Mechanism of visual perception and visuomotor adaptation of the body

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Abstract

In order to investigate the mechanism of visual perception and visuomotor adaptation, we designed the experiment that subjects reached their right hands for and to pinch an object wearing eye glasses that shifted the visual field with eyes open or closed. During trials, an electric stimulation was given on fingers. Performance was measured by the distance between the object and fingers. Subjects reached the object in fewer trials with their eyes closed than with their eyes opened. Moreover, distance between fingers and the object was smallest when electrical stimuli were delivered to the right hand during the closed eye whereas the left hand stimulation had no significant effect. We concluded that 1) subjects knew they reached to the wrong place after the first trial and with eyes closed there was no conflict between the visual and 2) proprioceptive systems during subsequent trials the electrical stimulus to the right hand might have provided false knowledge of result.

Key Words : visuomotor, perception, adaptation, prism

Introduction

The CNS (central nervous system) typically receives multimodal sensory information about single objects or events. In some behavioral tasks, vision seems to be the dominating sensory source of information for perceptual and behavioral tasks[1]. This is, however, not always the case[2, 3] .The optimal integration model proposes that sensory information is weighted in accordance with its precision[4, 5, 6]. The adaptation to prism lenses when reaching for objects must depend on visual and proprioceptive as well as haptic information.

We investigated how normal subjects adapt to prism lenses with full vision, with closed eyes, and when provided with spurious knowledge of results by means of haptic cues.

Method

1) Subjects, task and devices (Fig. 1, Fi. 2)

Subjects were seven naïve healthy adults. Task was reaching for and pinching an object with thumb and index finger of the right hand. An object equipped with force sensors of normal force were located 28 cm from the fixed starting position at position spaced 10 degree. The position sensor (Polhems 3SF0002, 6D sensors) was attached to the index finger and thumb. Cutaneous stimulator was given to the tips of the index finger and the thumb by wrapping with thin metal wires. The stimulation voltage was adjusted for each individual to be just above the perceptual threshold. All subjects reported that they perceived the stimulus as a soft ‘touch’.

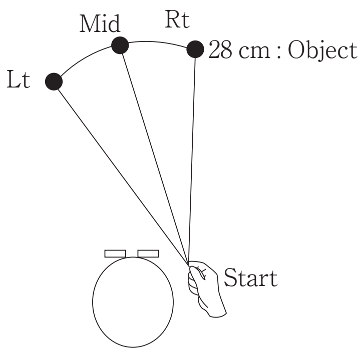

Fig. 1 : Task & Object

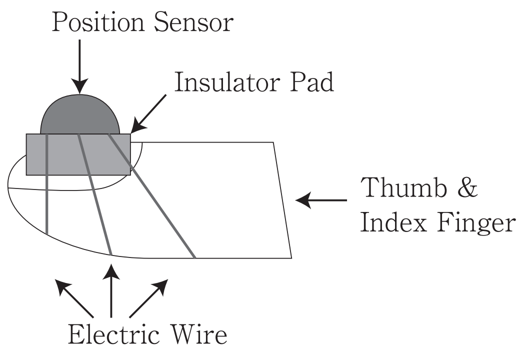

Fig. 2 : Position sensor & Cutaneous stimulation

2) Visual conditions (Fig. 3) and Cutaneous conditions (Fig. 4, 5)

Three sets of lenses were used. They shifted the visual field horizontally by -10 degrees (to the left), 0 degree (no shift) and + 10 degrees (to the right). The lens used and the target location was changed in an unpredictable way between sessions.

Each session consisted of 10 trials. The subjects had full vision during the first trial of all sessions but performed the remaining 9 trials with either the eyes opened or closed. The only sessions included in the analyses were those in which the subjects were adapting to a + 10 degrees lens and preceded by sessions with a 0 degree lens.

