Hanger Reflex of the Head and Waist with Translational and Rotational Force Perception

Yuki Kon[*1], Takuto Nakamura[*1*2], Michi Sato[*1],
Takashi Asahi[*3], Hiroyuki Kajimoto[*1]

*1 The University of Electro-Communications,
1-5-1 Chofugaoka, Chofu, Tokyo 182-8585, Japan
*2 JSPS Research Fellow
{kon, n.takuto, michi, kajimoto}@kaji-lab.jp
*3 Kanazawa Neurosurgical Hospital, Department of Neurosurgery, 262-2 Gomachi,
Nonoichi, Ishikawa 921-8841, Japan
takashi-tym@umin.ac.jp

Abstract. The hanger reflex is a phenomenon in which the head involuntarily rotates when force is applied via a wire hanger placed on the head. The application of pressure to particular points of the head is necessary to induce this phenomenon, which occurs when shear deformation of the skin induces illusory force perception. Because the hanger reflex represents the induction of force and motion using a simple device, and has been found in other body parts such as the wrist, waist, and ankle, it is expected to be useful as an application in haptic interface technology. In this paper, we describe new directions of force associated with the hanger reflex; four translation, and two rotational directions of the head, and four translation and one rotational direction of the waist.

Keywords: Hanger Reflex, Perceptual Force, Haptic Display, Skin stretch

1 Introduction

Hanger reflex is a phenomenon in which the head involuntarily rotates when forces are applied in specific locations, such as those created by placing a wire hanger on the head, as shown in Fig 1 [1][2]. Sato et al. measured the pressure distribution of the points of contact of the hanger necessary to induce the hanger reflex, and found “sweet spots”, i.e., an optimal position for the hanger. Specifically, they showed that the direction of lateral skin stretch contributes to the direction of the hanger reflex [2][3], as per the previously observed skin stretch force sensations [4][5][6][7]. Because the hanger reflex represents the induction of force and motion using a simple device, and has also been observed with other parts of the body such as the wrist, waist, and ankle [8][9][10][11], it is expected to have useful application in generating haptic interfaces. Thus, the mechanism and conditions leading to this phenomenon have been previously investigated (Fig 2). In this paper, we sought to further examine the hanger reflex with respect to other directions of translation or rotation. To this end, we developed new

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device enabling to study the whole-body hanger reflex with arbitrary directions of translation and rotation.

Fig 1. Hanger reflex [2]

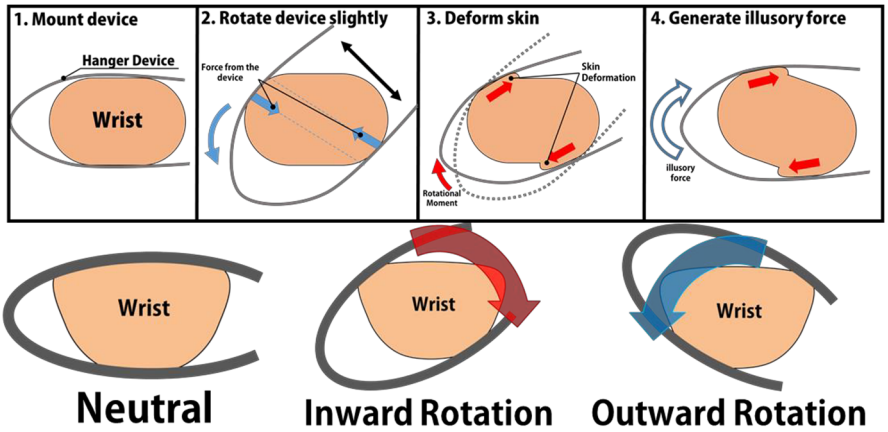

Fig 2. Mechanism of the hanger reflex device (wrist) : By changing the orientation of the device, an illusory force can be induced in two directions [10]

2 Device and preliminary trials

2.1 Head-type hanger reflex device

In previous research, the hanger reflex of the head had been confirmed only with respect to the yaw axis (i.e., along the long axis of body parts) [1][2]. However, as the main cause of the hanger reflex is considered to be the illusory perception of force generated by shear deformation of the skin [3], it is probable that appropriate shear deformation of the skin around other body axes will also generate rotation, and possibly translation as well.

