Enhancement of Perceived Force from the Hanger Reflex on Head and Ankle by Adding Vibration

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Abstract.
The "Hanger Reflex" is a phenomenon in which a participant involuntarily rotates their head when a wire hanger is attached it, and has also been observed on the wrist and the ankle. Moreover, the force caused by the Hanger Reflex on the wrist is enhanced by adding a vibration stimulus. These phenomena might be potentially useful for the rehabilitation of movement disorders characterized by abnormal posture. In this paper, we generalize this "vibration effect" on the Hanger Reflex by applying vibration to the head and ankle. We developed devices to generate both skin deformation and vibration, and conducted a user study. We observed that all participants perceived the enhancement of the force, and slightly rotated the stimulated parts of the body.

Keywords: Hanger Reflex, Haptic display, Perceptual illusion, Skin stretch

1 Introduction

In the field of virtual reality and mediated sports training, force feedback plays an important role in improving the immersion of the system and in increasing training efficiency. Force feedback is also effective in medical fields such as rehabilitation, because it can teach correct posture or motion to patients.

However, the widespread use of conventional force feedback devices remains limited, because of issues of size, price, and energy consumption. Conventional devices present a physical force to the user using actuators such as motors. Therefore, whether a device can present a posture to the user or not depends on the performance of the actuator, and high-cost actuators are required to achieve a high-quality experience.

To address these issues, many methods that manipulate the perception of force (i.e. perceptual illusions) have been proposed in recent years [1–5]. These methods induce a perceived force using haptic or visual stimuli, and can be realized by devices with lower sizes, prices, and energy consumption. However, the strength of the force that can be induced by such methods is limited, and it is difficult to use them to present a large motion.

One phenomenon that can induce a large motion is called the Hanger Reflex. In this phenomenon, a participant rotates their head involuntarily when they wear a wire

hanger on their head [6][7]. During this sensory illusion, the participant feels as if their head is being rotated by someone else. Sato et al. [8][9] confirmed that the deformation of the skin caused by pushing specific points on the head contributes to this phenomenon. The Hanger Reflex on the head has been applied to the treatment of the movement disorder called “cervical dystonia” involving involuntary abnormal head posture [13], and has additionally been observed on the wrist, waist, and ankle [10] [11].

Recently, we reported that a perceptual force caused by the Hanger Reflex on the wrist is enhanced by adding vibration stimulus [12]. Because these phenomena are associated with a specific change in posture with small latency, they are promising avenue for application to the field of virtual reality and sports.

This paper is the generalization of this finding, by adding the vibration stimulus to already known Hanger Reflex sites, particularly the head and ankle. We developed devices to present both skin stretch and vibration, and conducted a user study to confirm the phenomenon.

2 Devices

2.1 Device for the head

In the Hanger Reflex on the head, the "sweet spots"[8], which efficiently induce the Hanger Reflex, are located on the front side of temporal region and the back side of the other temporal region. We prepared an elliptical shape device that is made of CFRP(Carbon Fiber Reinforced Plastics) and deforms elastically [13][14](Fig. 1). When the device is worn and rotated slightly, it deforms and presses the head to induce the Hanger Reflex (Fig. 2). To present the vibration stimulus, we placed two vibrators (Vibro-Transducer Vp2, Acouve Laboratory Inc.) on the device, which are driven by the signal generated by a PC and amplified by an audio amplifier (RSDA202, RASTEME SYSTEMS Inc., Niigata, Japan) (Fig. 3).

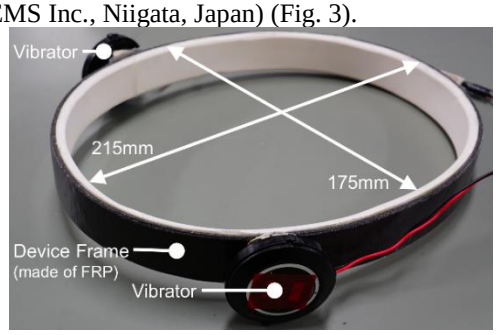

Fig. 1 The developed device for the head: the device is made of FRP, so it deforms elastically when the user wears it.

Fig. 2 Procedure for inducing the Hanger Reflex on the head using the device

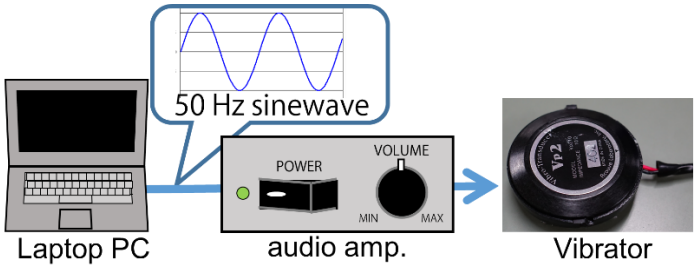

Fig. 3 The system for the hanger device: the laptop PC generates 50Hz sinewave audio signal and the amplified signal is outputted by the vibrator

2.2 Device for the ankle

We also prepared a device to produce skin deformation on the ankle and trigger the Hanger Reflex. The device is U-shaped and made of ABS resin (Fig. 4). The wave-shaped part enables the device to bend elastically, and the open part of the device is fastened by Velcro to induce the Hanger Reflex more strongly (Fig. 5). We also placed two vibrators on the sides of the device, like for the head mounted device.

