Original Article

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Strengthening tactile sense capability by using the fingertips

Manabu Yoshioka, Junichi Shimizu*

Abstract

The objective of this study is to verify that frequently using the fingertips results in a high ability level for tactile sensibility. The subject was 8 general students (a general student group), 10 computer club students (PC student group ; composed of members who used their fingertips for five hours or more for a day), and 5 blind school students (a blind school student group).

At first, we investigated the characteristics of vibrations from the long cane to evaluate vibrotactile sensibility. Next, a static two-point discrimination test, moving two-point discrimination test (the distance of two points : 2, 3, and 5mm) and two-point vibrotactile discrimination test (the distance of two points : 2, 3, and 5 mm, the diameters of contactor : 0.5, 0.8, and 1.0 mm, the dominant frequencies of long cane were 30, 125, and 250Hz) were used to evaluate vibrotactile sensibility. As a result, in the static two-point discrimination test and moving two-point discrimination test, when the distance of the two points was 2 mm, only two people in the general student group were not able to detect the two point's stimuli (75%). When the distance of the two points was 3 and 5 mm, all subjects were able to detect the two points' stimuli (100%). In the distinction in the two-point vibrotactile discrimination test, when the dominant frequencies of long cane were 30Hz, there was an interaction between the three groups and the diameters of contactor ($P < 0.05$). A significant difference was seen among the three groups and the diameters of contactor ($P < 0.05$). At 125 and 250Hz, significant difference was seen among the three groups and the diameters of contactor ($P < 0.05$). It was shown that the ability of tactile sensibility was high in order of a general student group, PC student group, and blind school student group.

It seems reasonable to conclude that using the fingertip for a certain purpose more frequently enhances the discriminability of two-point vibration.

Key words

Tactile sensibility, Vibrotactile threshold, Fingertip, Visual-impaired student

INTRODUCTION

Actions are often decided through the use of mostly visual information[1]. However, this type of information is not the only means available. For example, a blind person does not have the ability to gather visual information and instead chooses to use a cane for guidance along a walking surface. By skillfully tapping or sliding the cane, vibrations are created and sent up to his hand, thereby helping him judge the walking surface[2]. Thus, it can be said that tactile information received from the hands and fingertips is another means through which decisions can be made.

In a past study of the vibrotactile threshold, it was reported that frequency characteristics for a vibrotactile threshold of one-point stimulus were not shown in a contactor area of less than 0.02 (cm^2), but frequency characteristics indicating the

Kanazawa University Graduate School of Medicine, Division of Health Sciences Rehabilitation Science Area
* Kanazawa University Graduate School of Medicine, Division of Health Sciences

minimum threshold of approximately 200 Hz were shown in a contact area of more than 0.08 (cm^2)[3]. Also, in the vibrotactile threshold study by the subsequent one-point vibrator, the result was the same[4]. It cannot be said that the vibrotactile threshold in daily life is appropriately evaluated by one-point vibration discrimination test because the one-point vibrotactile discrimination test is greatly influenced by the distribution density of the receptor organ at the place where stimulation is added[5]. Furthermore, it could not appropriately evaluate the hypothesis that fingertips which are often used for hitting the keys on a computer or tapping a long cane are more sensitive.

The objectives of this study were: (1) to measure hand-transmitted vibrations from the long cane; (2) to investigate the characteristics of tapping vibrations from the long cane; (3) to investigate the frequency characteristics of the vibrotactile threshold of a general student, PC student group, and a blind school student; (4) to evaluate the hypothesis that using the fingertips for a certain purpose more frequently enhances the ability of tactile sensibility to stimulation.

Experiment 1

Methods

1. Subjects and Long Cane

A blind school student was used as a subject in this study (age 17). She was congenital visually-impaired student. Her own long cane was used for the measurement because the length of the cane had been adjusted for her height. The suitable length for a cane is calculated from a position slightly below a person's chest (normally the person's height minus 45 cm). The long cane used in this study is one that is commonly used by cane users in Japan.

