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Late-News Paper

Development of Tactile Display for Measuring Human Dexterity

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ABSTRACT

We aim to develop a tactile display that can easily evaluate a person's dexterity. In this study, we focus on the stick rabbit illusion as a fundamental phenomenon and investigate its relationship with dexterity. Through our investigation, we clarified that stick rabbit illusion can be used as dexterity tester.

1 Introduction

In Japan, the population is aging worldwide, about 29% of the population will be aged 65 years or older in 2022 [1]. Since the elderly seems to be poor at dexterous operations, it is expected that the number of people who can perform dexterous operations will decrease in the future. Thus, rehabilitation that maintains dexterity is considered necessary. However, the rehabilitation cannot be effectively implemented unless its effects are fed back to the patients. To be effective for rehabilitation of dexterity maintenance, a dexterity tester is required. Moreover, if the tester can be easily used at medical facilities and at home, it could be useful for daily rehabilitation. Thus, the tester should be a wearable device.

On the other hand, there are two phenomena that seem to be related to "human dexterity": the cutaneous rabbit illusion [2] and the stick rabbit illusion [3]. The cutaneous rabbit illusion, as shown in Figure 1, is a phenomenon in which subjective sensation deviates from the actual stimuli. About the stimuli of the cutaneous rabbit illusion, at first a series of quick, light blows are given to a common point ① and ② on the skin. Second, another blow is given to another point ③. In this illusion, the feeling of the second blow point ② is felt between the two points ① and ③, despite blows are given to a common point ① and ②. The stick rabbit illusion is an extension of the cutaneous rabbit illusion to a tool, as shown in Figure 2. When a stick is struck as in the case of skin, the feeling of the strike point ② is shifted toward the strike point ③. In a previous study, the degree of occurrence of the two illusions was examined for normal subjects and those with autism spectrum disorder. The results showed that the degree of occurrence of the stick rabbit illusion was significantly lower for those on the autism spectrum disorder [4].

In this study, we investigate whether the stick rabbit illusion is useful for evaluating dexterity. First, we will develop a device to generate illusions. Second, we investigate the relationship between the time interval of stimuli and the position of the illusions, as well as the relationship between dexterity and the illusions by means of questionnaires.

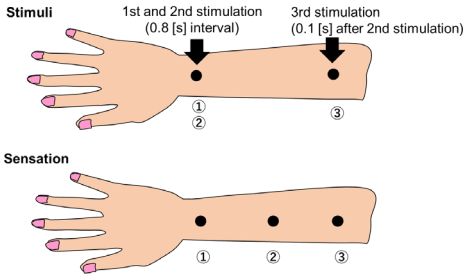

Fig. 1 Cutaneous Rabbit Illusion

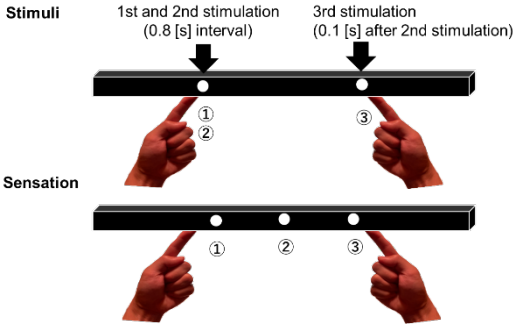

Fig. 2 Stick Rabbit Illusion

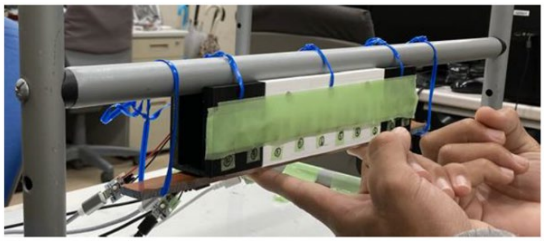

Fig. 3 Wearable device of Stick Rabbit Illusion

2 Experimental devices

The following is a description of the experimental apparatus. We developed a device (Figure 3) for presenting the stick rabbit illusion. The stick rabbit illusion device consists of six solenoids (SSBH-0830, TAKAHA KIKO CO., LTD, Japan), which are hung horizontally in parallel, as shown in Figure 3. The subject holds two points of a square aluminum rod with the index fingers of both hands and touches the underside of the solenoid array with the aluminum rod. 6 solenoids are controlled by an Arduino.

