Vibration of the White Cane Causing a Hardness Sense of an Object

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Abstract. Previously, we conducted a psychological experiment to measure sensitivity to hardness using a white cane. The Results showed that participants had higher sensitivity to hardness when using the white cane compared to when actually tapping the target with their fingertip. This suggests that the white cane acts to provide enhanced feedback on hardness. In this study, we investigated the relationship between vibration and sense of hardness using white canes. We measured frequency of vibration of the ferrule of the cane by acceleration sensor when the cane contacted with target. And using psychological experiments, we then had participants estimate their sense of hardness for each hardness degree. It was found that there is a correlation between the hardness sense and frequency of vibration.

Keywords: white cane, hardness sense, frequency of vibration.

1 Introduction

The white cane is one of the most widely used tools used by the visually impaired to support independent mobility. The white cane has a number of disadvantages. The area that users can perceive by using it is narrow, because objects can only be perceived by touching them with the cane. And it is also physically tiring to constantly swung the cane from side to side while walking. Two approaches have been making progress in addressing these issues. The first is the development of an electronic white cane that incorporates ultrasonic sensors, acceleration sensors, infrared light, lasers, etc. This electronic white cane allows people to detect and avoid obstacles from a distance, avoid hitting their head or face against objects that are above the level of the cane and there is no need to be swinging the cane. The second approach has been to make a lighter and more durable cane by improving and developing better materials. Both approach reduce fatigue. And some studies are already at the product evaluation stage. Through the developments discussed above, the convenience of the white cane has increased. To follow up on these two approaches, further developments need to

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take into account the nature of white cane use. The primary purpose of using a white cane is to be able to detect street conditions and obstacles based on the reverberations and tactile information that is gathered from the tip, not specifically what those obstacles are. But white cane users reported in interviews that in some cases they wanted to avoid directly touching a surface with their hands, and instead used their canes to distinguish between various materials or recognize certain objects. This indicates that target recognition occupies a large part of how white canes are used. Therefore, it is critical to develop a third approach that is focused on improving target recognition using the white cane. And furthermore, there are some users that imagine the cane as an extension of their hands, suggesting the possibility of somatization of tools. If the white cane were to become a part of a person's body, and could be used without discomfort, it could be considered a user-oriented tool, which is a desirable property for tools and assistive devices.

White canes are either straight and long, or collapsible. Both types consist of a grip at the top, a shaft, and a ferrule (a tip at the bottom). The grip is normally made from rubber. The shaft is crafted from materials such as aluminum, glass fiber, or carbon fiber, and the ferrule is typically made from nylon. This construction allows information, in the form of vibrations, to be transmitted to the user. Information about objects touched by the cane is transmitted to the user's palm through the structure above as vibrations. Research on the characteristics of objects, that are obtained through direct and active tactile exploration, such as texture, temperature, hardness, weight, size, shape of the whole and part of the object, has been conducted. It might be possible to obtain information about these characteristics with the white cane, by developing skills of using the cane. We conducted a psychological experiment on sensitivity to hardness [1] and [2]. Sighted university students wearing an eye mask (N=16) and blind people that usually use the white cane and walk independently (N=7) participated in the study. They were required to tap a rubber board with the tip of the forefinger of their dominant hand, and with the tip of the cane held by the dominant hand. The relationship between the actual hardness of the rubber and the sense of hardness was investigated, by using magnitude estimations. The exponents indicated by the results of the study with a standard grip were as follows: for sighted university students; 0.36 for the forefinger and 0.66 for the cane, for blind people; 0.37 for the forefinger and 0.59 for the cane. An exponent of 1 indicated that the physical and psychological values corresponded with each other. The observed exponent of less than 1 suggested that the sense of hardness did not increase significantly, even though physical hardness did increase, indicative of low sensitivity to changes in hardness. Furthermore, sensitivity to hardness when using the cane was higher than when using the forefinger, suggesting that the cane might amplify information about the hardness of a surface. In this study, we investigate the relationship between vibration and sense of hardness using white canes. We measure the frequency of vibration from the tip of the white cane at the point of contact with targets of various hardness degrees. Using psychological experiments, we then had participants estimate their sense of hardness for each hardness degree.

2 Experiment

A square rubber board 300 mm long and 12 mm thick was used to estimate hardness. Four rubber boards with the following degrees of hardness were prepared: 20, 40, 60, and 80 degrees (unit: JISA; manufactured by SHOWA RUBBER Co., Ltd, measured using Durometer Hardness Tester GS-719G type A, manufactured by TECLOCK Co., Ltd). The main body of the white cane (manufactured by G & OM Aids Inc.) was made of aluminum alloy (light metal), 1200 mm in length, including the rubber grip (260 mm) and the nylon ferrule (75 mm). The weight of the cane was approximately 200g with the inside of the shaft being hollow. Vibrations were measured using a conditioning amplifier（2-channel (single probe) Intensity Conditioning Amplifier, Type 2693-0S1, B&K Co., Ltd）, accelerometer (Miniature tear-drop CCLD accelerometer, Type 4517, B&K Co., Ltd), and an A/D converter (PowerLab/4ST, ADINSTRUMENTS, Inc.). The sensor was situated 2 cm from the tip of the ferrule (Fig.1). The floor was covered with a tile carpet during measurement and the rubber boards were placed on it.