2. Procedure

Figure 1 shows the location where the accelerometer was fixed. The vibration acceleration signals of the long cane were measured close to the hand in three directions designated X, Y, and Z using a piezoelectric accelerometer (APA300, STAR Co. Ltd). In accordance with mentioned ISO (International Organization for Standardization) 5349 standards, the three directions of an orthogonal coordinate system, in which the accelerations should be measured, were as follows: X-axis directed the longitudinal axis of the grip. Y-axis

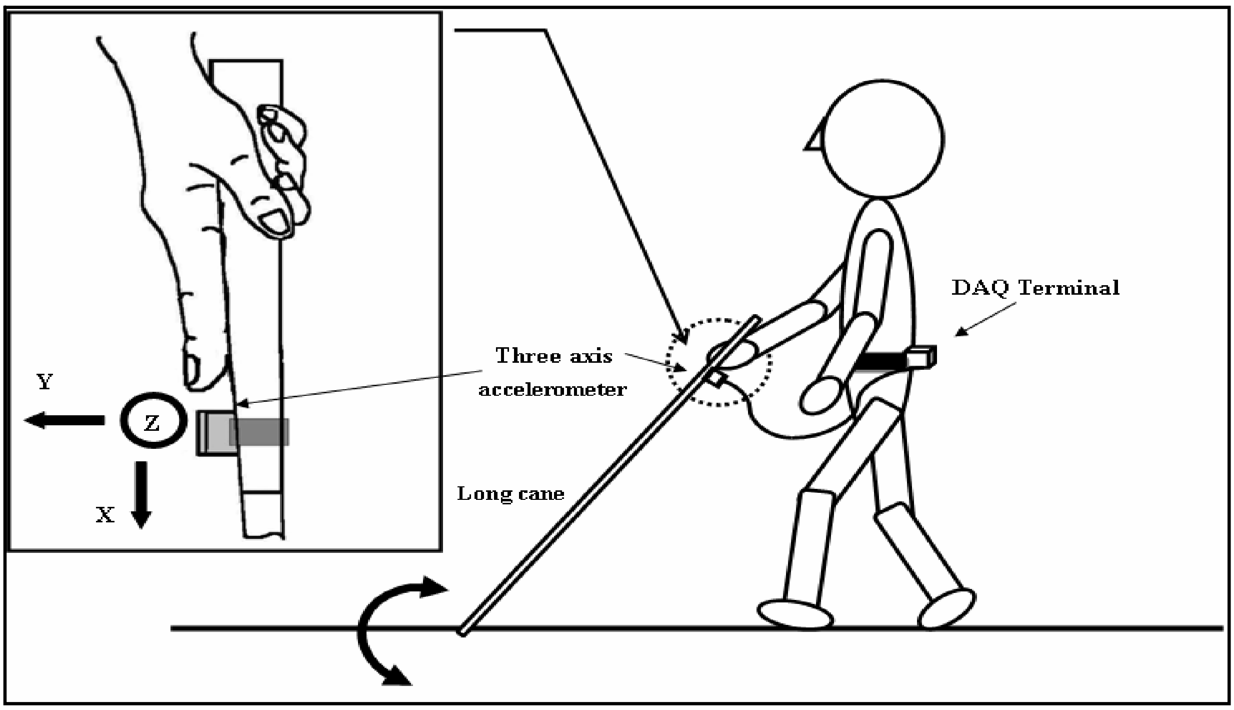

Figure 1. Location of accelerometer and Apparatus
The vibration acceleration signals of the long cane were measured close to the hand in three directions designated X, Y, and Z using a piezoelectric accelerometer.