3 Evaluation of dexterity

The purpose of this study is to clarify the relationship between the stick rabbit illusion and dexterity. For this purpose, the dexterity is evaluated in a questionnaire format. This evaluation index consisted of 17 questions, each of which is answered using a 5-point scale (1. strongly disagree, 2. disagree, 3. neither agree nor disagree, 4. agree, 5. strongly agree). The sum of these questionnaire results is used as the dexterity score.

Table 1 Evaluation of dexterity

	Item	Rating
Q. 01	Good at operating the keyboard	1·2·3·4·5
Q. 02	Good at threading needles	1·2·3·4·5
Q. 03	Good at drawing	1·2·3·4·5
Q. 04	Got good grades in arts and crafts class	1·2·3·4·5
Q. 05	Like detailed work	1·2·3·4·5
Q. 06	Good at games	1·2·3·4·5
Q. 07	Had good grades in sports	1·2·3·4·5
Q. 08	Have played sports that use tools	1·2·3·4·5
Q. 09	Good at sports that use tools	1·2·3·4·5
Q. 10	Didn't take long to ride a bicycle for the first time	1·2·3·4·5
Q. 11	I am highly concentrated	1·2·3·4·5
Q. 12	Care about the details	1·2·3·4·5
Q. 13	Learn work quickly	1·2·3·4·5
Q. 14	Can do things in parallel	1·2·3·4·5
Q. 15	It is said that you are resourceful	1·2·3·4·5
Q. 16	Often told by family and friends that you are dexterous	1·2·3·4·5
Q. 17	I think I'm a handy person	1·2·3·4·5

4 Experiment 1

4.1 Experimental condition

The basic conditions for the time difference in the stick rabbit illusion have been clarified by previous studies. The basic conditions are known that the time between stimuli ① and ② is about 0.8 [s], and that the time between stimuli ② and ③ is 0.1 [s] or less. On the other hand, there is little knowledge about the distance between ② and ③ that maximizes the probability of the occurrence of the illusion. Thus, we investigated the probability of the occurrence of the illusion by using the distance between ② and ③ as a variable. The experimental conditions are shown in Table 2. There are six participants in this experiment. In the evaluation, the aluminum rods were numbered from end to end from 1 to 10. Participants in the experiment were asked to respond numerically to the position that they felt stimulated by each of the stimuli ①, ②, and ③. The stick rabbit illusion is defined as the illusion of feeling the stimulus ② between ① and ③. Thus, only the responses that matched this definition were considered as the occurrence of the illusion.

Table 2 Experimental condition 1

condition	value
Time difference T_b [s] between ① and ②	0.8 [s]
Time difference T_c [s] between ② and ③	0.1 [s]
Distance between ② and ③	25, 50, 75, 100, 125 [mm]

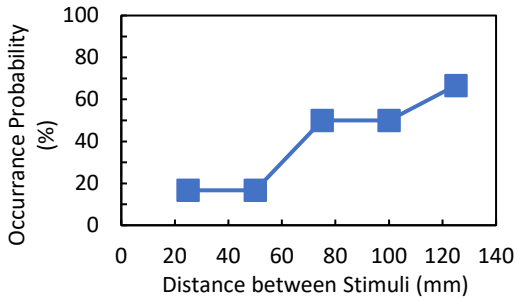

Fig. 4 Occurrence probability of stick rabbit illusion

4.2 Result 1

The results revealed that the stick rabbit illusion is more likely to occur when the distance between the second and third stimuli was large (Figure 4). Based on this result, we will proceed with the next experiment using the distance of 125 [mm] between ② and ③.

5 Experiment 2

5.1 Experimental condition

In this experiment, we investigate the relationship between the stick rabbit illusion and dexterity. We expected that more dexterous people are more sensitive to changes in the stick rabbit illusion caused by changes in the stimulus conditions.

