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A consideration of perceptual-motor coordination with active and passive movements

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ABSTRACT

In perceptual-motor coordination with active and passive movements, it has been an ordinary paradigm that efferent copy of motor command affects space perception. In this report, we submitted that the phenomenal difference of space perception should depend on not efferent copy but intention on sensory integration. In the task of reaching a visual target, the result with passive movements was equal to the result in the task of visual fixation to a motionless point which the subject was grasping. In the task of reaching for a haptic target, the results with active and passive movements had no difference.

KEYWORDS: perceptual-motor coordination, active/passive movement, sensory integration

1. Introduction

In the experiments of perceptual-motor coordination focused on active and passive movements, it has been an ordinary paradigm that efferent copy of motor command affects space perception[1]. The paradigm was based on the concept that the active movement was caused with voluntary motor command and the passive movement was not. However, the voluntary motor command was made from the perception under the condition of the active/passive movement. Whether the presence of the motor command caused the difference of perception or was caused by it ?

In this report, we submitted that the phenomenal difference of space perception should depend on not efferent copy but intention on sensory integration. In the first experiment, The difference between active movement condition and passive movement condition was confirmed. The results in the experiment of reaching a visual target with active and passive movements have difference from each other. This observation submitted that such adaptation for prismatic stimulation was not needed to define the difference between the condition with active movement and the condition with passive movement. The second experiment was the task of reaching for a haptic target without vision. The results with active and passive movements had no difference. This observation submitted that the efferent copy of motor command was not significant for the difference between the condition with active movement and the condition with passive movement. The third experiment was the adaptation for prismatic stimulation on visual reaching tasks. The results confirmed that, in each movement condition, the same movement task adapted much better than the other movement. It submitted that the conversion processes to each organ to be controlled was independent from each other, therefore it also submitted that the phenomenal difference of space perception with active and passive movements would come from the mechanism of sensory integration between eyes and arms.

2. Visual Reaching Task on Active/Passive Movement

The most ordinary perceptual-motor coordination experiment about active/passive movement was based on the adaptation for prismatic stimulation on visual reaching tasks. The adaptation was quicker with active movement than with passive movement. However many experiments submitted that the active movement was not the determinative factor but only an effective and facilitative factor[2]. Therefore there was another adaptation mechanism independent from efferent copy of motor command, and the mechanism also integrated senses for space perception.

On the other hand, obvious constant errors were observed in such visual reaching task without visual information about the hand[3,4]. These constant errors may be sufficient to define the difference between the condition with active movement and the condition with passive movement. In this paper, the experiments of visual reaching were done in active/passive movement conditions without the adaptation for prismatic stimulation and without visual information about the hand.

Experiment 1

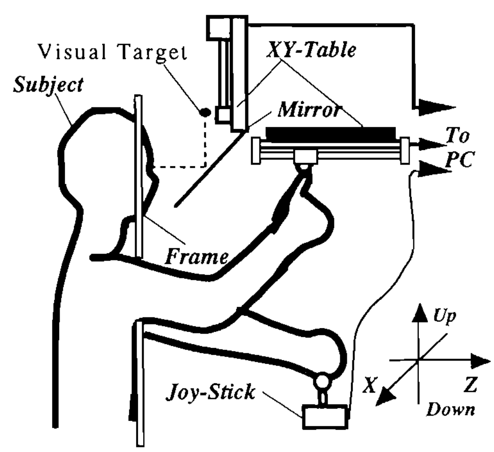

Figure 1: Experimental Apparatus

Apparatus

The apparatus we used is illustrated schematically in Figure.1. An orange light-emitting diode (LED) was located above a full-reflecting mirror, and was relocated with X-Y motion table. Over the mirror was another X-Y motion table with a hook, on which the virtual image of the LED was projected. A subject was seated in front of the apparatus with the index finger of his right hand resting on the hook. The subject's head and breast was immobilized with a frame. The image of the LED and the hook were always on the horizontal plane on his eye height. The subject could not see his hand while the experiment. While the X-Y table with a hook was powered off, he could move smoothly the hook by his index finger. It was used for the active movement condition. While the X-Y table with a hook was powered on, his index finger was relocated by the hook. It was used for the passive movement condition.

Procedure

Six subjects with normal vision were tested. They were instructed to keep their gaze on the image of LED and to keep the index finger of their right hand on the hook, which were initially located on a central position. When the target image was off and reappeared at a randomly selected position, they were required "to look and point to the target as accurately as possible, no use to haste". When subjects completed their pointing movement, they pushed a button with their left hand to record their reaching point. This experiment was done in darkness except for target LED. Subject therefore had no visual information about the accuracy of their pointing movement to the target. Peripheral targets were presented on the horizontal plane on the eye height at the cross points of the locus at bipolar latitude of -10, 0, 10 degree from the median plane and the locus at vergence angle of 10, 11, 12 degree. In active movement condition, the subjects moved the hook with the index finger of their right hand and pointed at the target point of the LED image. In passive movement condition, the subjects operated the hook with the switches of a joystick operated with his left hand. They could not operate the speed and the distance of relocation. Those were randomly selected on each relocation. The subjects could operate only the direction of relocation. This experiment had no time limit for pointing, but was intermitted up to 15 minutes of total time. The subjects rested in an illuminated room for at least 5 minutes before restarted this experiment.