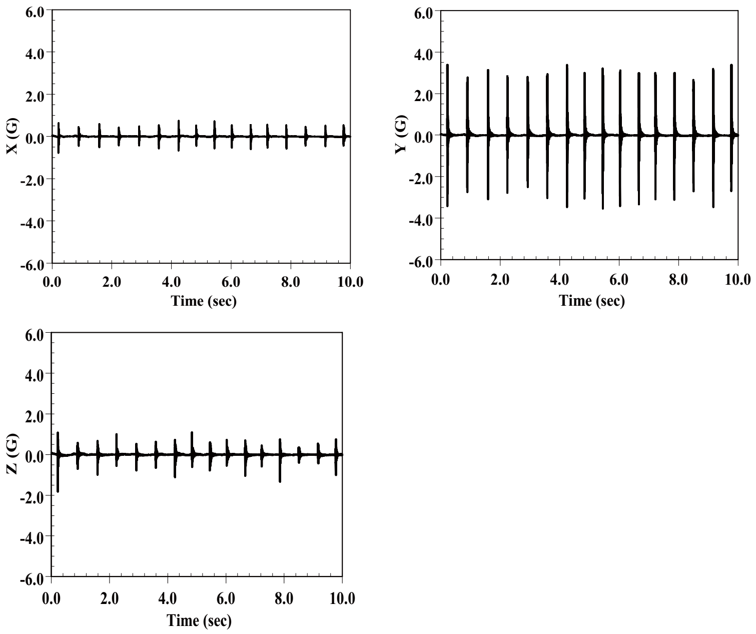

Figure 2. Acceleration time history of the three axes of the long cane
The tapping vibration signals were repeated at constant rate in the range 1.6 (1/s).
The impulse of the vibration in the Y-axis tended to be greater than any other axis.

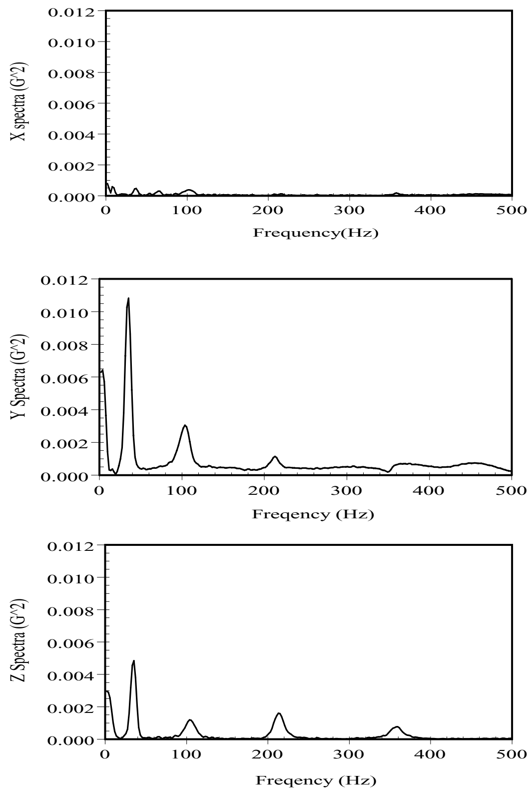

Figure 3. Frequency spectra of the three axes of the long cane
The frequencies in the power spectra extended from 0Hz to 500Hz.
The dominant frequencies were about 30Hz, 125Hz, and about 250Hz.

directed along the metacarpus bone of the hand. Z-axis perpendicular to the X-axis (both these axes are normal to the longitudinal axis of the grip). A Miniature DAQ Terminal (intercross-410, INTERCROSS Co. Ltd) was used to conduct the measurement and analyze the acquired data. The sample rate was 2,000 per sec, and each measurement duration was 10 sec. In order to measure the tapping vibration while the subject was walking, the Miniature DAQ Terminal was put on the body. The location for the experiment was an indoor area in which the blind person usually walks with a long cane.

3. Ethical considerations

We gained the approval of the medical ethics screening committee of the Kanazawa University School of Medical Science. We explained the purpose of the study, study methods. We also received the consent of both students and parents. All personal identification was removed from the data.

4. Results

Acceleration time-history and frequency spectra

The acceleration time-history and frequency spectra are shown in Figure 2 and 3. As can be seen in Figure 2, the tapping vibration signals were repeated at a constant rate in the range 1.6 s^{-1}. The impulse of the vibration in the Y-axis tended to be greater than any other axis. Regarding the frequency spectra of the tapping vibration, frequencies in the power spectra extended from 0 Hz to approximately 500 Hz, as shown in Figure 3. There were frequency peak points in the Y-axis and the Z-axis. The dominant frequencies were approximately 30 Hz, 125 Hz, and 220 Hz. Detection thresholds rise steeply below and above the range of 80 Hz to 250 Hz[6], so this range is likely to contain frequencies that are useful for conveying surface information to a pedestrian who is blind. Although it is possible to analyse a source on all frequency by frequency basis, this is both impractical and time-consuming. For this reason, 30Hz was selected as a scale of dominant frequency and 125 and 250Hz were selected as a scale of an octave band for the next experiments.

Experiment 2

Method

1. Subjects

Subjects were recruited from word-of-mouth in the community. A total of 23 individuals served in this experiment. The subjects consisted of 8 general high school students (ages 16－17), 10 computer club students (ages 16－17), and 5 blind school students (ages 15－17) (including the subject who participated in Experiment 1). They were assigned to three groups (general student group, PC student group, and blind school student group). All subjects did not have a history of a nerve related disease or an orthopedics disease, and the dominant hand was the right hand.