Thus, we investigate the change in the position of the stick rabbit illusion when the time difference between stimuli ① and ② is changed in seven steps (Table 3: condition 2-A). Next, we investigate the change of the illusory position when the time difference between stimuli ② and ③ is changed in 10 steps (Table 4: condition 2-B). The position of the illusion is evaluated using standardized coordinates as shown in Figure 5. In the standardized coordinates, the distance between the perceived positions of stimuli ① and ③ is set to 1. Then, the distance of the position where the subject felt the stimulus ② from the position where the subject felt the stimulus ① is calculated. After being stimulated the parts of ①, ②, and ③, subjects responded to the location of each of the three stimuli based on the experiment 1 rule and the standardized coordinates were calculated from the results of these responses.

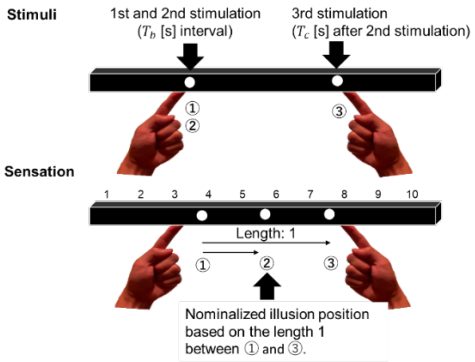

Fig. 5 Stimulus position of Stick rabbit illusion

5.2 Result 2

Table 3 Experimental condition 2-A

condition	value
Time difference T_b [s] between stimuli ① and ②	0.5 - 1.2 [s] (0.1 [s] interval)
Time difference T_c [s] between stimuli ② and ③	0.1 [s]
Distance between stimuli ② and ③	125 [mm]

Table 4 Experimental condition 2-B

condition	value
Time difference T_b [s] between stimuli ① and ②	0.8 [s]
Time difference T_c [s] between stimuli ② and ③	0.05～0.5 [s] (0.05 [s] interval)
Distance between stimuli ② and ③	125 [mm]

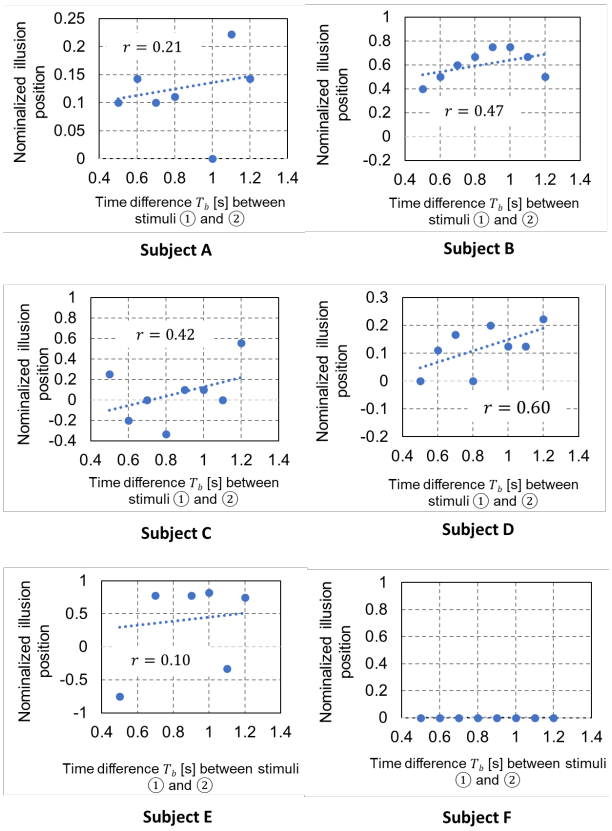

Fig. 6 Relationship between T_b and nominalized illusion position in each participant

