

Presenting a pseudo-force sensation using a clothespin

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Abstract. Here, we describe a phenomenon in which a pseudo-force sensation can be elicited by pinching the finger of a participant using a clothespin. When the clothespin pinches the finger from the palm side, a pseudo-force is felt in the direction in which the hand naturally bends, and when the clothespin pinches the finger from the back of the hand, the pseudo-force is felt in the extension direction. We investigated the occurrence frequency of this phenomenon and assessed the possibilities for use as a human interface. We examined the relationship between the location/pinch direction and force/posture elicited. As a result, we confirmed that a pseudo-force sensation occurred in the extension and bending directions, except for when the distal phalanx was pinched from the back side of the hand. In future work, we plan to investigate the cause of this phenomenon by developing skin deformation-based or compression based devices, with the goal of application in VR environments.

Keywords: Clothespin, Pseudo force, Human interface, Virtual Reality.

1 Introduction

When a person touches an object, they receive information about hardness, size, and texture as tactile force information. Several methods for reproducing haptic information in virtual reality (VR) space have been proposed. These include the use of external skeletal devices [1][2] and gripping devices [3][4]. However, these methods are not optimal, as they require large equipment and complicated mechanisms.

To tackle this issue, several researches groups have attempted to use illusion phenomena to present force sensations. A typical example of this is the presentation of a pseudo-force sensation via pressure to the skin on the fingerpads [5][6][7][8]. While such devices are often portable and suitable for presenting tactile sensations in VR space, practical issues remain. For instance, as these devices completely cover the fingerpad, in practical situations such as those that necessitate frequent use of a mechanical keyboard or other input devices during the VR experience, the device must be taken off.

Several reports have proposed methods of tactile presentation that do not cover the fingerpad, but instead are attached to the middle phalanx [9][10]. However, these have been aimed at the presentation of tactile cues, and are not intended to provide realistic force illusions. Other proposals have been centered on electrical muscle stimulation [11][12], which can present clear force sensations at the fingertip without covering the

fingerpad. However, the use of electrical stimulation is complicated by several challenges, such as the stability of the sensation.

In this study, we describe a pseudo-force sensation that might be applicable to finger force presentation without covering the fingerpad. The phenomenon is elicited by pinching a clothespin on the middle phalanges. In this method, when the clothespin pinches the finger from the palm side, the pseudo-force is felt in the direction in which the hand naturally bends, i.e., the bending direction. When the clothespin pinches the finger from the back side of the hand, a pseudo-force is felt in the extension direction (Fig. 1). Although the mechanism of this phenomenon has not been investigated, we confirmed that compression and skin deformation occurred when the clothespin was used to pinch the hand (Fig. 2).

The goal of this study was the development of a pseudo-force presentation device that could reproduce the clothespin phenomenon. In this paper, we report on our preliminary investigation of the occurrence frequency of this phenomenon and assess the possibilities for use as a human interface.

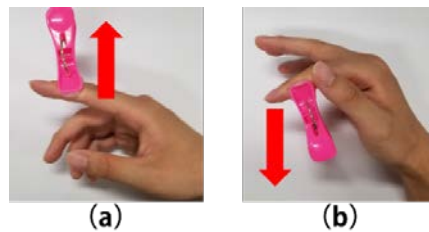


Fig. 1. The direction of the pseudo-force sensation: (a) extending, pinched from the back of the hand, (b) bending, pinched from the palm side of the hand



Fig. 2. Skin deformation occurs in the extension direction when the clothespin is attached at the back side of the hand, and in the bending direction when the clothespin is attached from the palm side of the hand.

2 Experiment

2.1 Outline of experiment

In this experiment, we investigated whether the pseudo-force sensation occurred in the extension direction or the bending direction when the location of the pinching was varied. The strength of the sensation was also quantified.

2.2 Experimental conditions

Participants were six men (21 to 24 years old, all right-handed) who were laboratory members. The experimenter instructed them to keep their eyes closed and not resist the force sensation that they felt during the experiment. To identify the stimulation sites where this phenomenon occurs, we divided the finger into five parts, A to E, as shown in Fig. 3. The experimenter stimulated each site from the back or palm side of the hand using a clothespin. A, C, and E refer to the distal phalanx, middle phalanx, and proximal phalanx of the finger, and B and D are the joints that connect these regions.