2. Apparatus

Tactile sensibility was assessed with the static two-point discrimination test and the moving two-point discrimination test using a Touch-Test Two-Point Discriminator (NC12776, a North Coast Medical, Inc).

3. Measurement area

The site to measure was set at the point 1/4 of a distal segment from the tip of the dominant hand's index finger.

4. Procedure

Evaluation included the static two-point discrimination test and the moving two-point discrimination test[7]. All the subjects sat in a chair at room temperature (22－25℃), and the experiment was conducted with relaxed posture. Each subject was given a full explanation about the examination before testing. In all subjects except for the blind school student group, visual stimuli were removed with the application of a blindfold. In this experiment, examiners used a Touch-Test Two-Point Discriminator. The skin sensitivity test was performed by trained examiners after the technique had been standardized. The slight distance wherein the two point's stimulus could be distinguished was measured in the index finger of the right hand longitudinally.

The initial distance of the two points was ＞2 cm, which was wide enough for almost all subjects to detect the two points. The measurement distance of two points was 2 mm, 3 mm and 5 mm from the report of a preliminary experiment, prior research[8], and the distribution density of tactile receptors. All subjects judged whether it stimulated the two-points. The order of the components of the evaluation was randomized for each session. A minimum of 10 minutes between testing sessions was allowed to minimize subject fatigue. Results were recorded on standard data-collection forms.

5. Results

When the distance of the two points was 2 mm, only two people in the general student group were not able to detect the two point's stimuli (75%). when the distance of the two points was 3 mm and 5 mm, all subjects were able to detect the two points' stimuli (100%).

Experiment 3

Method

1. Subjects

The subjects consisted of 8 general high school students (ages 16－17), 10 computer club students (ages 16－17), and 5 blind school students (ages 15－17). All of them had also participated in Experiment 2.

2. Apparatus

The two-point vibrotactile discrimination test used the two-point vibrator (Figure 4). This apparatus was an improvement of the one-point vibration apparatus that Kajimoto Designed[9]. A block diagram of the apparatus is shown in Figure 4. For each frequency used, sinusoidal vibratory stimuli were delivered to the fingertips of the right hand. This vibrator could add fingertips by generating various vibrations by the speaker (Model No. T77C16C-1, Toptone company), and could change the frequency and the amplitude. A sinusoidal electrical signal was generated by a Wide Band Oscillator (Model CR-421A, Nippon Keisoku). The output of the generator was modulated by the electric switch so that the signal was on for 1 sec. and off for 1 sec. The two-point vibrator assembly was positioned on a stand that could adjust in height, and that stand could be raised and lowered to regulate precisely the depression of the contactor into the subject's