We developed a new elliptical hanger reflex device made of carbon fiber reinforced plastic that is elastic (Fig 3a,b,c) [12]. To produce the hanger reflex, the user must rotate the device around their head to produce an appropriate pressure distribution and shear deformation of the skin. We developed three versions of the device to generate different types of skin deformation, as shown in Fig 3d,e,f,g. We confirmed that (1) pressure applied to the upper frontal and lower back regions of the head generated illusory force

and rotational motion along the pitch axis (Fig 3d), and (2) pressure to the upper lateral and lower contralateral regions of the head generated illusory force and rotational motion along the roll axis (Fig 3e). Furthermore, (3) pressure applied to two back temporal regions generated translational force and movement towards the rear. This was also observed for the front, left and right directions (Fig 3f,g).

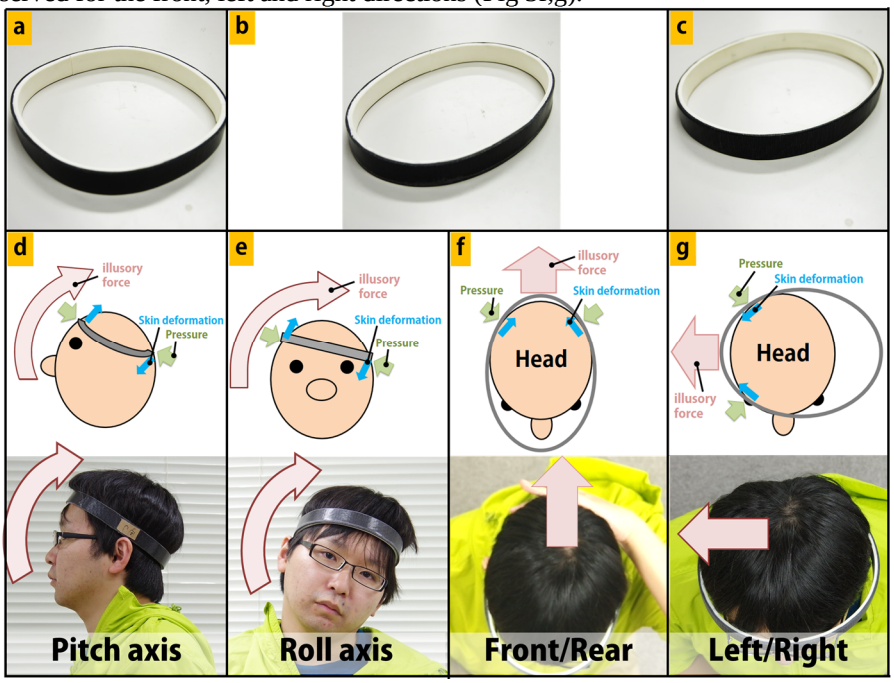

Fig 3. Head-type hanger reflex (Rotation along the pitch and roll axes, and translation towards the front, rear, left, and right directions)

2.2 Waist-type hanger reflex device

We have found the hanger reflex of the waist, in which the waist rotates along the yaw axis (Fig 4) [8]. As with the hanger reflex of the head, it is probable that appropriate shear skin deformation will produce rotation along other axes, and possibly translation as well. As body size can vary among individuals, and the device must be relatively large compared with the head-type hanger reflex device, we sought to make a device that was light weight and adjustable.

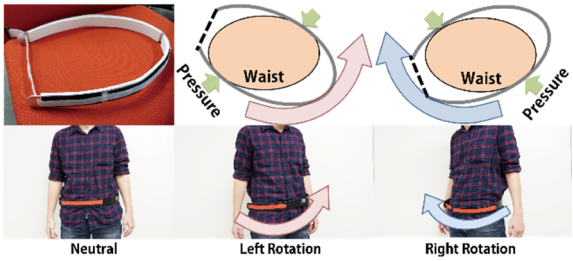

Fig 4. Waist-type hanger reflex [11]

We developed a new U-shaped hanger reflex device made of stainless steel (SUS304-CSP) (Fig 5a). The open ends of the device connected via a hook and loop fastener strap, enabling it to fit to any user. The total weight was 400g. To generate shear deformation of the skin, two contactors made of polyethylene foam and rubber, were placed between the stainless steel frame and the body. The positions of the contactors were adjusted for each case.