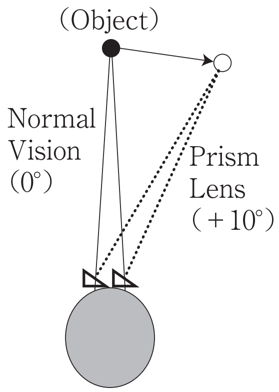

Fig. 3 : Visual condition

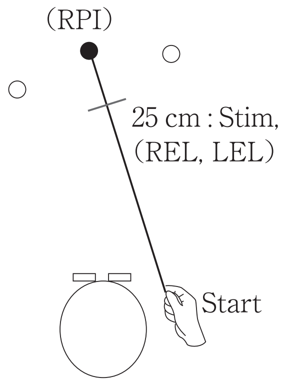

Fig. 4 : Cutaneous stimulation

The position and force sensors were sampled at 400 Hz for offline analyses. The reaching phase was defined from the first time derivative of the finger positions, i.e., from the moment the velocity reached 30 cm/s until the first velocity minimum.

Table1：Summary of conditions

Vision （2 levels）	Eyes open Eyes closed
Electrical stimulation （3 levels）	Right hand when object was pinched Right hand when right hand had moved 25 cm Left hand when right hand had moved 25 cm

In all trials, an electric pulse was given to the thumb and index finger of the right or the left hand either when the object was pinched, or when the right hand had moved 25 cm from its fixed starting position.

3)　Analysis（Fig. 5）

Performance was assessed at the end of reaching by measuring the absolute distance（ERR＝error）between the object and the midpoint between the two digits. Results were analyzed by repeated measure ANOVA.

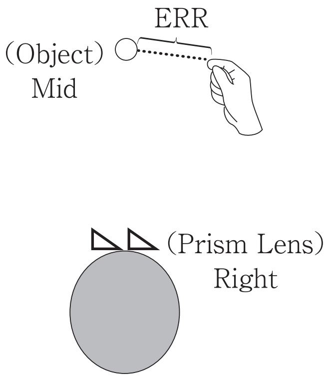

Fig. 5：Analysis data; ERR
（ERR＝error）

Results

1)　Open or closed eyes（Fig. 6）

During all sessions, subjects typically adapted to the lenses and eventually pinched the object but subjects reached the target object in fewer trials with their eyes closed than with their eyes opened.（p＜0.01）

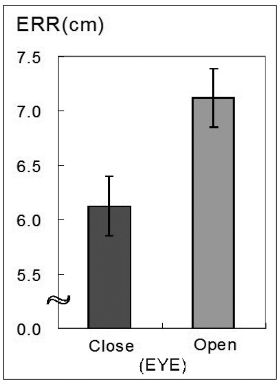

Fig. 6：Mean and SEM
（standard error of the mean）of ERR（error）
during the eyes opened and eyes closed condition

2) Tactile stimulation (Fig. 7)

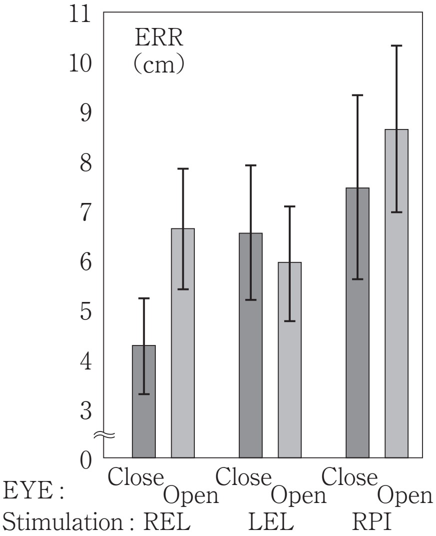

Fig. 7 : Mean and SEM of ERR among tactile stimulus

Subjects performed best with their eyes closed in combination with spurious haptic information to their right hand (p<0.01).

There was no statistically significant difference between the condition when electrical stimuli were delivered to the right hand when it made contact with the object (RPI) and when the left hand was stimulated when the right hand had moved 25 cm (LEL).