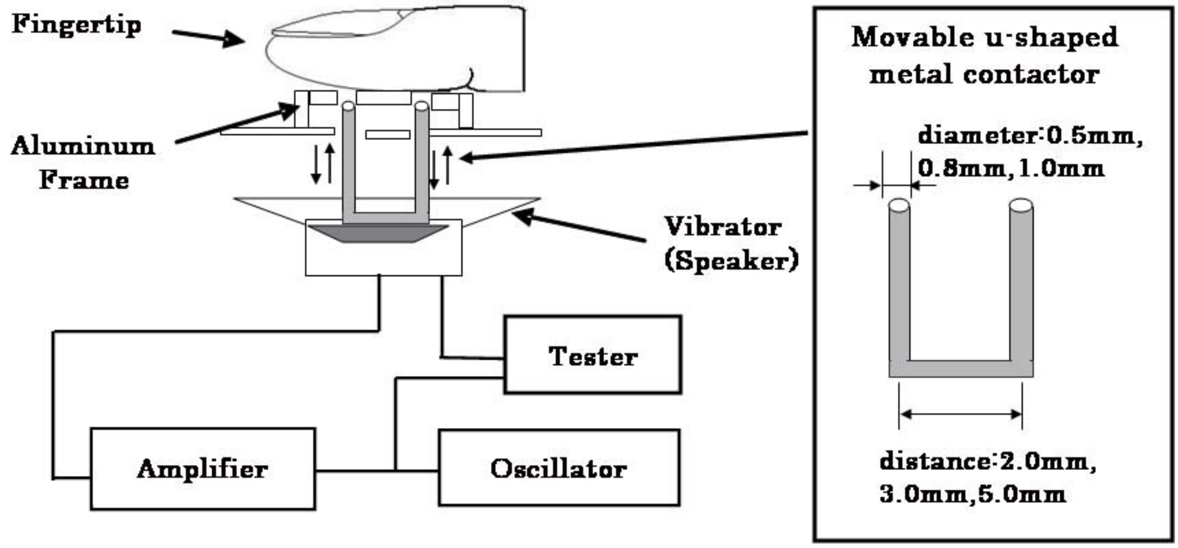

Figure 4. Block diagram of apparatus and diagram of vibrator
The two-point vibrotactile discrimination test used two-point vibrator. This device was an improvement of the one-point vibration device. Sinusoidal vibratory stimuli were delivered to the fingertips of the right hand. The diameter of contactor was three types of 0.5, 0.8, and 1.0mm. The frequencies of sinusoidal vibratory stimuli were 30, 125, and 250Hz.

fingertips. The subjects were instructed to place their right hand onto a contactor that protruded 0.5 mm above the surface of the table. The point of initial contact with the skin was determined by adjusting the height of the two-point vibrator assembly until a non-infinite electrical resistance could be read from digital multimeter (No723-03, IWATSU.CO. Ltd). The vibration amplitude can be measured by the photo reflector. The relation between the output-voltage of the photo reflector and the amplitude distance is calibrated by a height gauge. Displacement amplitudes were then calculated and recorded as dB per 1 μm peak. The contactor size was 0.2 (mm^2) (Diameter: 0.5 mm), 0.5 (mm^2) (Diameter: 0.8 mm), and 0.8 (mm^2) (Diameter: 1.0 mm). The diameters of the contactors were smaller than the contactor which Verrillo[3] used. The subject was located in a booth isolated from extraneous sound and vibration. Earplugs were worn to make high-frequency sound from the vibrator inaudible.

3. Procedure

In the two-point vibrotactile discrimination test, subjects were comfortably seated at the experimental table. They were given a full explanation about the experiment before testing. A small cushion was then placed under the wrist to stabilize the hand. The contactor intensity of the 10-Hz stimulus was adjusted by the experimenter to a level where the subject could just barely feel it on every presentation. This intensity was used as the baseline level for the series that was to follow. These initial adjustments at 10 Hz were made because that is the frequency at which subjects are least sensitive. Subjects were then presented with 3 blocks of trials, one block at each of 3 sinusoidal frequencies (30, 125, and 250 Hz). These frequencies were determined from the result of Experiment 1. Two kinds of experiments were performed. The first experiment gradually raised strength from minimum stimulation, and it measured the minimum strength at which a subject could perceive two-point vibration (Ascending series). The second experiment gradually lowered strength from maximal stimulation, and it measured the minimum strength at which a subject could perceive the two-point vibration (Descending series). The vibrotactile threshold was measured by a function of the frequency, a function of the contact maker area, and a function of the distance of two points of vibrators.

4. Results

The threshold data were analyzed by three way ANOVA with a significance level of $p < 0.05$. And

Table 1. Comparison of mean values of among three student groups, Three way ANOVA, Tukey HSD comparison; Diameter of contactor: *p<0.05, Student groups: **p<0.05.

Frequency (Hz)		30								
Distance of contactor (mm)		2			3			5		
Diameter of contactor (mm)		0.5	0.8	1.0	0.5	0.8	1.0	0.5	0.8	1.0
A general student group	Threshold (dB) (Mean)	15.23	12.96	12.35	13.90	14.80	12.09	10.92	14.40	12.22
	Standard deviation (SD)	±3.41	±2.10	±2.19	±3.04	±1.44	±1.66	±2.92	±1.99	±1.49
PC student group	Threshold (dB) (Mean)	13.61	11.58	10.45	12.11	12.49	7.81	12.89	11.82	9.96
	Standard deviation (SD)	±1.77	±3.38	±4.26	±2.23	±1.54	±4.84	±3.36	±3.54	±4.09
Blind student group	Threshold (dB) (Mean)	7.90	4.12	-1.98	7.76	5.55	-4.60	9.09	6.46	-2.16
	Standard deviation (SD)	±0.59	±4.29	±13.39	±2.81	±7.35	±7.72	±0.21	±1.42	±8.92

