. Participants were all clean their fingers with soap then dry with tissues. During the measurement, participants were instructed to sit facing the table and to use only their index finger to slide on the substrate at an angle of about 30 degrees with the wrist hanging in the air. As shown in Fig. 2, there were two light green indicator bars on the screen indicating the direction and distance of the slide. The participants were asked to drag the cursor along the bar from the start to the end (Length: 10 cm), there are no restrictions or hints of sliding speed and force. Participants were asked to slide firstly the cursor on the top, then the cursor on the bottom. Two slides on up and down were took as one set, and 10 sets as a trial. There are total of four trials of 80 slides for each participant, with a short break between each trial. Besides, the substrates and fingers were additionally cleaned the with ethanol between two trials. The total number of participants were three (three male, 21 to 27 years, right-handed). All tests were conducted in the laboratory, with room temperature of 21±3 °C and room humidity of 50±5 RH%.

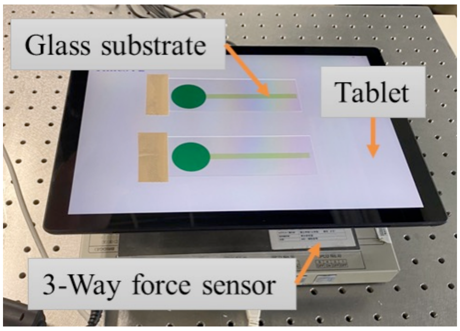

Fig. 2 Ratio of sliding speed (TD: time-delay)

3. Results and Discussion

Figure 3 and 4 shows the results obtained from the friction measurement with three participants. The average value of 3 participants was used in both figures. Since one time-delay mode and one normal mode were considered as a set, the data shown in Fig 3 and 4 show the relationship in each set by calculating both ratios of sliding speed and normal load with time-delay mode to those with normal mode.

From Fig. 3, the vast majority of relative sliding speed showed the value below 1, which indicates most participants slide slower within time-delay mode than in normal mode. There was a declining trend of sliding ratio when the delay time was getting longer, which means as delay time grew, the sliding speed in time-delay mode was more noticeably slower than that in normal mode. It can also be seen from Fig. 3 that the difference in the relative sliding speeds between the two modes was not very large for the different participants.

Figure 4 shows that most of the relative normal load was greater than 1, which means in most cases participants applied more pressure in time-delay mode than in normal mode. They slid their fingers even harder as the delay time increased, which means this change was also proportional to the delay time. Additionally, compared to the relative sliding speed, the relative normal load is more turbulent and has a larger error bar. It is possible that in such a visually referenced sliding task, the mechanics could change more randomly and have more freedom compared to the kinematic changes.

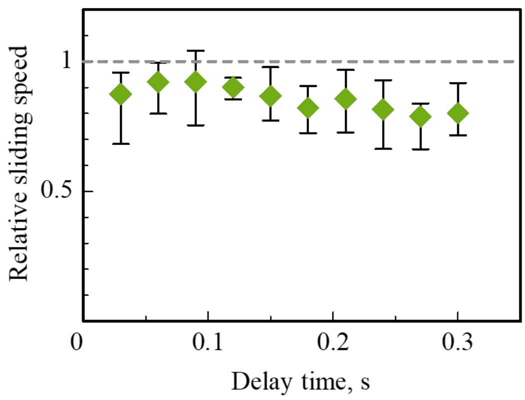

Fig. 3 Relative sliding speed vs. delay time

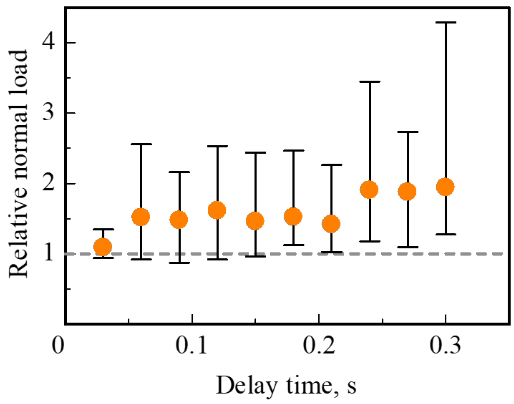

Fig. 4 Relative normal load vs. delay time

4. Conclusion

- The visual stimuli of time-delay caused participants to slide more slowly and apply more pressure than they did with normal mode when sliding on a tablet in a free condition.
- These changes in sliding speed and normal load tended to be more pronounced as the delay time increases.
- Unlike the more stable ratios in velocity changes, the ratio of pressure applied to different visual stimuli varied considerably from individual to individual.

References

1) Abtahi, Parastoo, and Sean Follmer. "Visuo-haptic illusions for improving the perceived performance of shape displays." Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. 2018.
2) Samad, Majed, et al. "Pseudo-haptic weight: Changing the perceived weight of virtual objects by manipulating control-display ratio." Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. 2019.