3) Adaptation process by trials (Fig. 8)

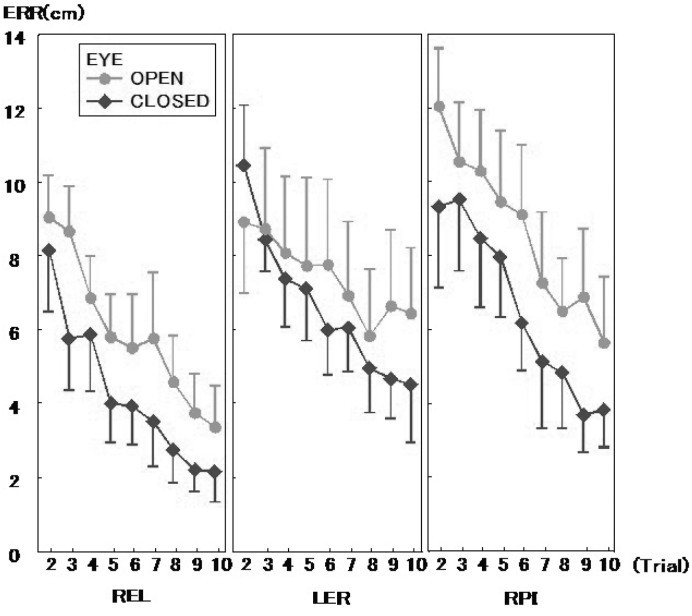

Fig. 8 : Mean and SEM of ERR through adaptation process (by trials)

ERR was smallest and subjects could reach the object in fewer trials when REL with eyes closed.

(2 cm was average error margin between position sensors and the center of the object which diameter was 2 cm.)

Discussion

Once the subjects had seen their first attempt to reach the target object, they reached it quicker in subsequent attempts when their eyes were closed than with they had visual feedback. Moreover, subjects reached the target objects quicker when their eyes were closed and they were provided with spurious haptic cues.

These results can be explained in terms of (1) visual dominance over propriocepive information when adapting to horizontal visual shifts and in terms of (2) 'knowledge of results'.

van Beers et.al. (2002) reported that vision is weighted more heavily than proprioception in azimuth direction, contrary to in depth direction[5]. And Plooy et. al. (1998) reported that proprioception may play a relatively minor role when vision is available[3]. Because, in this our experiment, the task movement direction was in horizontal and subjects could see both the target and their task fingers closing to the object, vision might be dominant and ERR might be larger with eyes opened. With eye opened, subjects should adapt to prism lenses trial by trial.

Due to the +10 degrees lens the subjects invariably reached to the right of the object in the first trial in each session and they were allowed to see this. Thus, in the first trial the subjects observed an error and its direction.

In subsequent trials, the subjects with their eyes closed could rely on the memory of the first trial and probing for the object in subsequent trials without taking further visual information into account.

It might be easier to perform using memory of previous trial without distorted visual input than to adapt to prism lens, because of the dominance of vision.

When artificial tactile inputs in addition appeared close in time to when contact with the object was expected, it is hypothesized that subjects might interpreted this as one kind of 'knowledge of results' which confirmed that the adjustments were in the correct direction. Salmoni and Walter mentioned in their review (1984) the alternate forms of KR and a guidance role for KR[7]. The hypothesis that needs further investigations could be proposed that in our experiment subjects might interpret spurious haptic cues as KR and might use this KR as guidance of movement direction.

References

(1) Hay JC, Pick HL, Ikeda K (1962) Visual capture produced by prism spectacles. Psycol Sci 2: 215–216.

(2) Mon-William M, Wann JP, Jenkinson M, Rushton K (1997) Synaesthesia in the normal limb. Proc R Soc Lond B Biol Sci B246: 1007–1010.

(3) Pooly A, Tresilian JR, Mon-Williams M, Wann JP (1998) The contribution of vision and proprioception to judgements of finger proximity. Exp Brain Res 118: 415–420.

(4) Van-Beers RJ, Sitting AC, Gon JJ (1999) Integration of proprioceptive and visual position-information: An experimental support model. J Neurophysiol 81: 1355–1364.

(5) Van-Beers RJ, Wolpert DM, Haggare P (2002) When feeling is more important than seeing in sensorimotor adaptation. Curr Biol 12: 834–837

(6) Ernst MO, Banks MS (2002) Humans integrative visual and haptic information in a statistically optimal fash-

ion. Nature 415: 429–433.
（7）Salmoni AW, Schmidt RI, Walter CB（1984）Knowledge of results and motor learning: A review and critical reappraisal. Psychol Bull 95: 355–386