To induce translational force, the contactors were attached to the bottom part of the U-shape, where they pinched the body skin (Fig 5b,c). To induce a rotational force along the pitch axis, the frame was attached along one shoulder, as shown in (Fig 5d).

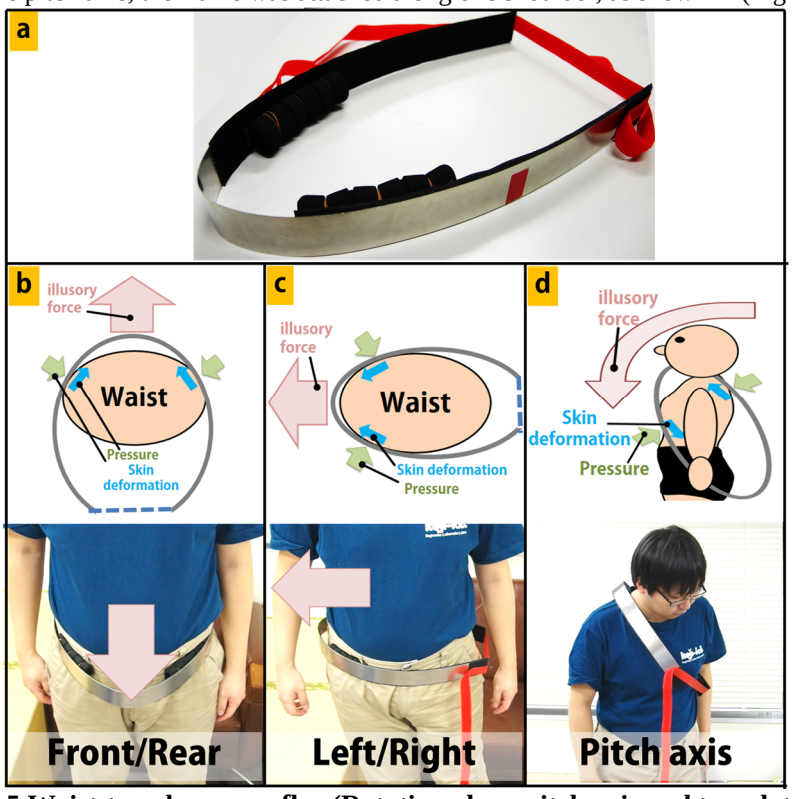

Fig 5 Waist-type hanger reflex (Rotation along pitch axis and translation to the front, rear, left, and right)

3 User Study

To confirm the reproducibility of this phenomenon, we recruited six participants, all male, aged 21–25 years. They had knowledge of the head-type hanger reflex, but were naïve with respect to the newly developed device. We asked them to attach the device in the various positions described above, and to report the direction of the perceived force. We prepared eight choices (rotation of pitch axis, rotation of roll axis, and translation to the front, rear, left, and right directions) for the head-type device, and six choices (rotation of pitch axis, and translation of front, rear, left and right) for the waist-type device. Trials with head type device were conducted first, followed by the waist type device. For each type of device, the mounting conditions were presented in random order. For example, when presenting the head-type hanger reflex pitch, roll, and translations were presented randomly, and the participants were asked to answer a single perceived force direction for each trial.

For the head-type device, three participants reported the directions of perceived movement as expected. We believe this relatively low rate of correct answers to be due to slip between the device and hairs.

For the waist-type device, four participants reported perceiving force in the expected direction for the translational force to the left, and five participants reported experiencing perceived force in the expected direction for the translational force to the front, rear, and right directions.

Participants did not comment any difficulty in answering easily for any specific body parts, but experimental results showed that perception of the head-type hanger reflex is actually difficult if the rotational and translational conditions are mixed.

4 Conclusion

In this paper, we extended the hanger reflex to additional directions of movement. Specifically, our data indicate that the hanger reflex might be able to induce translational and rotational force illusions in eight directions for the head and six directions for the waist.

As this study is preliminary, we plan to further investigate the detailed conditions leading to the hanger reflex in additional body parts. Additionally, we hope to improve the developed devices, and evaluate them in terms of rate of illusion, strength of illusion, and temporal characteristics such as latency and adaptation. We then hope to further apply the device to the development of whole-body haptic interfaces, for use in the fields of virtual reality, training and rehabilitation.

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