Vibrotactile Cueing for Biasing Perceived Inertia of Gripped Object

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Abstract. Motion-synchronized vibrotactile stimuli on a finger pad influence the perception of the inertia and viscosity of an object being jiggled by the finger [1]. We designed a hand held device that imposed vibrotactile stimuli to gripping finger pads. The device allowed us to experience the illusory change in the perceived inertia of the device by vibrotactile stimulation synchronized with the acceleration of the hand movement.

Keywords: Vibrotactile stimulation, Mass, Skin stretch

1 Introduction

The perception of the dynamic properties of objects is instrumental for a variety of manipulation tasks. Such percepts are mainly mediated by proprioceptive sensations. In addition, cutaneous sensations influence the perception of objects' properties. For example, the stretching of finger pad skin while handing objects would affect the perception of the mass [2] or frictional properties [3] of objects.

Okamoto et al. demonstrated that the perception of inertia or viscosity of an object was biased by vibrotactile stimuli [1]. In their experiments, the vibrotactile stimuli were provided to a finger pad while jiggling a computer-controlled slider. On the basis of this finding, we designed a hand held device that provided a

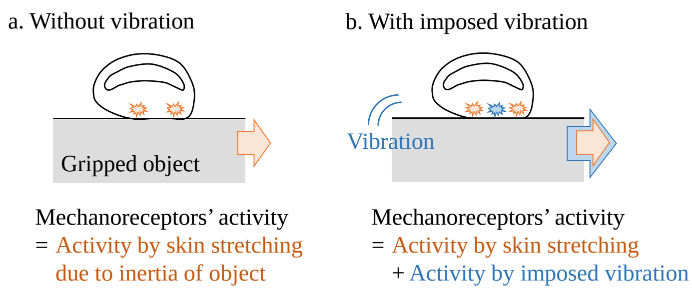

Fig. 1. Imposed vibration biases the perception of inertia of an object

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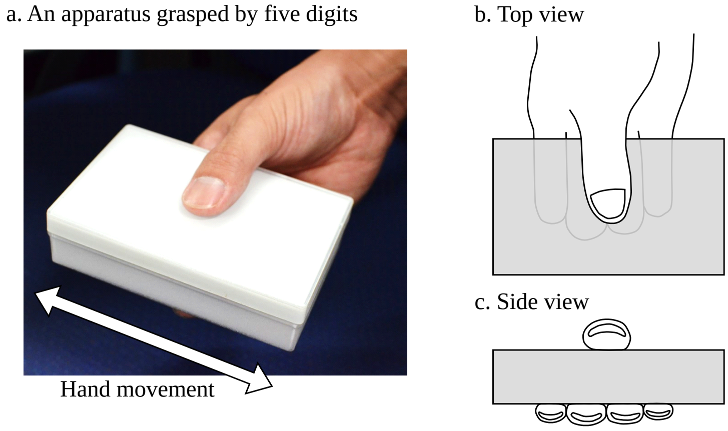

Fig. 2. Apparatus used to apply vibrotactile stimulation to multiple fingers

pseudo-increase in the inertial sensation using vibrotactile stimuli. Such a hand held pseudo-force feedback device is invaluable for mobile interfaces that cannot be grounded to receive the reaction force provided by the device.

2 Illusion of inertia or viscosity by vibrotactile stimuli in synchronicity with hand motions

The illusory change in the perceived inertia or viscosity of a vibrotactile feedback device has been demonstrated [1]. The phase of the change in stretched finger skin caused by an increase in the mass of an object is close to the phase of the acceleration of the finger that jiggles the object. On the basis of this relationship, the perception of the inertia of the object was influenced by the vibrotactile stimuli on the finger pad that is synchronized with the finger acceleration. As shown in Fig. 1, the illusory change in the perception of the inertia of an object was presumed to be caused by the superactivation of skin mechanoreceptors by vibrations. The vibrotactile stimuli would add to the receptors' activation in synchronizing the stretching of finger skin. In addition, the vibrotactile stimuli that are synchronized with the finger velocity biased the perceived viscosity of an object on the basis of the relationship that the phase of the stretched skin change due to an increase in the viscosity of an object was close to that of the finger velocity.

3 Apparatus and stimuli

The device (Fig. 2) we designed was composed of a box-shaped acrylic enclosure, two actuators (Force Reactor, Alps Electric Co., Tokyo, Japan), a microcontroller (mbed NXP LPC1768, NXP semiconductors, Netherlands), an accelerometer (ADXL335, Analog Devices, Norwood, USA), an electronic circuit, and a power supply. All components were internally located in the enclosure. Each of the two actuators was attached to the ceiling and bottom of the enclosure, which generated vibrotactile stimulation as commanded by the microcontroller. The rates of control and measurement were set to 1 kHz.

The actuators were driven by PWM at a frequency of 280 Hz through a current amplifier. The fast adaptive units could be mainly activated by the vibrations. The duty ratio was determined by

$$D(t) = \begin{cases} a_i & (|\ddot{x}(t)| < b_i) \\ a_i(1 + \dfrac{|\ddot{x}(t)| - b_i}{c_i}) & (|\ddot{x}(t)| \geq b_i), \end{cases} \tag{1}$$

where $\ddot{x}(t)$, a_i, b_i, and c_i are the acceleration of the device, the duty ratio when the finger movement was at rest, a constant value representing the insensitive range of finger acceleration, and the gain of the acceleration of the box, respectively; $a_i = 0.02$, $b_i = 15.0$ m/s^2, and $c_i = 2.0$ m/s^2. In our experiment, this combination of values was likely to bias the perceived inertia of the apparatus.

4 Demonstration

In order to authenticate the illusion, voluntary participants swung the device horizontally. To control the conditions of the demonstration, in which the frequency and width of the horizontal movements were 1.75 Hz and 0.5 m, respectively, the participants swung the device in rhythm to a metronome with the instructed width as accurately as possible. The frequency and width of the movements were determined by the researcher. The participants experienced illusory and non-illusory conditions and reported the increases in inertia under the illusionary conditions.

References

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