Diameter of contactor : *P<0.05 , Student groups : **P<0.05

Frequency (Hz)		125								
Distance of contactor (mm)		2			3			5		
Diameter of contactor (mm)		0.5	0.8	1.0	0.5	0.8	1.0	0.5	0.8	1.0
A general student group	Threshold (dB) (Mean)	9.93	9.35	2.81	7.59	6.91	1.29	7.48	7.23	1.57
	Standard deviation (SD)	±2.67	±3.25	±2.32	±3.60	±3.17	±2.67	±2.84	±7.12	±4.21
PC student group	Threshold (dB) (Mean)	-5.36	-7.15	-9.38	0.55	-5.87	-10.32	-0.11	-8.82	-7.59
	Standard deviation (SD)	±3.85	±7.64	±6.31	±6.60	±5.10	±6.08	±5.90	±9.95	±8.74
Blind student group	Threshold (dB) (Mean)	-6.49	-15.79	-15.41	-15.07	-10.33	-15.68	-3.57	-18.45	-18.05
	Standard deviation (SD)	±6.75	±5.14	±4.51	±0.45	±1.86	±1.84	±2.51	±1.05	±6.31

Diameter of contactor : *P<0.05 , Student groups : **P<0.05

Frequency (Hz)		250								
Distance of contactor (mm)		2			3			5		
Diameter of contactor (mm)		0.5	0.8	1.0	0.5	0.8	1.0	0.5	0.8	1.0
A general student group	Threshold (dB) (Mean)	-2.39	-3.13	-8.60	1.61	-1.81	-2.87	2.20	-4.20	-6.37
	Standard deviation (SD)	±8.72	±5.74	±4.36	±5.55	±6.39	±5.00	±4.03	±4.51	±3.36
PC student group	Threshold (dB) (Mean)	-17.15	-13.13	-18.64	-8.43	-12.56	-17.12	-4.44	-17.84	-14.35
	Standard deviation (SD)	±2.17	±8.18	±5.11	±6.54	±7.32	±7.79	±2.64	±6.44	±8.24
Blind student group	Threshold (dB) (Mean)	-22.48	-24.01	-25.43	-28.10	-23.78	-24.51	-14.24	-25.49	-22.63
	Standard deviation (SD)	±1.41	±4.21	±5.07	±7.38	±2.38	±3.63	±4.57	±0.87	±3.86

Diameter of contactor : *P<0.05 , Student groups : **P<0.05

Tukey was used for pos-hoc testing. SPSS (Version 17.0 SPSS Inc.) was used for all statistical analyses. Each student type was a between-group variable (general student group, PC student group, and blind student group), and contactor size (Diameter: 0.5, 0.8, and 1.0 mm) and the contactor distance (2.0, 3.0, and 5.0 mm) were within-group variables for the three stimulus frequencies (Table 1, Table 2).

1) Relationship between threshold and each student groups

The effects of the threshold, student groups, the diameters of the contactor, and the distance of the contactors were analyzed using a three-way ANOVA. For this analysis, there was a main effect of student groups at the three frequencies ($p < 0.05$). Tukey post hoc comparisons showed significant difference in threshold between all student groups ($p < 0.05$). In the case of 125 and 250Hz, it is shown that the ability of tactile sensibility is high in order of a general student group, PC student group, and blind school student group. However, it can not always say that the ability of tactile sensibility was high in order of a general student group, PC student group, and blind school student group at 30Hz (interaction between student groups and diameters of contactor).

2) Relationship between threshold and contactor size

Table 1 shows the functional relationship

Table 2. Experiment 3 Results of three way ANOVA to Explore the Effects of Student groups, Distance of contactor, and Diameter of contactor on threshold of each frequency.