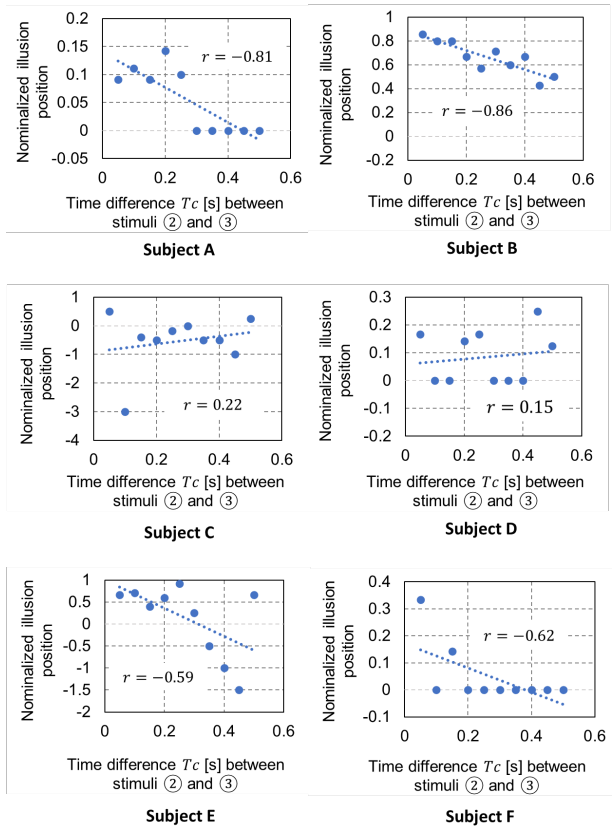

Fig. 8 Relationship between T_c and nominalized illusion position in each participant

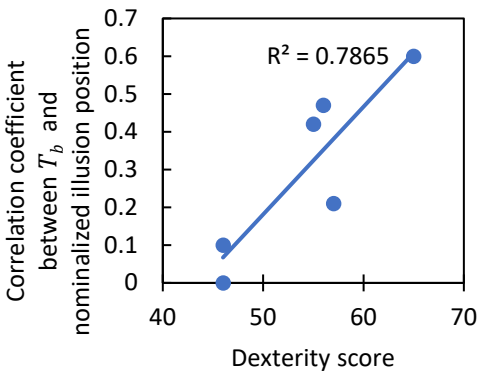

Fig. 7 Relationship between dexterity score and correlation coefficient between T_b and nominalized illusion position

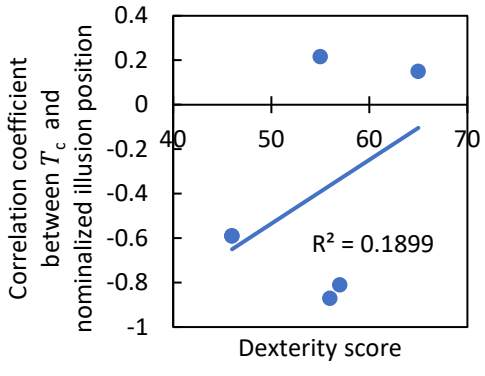

Fig. 9 Relationship between dexterity score and correlation coefficient between T_c and nominalized illusion position

First, the correlation coefficients between the time difference of ① and ② and the illusory position are calculated for each subject (Figure 6). Then, the correlation coefficients between this correlation coefficients and the dexterity scores of each subject are obtained (Figure 7). As a result, a very high correlation coefficient of 0.89 is obtained. Similarly, Figure 8 shows the relationship between the correlation coefficients of the time difference between ② and ③ and the illusory position. Figure 9 shows the correlation coefficient between this correlation coefficient and the dexterity score. In this case, a moderate correlation coefficient of 0.43 is confirmed.

Therefore, this result suggests that subjects who perceive that the illusory position moves in the direction of ③ are dexterous people when the time difference between ① and ②, or between ② and ③ is set long.

6 Discussion

In this session, we consider the reason why the illusory position changes depending on the length of the time difference between successive stimuli. This may be due to the well-known phenomenon in tactile perception that a short time difference between successive stimuli causes excitation, resulting in a stronger association with the second stimulus. In the stick rabbit illusion, the sensation of position is determined only by the force acting on the fingertip, so when the second stroke is strongly felt, the third stroke is relatively weak, and the estimated position of the second stroke becomes closer to that of the first stroke. Conversely, if the interval between the first and second hits becomes longer, the excitability effect described above disappears, and the estimated position of the second hit becomes closer to that of the third hit. The more dexterous the people are, the more subtle the force sensation becomes. The more dexterous people perceive subtle changes in the sense of force, the stronger the above tendency appears, and this is thought to be the reason for the above results.

7 Conclusions

We focused on the stick rabbit illusion as a method to quantitatively evaluate dexterity. To investigate the relationship between stick rabbit illusion and dexterity, we performed the psychophysical experiment. As a result, we found that dexterous individuals are more sensitive to changes in illusions. In the future, we plan to increase the number of subjects and conduct further studies.

Acknowledgments

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