Fig. 3. Stimulation site of index finger

2.3 Experimental procedure

As shown in Fig. 4, the participants placed their right forearm on the armrest, and the experimenter pinched a specific part of their index finger using a clothespin. The experimenter first asked the participants to state the strength of the force sensation and then to state the subjective position of the finger using a 7-level Likert scale. Number 4 was set as "feel the force sensation in neither direction" for the former question and "not moving in any direction" for the latter question. Number 7 indicated that the participant felt the force or posture towards the back side of the hand, and number 1 indicated that the force or posture was felt towards the palm side. There were three repetitions for each of five positions and two pinching directions, for a total of 30 trials. The order of the trials was randomized.



Fig. 4. Overview of the experiment

2.4 Experimental results

Fig. 5 (a) shows the experimental results with respect to force sensation. The vertical axis represents the subjective force strength and the horizontal axis represents the stimulation site. We performed Wilcoxon's signed rank test assuming that the normal force strength for all participants was 4. As a result, we found a significant difference between all conditions except for that in which site A was pinched from the back side of the hand.

Fig. 5 (b) shows the data regarding the subjective posture of the finger. The vertical axis represents the subjective posture of the finger and the horizontal axis represents the stimulation site. We performed Wilcoxon's signed rank test assuming that the normal posture of the finger for all subjects was 4. We found a significant difference between all conditions except for that in which site A and B were pinched from the back side.

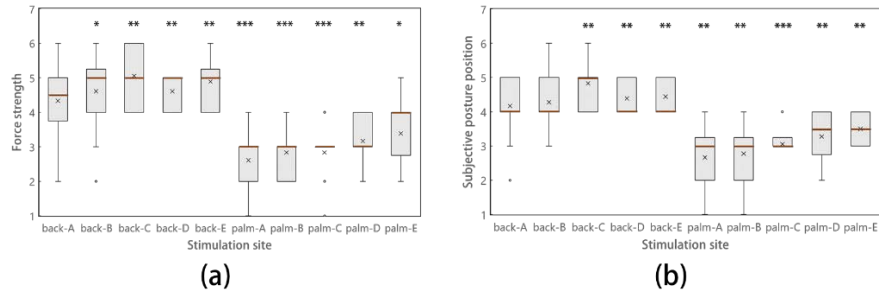


Fig. 5. (a) the subjective force strength, (b) the subjective posture of the finger
 (*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$)

3 Discussion

We examined the locations at which the pseudo-force sensation occurs in the extending and bending direction, with the clothespin applied from either the palm side or the back side of the hand.

We confirmed that the force and posture illusion occurred in both the extension and bending directions, except when the fingertip was pinched from the back side of the hand. As the sensation is quite stable, it might be possible to use it to create the sensation of touching an object in VR space, which has already been established using the head-type hanger reflex [13].

There are several candidate mechanisms for this phenomenon. One is that deformation of the skin induces the force illusion. This has been observed in many other parts of the body [14][15]. The hanger reflex may be similar to this phenomenon. In the hanger reflex, placement of a wire hanger on the head elicits involuntarily head rotation. The hanger reflex has been confirmed at a plurality of sites such as the wrist and the waist [16][17]. The hanger reflex is caused by compression of the body via a wire hanger [18], and the direction of rotation is the same as the direction of skin deformation

[19]. In the clothespin phenomenon in the present study, skin deformation occurred following pinching of the fingerpad via a clothespin, and the direction of pinching was the same as that of the pseudo-force sensation perceived by the user.

Other possible mechanisms for this phenomenon cannot be excluded. For example, mechanical stimulation to the finger tendon might stimulate sensory nerves around the tendon, which could elicit kinesthetic sensations similar to a kinesthetic illusion [20][21]. There is also the possibility that the tendon is physically pulled by the pinching action. Until further research is conducted, whether some or all of these factors are involved is unclear.

4 Conclusion

In this paper, we describe a new illusion in which pinching a finger with a clothespin produces an extension or bending force. We examined the relationship between the location/pinch direction and force/posture elicited. As a result, we confirmed that a pseudo-force sensation occurred in the extension and bending directions, except for when the distal phalanx was pinched from the back side of the hand.

Although the mechanism underlying this phenomenon has not yet been determined, we highly speculate that it is a type of hanger reflex. In future work, we plan to investigate the cause of this phenomenon by developing skin deformation-based or compression based devices, with the goal of application in VR environments.

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