Effect	Sum of squares	df	Mean Square	F-ration	P-value
30 Hz					
Student groups	472.76	2	236.38	303.01	< 0.05 *
Distance of contactor	1.21	2	0.60	0.77	> 0.05
Diameter of contactor	139.51	2	69.75	89.42	< 0.05 *
Student groups×Distance of contactor	6.68	4	1.67	2.14	> 0.05
Student groups×Diameter of contactor	86.58	4	21.65	27.75	< 0.05 *
Distance of contactor×Diameter of contacor	11.17	4	2.79	3.58	> 0.05
125 Hz					
Student groups	1697.64	2	848.82	74.93	< 0.05 *
Distance of contactor	0.75	2	0.37	0.03	> 0.05
Diameter of contactor	241.74	2	120.87	10.67	< 0.05 *
Student groups×Distance of contactor	17.09	4	4.27	0.38	> 0.05
Student groups×Diameter of contactor	34.39	4	8.60	0.76	> 0.05
Distance of contactor×Diameter of contacor	39.35	4	9.84	0.87	> 0.05
250 Hz					
Student groups	1905.928	2	952.964	138.052	< 0.05 *
Distance of contactor	43.275	2	21.637	3.135	> 0.05
Diameter of contactor	129.218	2	64.609	9.36	< 0.05 *
Student groups×Distance of contactor	41.343	4	10.336	1.497	> 0.05
Student groups×Diameter of contactor	17.417	4	4.354	0.631	> 0.05
Distance of contactor×Diameter of contacor	105.931	4	26.483	3.836	< 0.05 *

NOTE: Three way ANOVA: 3(Student groups; general student group, PC student group, and Blind student group)×3(Distance of contactor; 2, 3, and 5mm)×3(Diameter of contactor; 0.5, 0.8, and 1.0mm) with repeated measures on the latter two factors. At 125 and 250Hz, there are significant main effects of student groups, diameter of contactor.

between threshold and contactor size for each student group on the fingertip. The main effect of contactor size is significant to each student group at the three frequencies ($P<0.05$). Tukey post hoc comparisons shows significant differences in the contactor size. In the case of 125 and 250Hz, the threshold for two-point discrimination decreases with increasing contactor size between each student group. However, in the case of 30Hz, it is not always the case that the threshold for two-point discrimination decreases with increasing contactor size at each student group (interaction between student groups and diameters of contactor).

3) Relationship between threshold and the distances of contactor

Table 2 shows that there is no significant effect of the distances of contactor on the fingertip at the three frequencies.

Discussion

A precedent study in the sense of touch gave one point of vibration stimulation in the thenar of the right hand and measured the threshold. Verrillo[3] found that frequency properties existed in the relations of size and threshold of the contactor of one point of vibration stimulation. However, it was not explained as a phenomenon of the threshold in those days by the mechanism of the receptor and a viewpoint of the dissection physiology. Afterwards, the response of each receptor was measured directly and we understood the relation between each receptor and the senses[11]. In this study, the static two-point discrimination test, moving two-point discrimination test, and two-point vibration discrimination test were used as this vibrotactile evaluation system. The significance of the static two-point discrimination test is examination evaluating reaction to sustained contact. The moving two-point discrimination test is an examination evaluating reaction to dynamic contact, and the target receptor is the Meissner corpuscle. In addition, the one-point vibration discrimination test is known as an evaluation method of vibrotactile sensitivity. However, in the case of one-point vibration stimulation, a contactor may give vibration stimulation in a point that does not exist between the receptors. Therefore, we used the two-point vibration discrimination test to increase the probability that a contactor stimulates receptors directly and to evaluate reaction for fast vibration stimulation. In this examination, under the hypothesis that using fingertips for a certain purpose more frequently increases the ability of tactile sensibility to stimulation, we chose the computer club high school students who had been using computers for a long time and a blind school student who uses a long cane. In the case of the long cane operation, the fingertip receives stimulation of specific frequencies such as static contact, dynamic contact, and contact by vibration. The stimulation of the specific frequency was 30, 125, and 250Hz. Therefore, it may be said that performing vibration stimulation to fingertips was suitable for an evaluation of tactile sensibility. In addition, we paid attention to the Meissner corpuscle and the Pacinian corpuscle distributed over the fingertip as a receptor in regards to vibration stimulation. The Meissner corpuscle showed the lowest threshold at approximately 40 Hz[12], and it is a globe of a spiral structure of 32 μm in diameter. The distribution density at the finger-tip is 140/cm^2 (as for the individual distance of approximately 1.0 mm). On the other hand, the Pacinian corpuscle shows the lowest threshold at approximately 200 Hz[13], and it is an oval of 0.75 mm × 2.50 mm. The distribution density is 22/cm^2 (as for the individual distance of approximately 2.5 mm). Many previous studies have demonstrated the effect that one-point of vibration has on tactile sensitivity[14,15]. They defined the threshold as the lowest value at which subjects were able to sense vibration. However, in the case of this examination, we examined the threshold at the fingertip with two points of vibration. In addition, we defined the threshold as the lowest value at which subjects could discriminate against two points of vibration. Novak[16] studied an evaluation method of the hand sensibility of a sighted person and a blind person. They reported that the blind person was superior to the sighted person in sensitivity. As a result of examination 3, it was not always the case that the vibrotactile threshold was low in order of the blind school student group, PC student group, and general student group at 30Hz (interaction between student groups and diameters of contactor). However, in the case of 125 and 250Hz, the vibrotactile threshold was always low in order of the blind school student group, PC student group, and general student group. This was a result which was the same as the previous results at 125 and 250 Hz. Verrillo[3] and Gescheider[10] reported that the threshold decreased with an increase in contactor area at high frequencies as for the effect of the contactor area. Johansson[11] reported that the Pacinian corpuscle had only one zone of maximal sensitivity, and the rise of threshold from this zone to the periphery of the receptive field is very gentle. In case of the three student groups, the threshold for two-point discrimination decreased with increasing contactor size at 125 and 250Hz. This was a result which was the same as the previous results. However, it seems that the vibrotactile threshold showed a low value because the two-point vibration discrimination test could add more vibratory stimulation to both the Meissner corpuscle and Pacinian corpuscle than the one-point vibration discrimination test. The PC student group practiced typing every day (more than five hours). The blind school student group lived by the vibration from their fingers every day as a source of information. These activities continue giving vibratory stimulation consistently to the Meissner corpuscle and Pacinian corpuscle, which exist numerously in the fingers. On the other hand, the general school student group is not given vibratory stimulation to their fingertips consistently. Therefore, the PC student group and the blind school student group were more sensitive to vibratory stimulation (125 and 250Hz) of the fingertip than the general school student group. In other words, it may be said that our hypothesis is suitable for only a high frequency (125Hz and 250Hz).