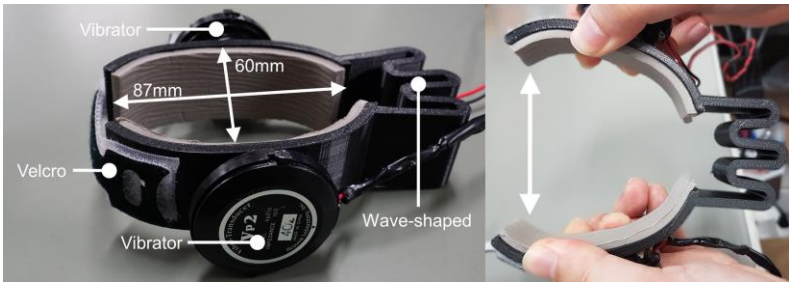

Fig. 4 The developed device for the ankle: the device deforms elastically because of the wave-shaped part

Fig. 5 Procedure to induce the Hanger Reflex on the ankle using the device

3 User study

To confirm that the enhancement of the Hanger Reflex by adding vibration occurs in naïve users, we conducted a user study. We recruited four laboratory members (four males, aged 21-23) who were naïve to this phenomenon. The participants were asked to wear the device and confirm whether the Hanger Reflex occurred, and then the experimenter presented the vibration after the confirmation. The presented vibration was a 50 Hz sinusoidal wave, which has previously been found to be the most effective in the Hanger Reflex on the wrist. We conducted this confirmation because we have previously noticed that the vibration can enhance the Hanger Reflex, but cannot generate it alone. After applying the device, they were interviewed about the changes in perceived force before and after the vibration stimulus was presented.

In case of the head-mounted device, all participants perceived the rotational force caused by the Hanger Reflex. The Hanger Reflex induced by the developed device generated a strong enough force to rotate their head involuntarily. When we additionally presented the vibration stimulus, all participants reported that they perceived an enhancement of the force. The result was shown not only in their comments, but also in the additional involuntary rotation of the head. We obtained one comment from the participants, which was: "I could oppose the force from the Hanger Reflex alone, but it was difficult to oppose the force from both the Hanger Reflex and the vibration, so I allowed this force to move me." We observed that some participants rotated their head to near the limit of the range of motion. Also, one participant commented on how the enhancement felt: "By presenting the vibration, I felt as if the Hanger Reflex occurred repeatedly."

In case of the ankle device, all four participants perceived the rotational force caused by the Hanger Reflex. When we additionally presented the vibration stimulus, all participants reported that they perceived the enhancement of the force. We applied the device to the participants in two postures: sitting, and standing on one foot, the one that was not wearing the device. The participants felt the force more clearly when they were standing on one foot. This result may imply that friction between the leg and the chair occurred and impeded the perception of force from the phenomenon.

Based on the results of the study, we can advance a hypothesis as to why this phenomenon occurs. In the case of the wrist, we propose two candidate reasons. First, the direction of the skin deformation was asymmetric, because we presented a symmetric

vibration (sinewave) to the deformed skin, which was generated by the device in advance. Second, the presented vibration was propagated to the muscle spindle and tendon that rotates the wrist, causing hyperextension kinesthesia [15]. Hyperextension kinesthesia is a phenomenon that is caused by presenting a vibration stimulus to the tendon, and induces the feeling of a bending joint without the actual movement of the joint. In this study, the muscles that move the head and ankle are not located around the stimulated area, and it is difficult to conclude that the second candidate relates this phenomenon. Therefore, the first candidate seems more likely: we suggested that skin deformation or skin sensation may relate to why this phenomenon occurs.

4 Conclusion

In this paper, we reported that the force caused by the Hanger Reflex on the head and the ankle is enhanced by adding vibration. We developed devices to induce the Hanger Reflex on the head and the ankle, and placed the vibrators on the devices to present the vibration stimulus. The results confirmed that naïve participants perceive an enhanced force when adding the vibration stimulus to the areas where the Hanger Reflex was induced. It is suggested that the cause of this phenomenon relates to skin deformation or skin sensation, because the muscles that move the head and ankle are not located around the stimulated area.

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