Sighted male university students (N=3) participated in the study. They had eye masks, earplugs and year muffs, stood in front of the rubber boards (Fig.2), and held the white cane with the standard grip by stretching the forefinger along the even plane of the grip and grasping lightly with the thumb and the other three fingers (Fig.3). When the experimenter gave a sign, the participants tapped the board once to confirm the hardness of the board. Just after the tap, the magnitude was estimated and the participants were required to report the number that corresponded to the hardness. The numbers were assigned such that numbers were larger as the hardness increased. The hardness of the rubber board and the order of testing the boards were combined and randomized. The estimate of hardness was conducted five times, for each degree of hardness.

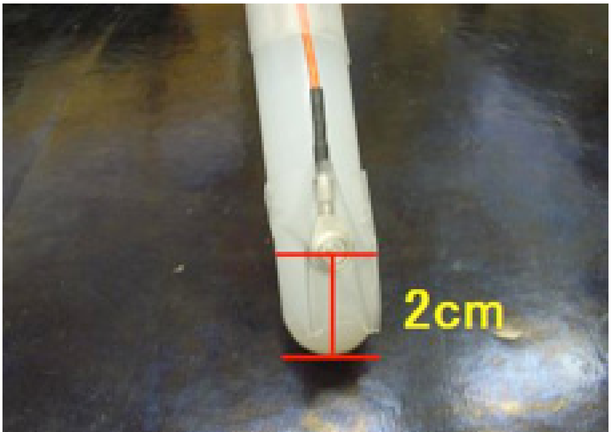

Fig. 1. Accelerometer setting

Fig. 2. Experimental setting

Fig. 3. Holding the white cane

3 Result

The results were processed using LabChart 7 (ADINSTRUMENTS, Inc.). Three participants indicated different frequency patterns. Moreover, each participant showed a characteristic frequency pattern to each degree of hardness. The figure shows the typical pattern indicated by subject A to each degree of hardness (Fig.4). The horizontal axis indicates the time course (sec) and the vertical axis, the frequency (Hz). This pattern was obviously different from the frequency pattern that was obtained by dropping the cane from a certain height on the rubber board, a person being involved. Furthermore, as the hardness of the board increased, the estimate given by the participants became larger.

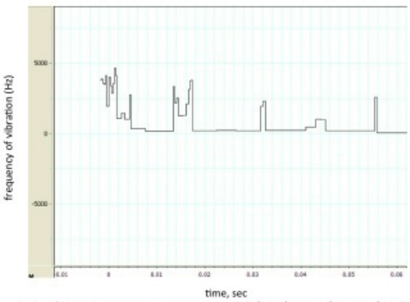

Fig.4a Frequency pattern on 20 hardness degree by Sub.A

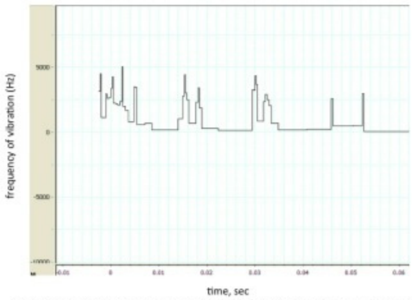

Fig.4b Frequency pattern on 40 hardness degree by Sub.A

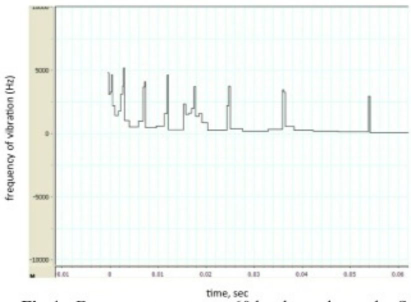

Fig.4c Frequency pattern on 60 hardness degree by Sub.A

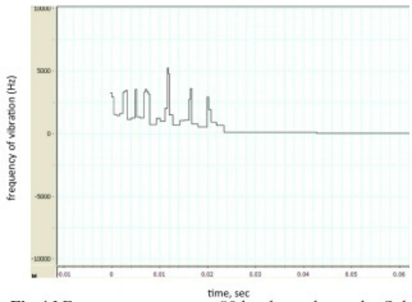

Fig.4d Frequency pattern on 80 hardness degree by Sub.A

Fig. 4. The typical Frequency pattern on each hardness degree by Sub.A

4 Discussion

It is suggested that vibrations might transmit information about the hardness of the board. Differences between the participants might have reflected differences in tapping techniques, such as the strength of the grip or the height at the position when tapping was initiated. Therefore, by investigating the relationship between tapping technique and the frequency band, and excluding the effects of the tapping technique from the resulting frequency patterns, it would be possible to identify vibration frequencies that corresponds to information about hardness of objects. And in this study, vibration at the tip of the cane, where the cane touches the object was assessed. In the next step, we should measure vibrations at participant's palm, where information is got.

References

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