Conclusion

This study was performed to appropriately evaluate the hypothesis that using fingertips more frequently increases the ability of tactile sensibility to stimulation. The subject was a general student group, PC student group which used fingertips for five hours or more a day, and a blind school student group. The static two-point discrimination test, moving two-point discrimination test, and two-point vibrotactile discrimination test were used for the experiment method. The following resulted from these experiments.

(1) The long cane had frequency peak points in the Y-axis and the Z-axis. The dominant frequencies were approximately 30, 125, and 250Hz.

(2) In the distinction in the two-point vibrotactile discrimination test, even if contactors of 1 mm or less in diameter are used, people can distinguish at 30, 125, and 250Hz.

(3) In two point vibrations, there were significant main effects of the three student groups and contactor sizes, and there was an interaction between student groups and diameters of contactor at 30Hz.

(4) In two point vibrations, there were significant main effects of the three student groups and contactor sizes at 125 and 250Hz.

(5) Using fingertips for a certain purpose more frequently enhances the discriminability of two-point vibration in PC student group and blind school student group.

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指先の使用による触覚能力の強化

吉岡　　学，清水　順市*

要　　旨

本研究の目的は、指先を使用することで触覚識別能力が高められることを証明することである。対象者は、一般学生８名、コンピュータ・クラブ学生10名（タイピング時間が一日５時間以上)、盲学生５名である。

最初に白杖が有する固有振動特性を調べた。次に静的２点識別、動的２点識別（２点間距離：２mm，３mm，５mm）および２点振動識別（２点間距離：２mm，３mm，５mm，接触子径：0.5mm，0.8mm，1.0mm、振動数：30Hz，125Hz，250Hz）を用いて評価した。

その結果、静的２点識別及び動的２点識別では、２点間距離が２mmにおいて、一般学生群の識別率は75％であり、その他の２群の識別率は100％であった。３mm，５mmにおいて、識別率は全ての群において100％であった。　２点振動識別では、振動数30Hzで３群間と接触子径間には交互作用がみられた（$P<0.05$）が、それぞれの要因に有意な差がみられた。125Hz、250Hzでは、接触子径および３群間に有意な差がみられた（$P<0.05$）。触覚識別能力は一般学生群、コンピュータ・クラブ学生群、盲学生群の順に高かった。

以上より、２点振動に対する触覚識別能力は、指先をある目的に対して使用することにより高まる可能性を示唆した。