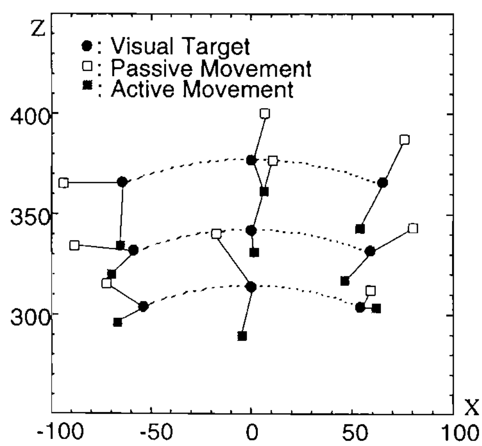

Figure 2: Reaching Points for Visual Targets

Results

A typical example of results is shown in Figure.2. In active movement condition, subjects had a strong tendency to undershoot the target. On the contrary, subjects had a strong tendency to overshoot the target in passive movement condition. These results submit the difference between the active condition and the passive condition as same as the results of the previous experiments with the adaptation for prismatic stimulation. However, these results don't submit the ordinary paradigm that efferent copy of motor command affects space perception, because subjects determined the reaching point without time limit in this experiment. When they determined the reaching point, their arms were in almost static condition

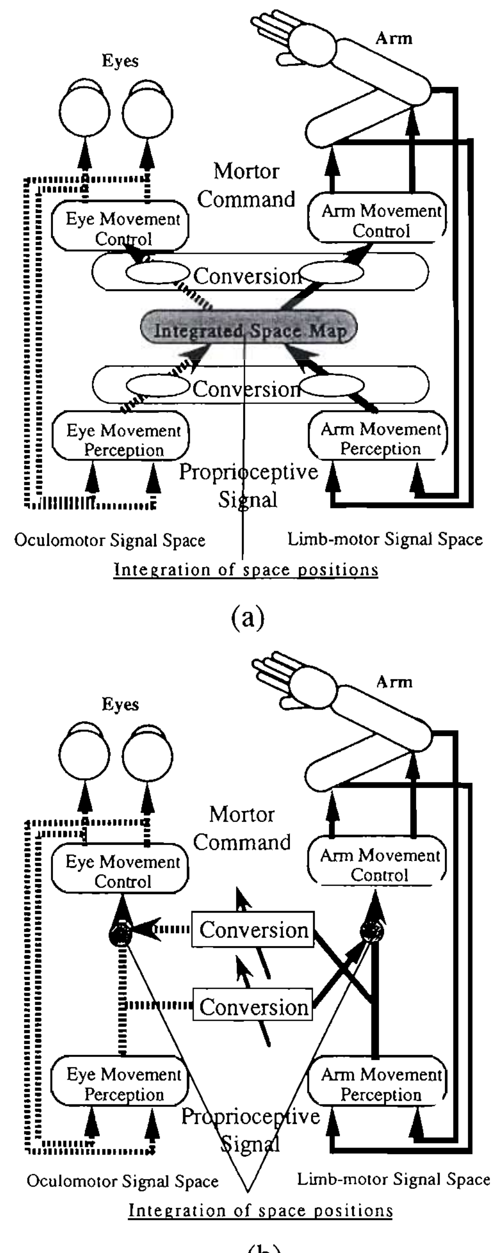

Figure 3: Mechanism for perceptual-motor coordination

In addition, the result in the condition with passive movement was very similar to the result in our previous experiment of visual fixation to a motionless point which the subject was grasping[5]. That experiment was very similar to the Experiment 1 in the condition with passive movement. The difference was that subjects operated the visual target in spite of the hook with the switches of a joystick operated with his left hand. In that experiment, the hook didn't move but subjects grasped it with voluntary movement. These observations submit it is necessary to redefine the passive movement against the active movement.

In our study, we submitted that the difference of space perception between the reaching task to visual targets and the binocular fixation task to haptic targets might reflect the aim of sensory motor control for the subject.

These phenomena were simulated with our neural network model named as ISLES model(Independent Scalar Learning Elements Summations Model). As the result,our model submitted that the sensory integrated process for the perceptual-motor coordination would have such a system like Figure 3(b) with parallel conversion processes for each other sensory coordinate, not like Figure 3(a) with an internal integrated universal coordinate for space perception.

Therefore, we submitted the difference between the conditions in Experiment 1 came from not the efferent copy of motor command but the difference between conversion processes to each organ to be controlled.

3. Somatosensory Reaching Task on Active/Passive Movement

From the observations of Experiment 1, it was necessary to experiment whether the efferent copy of motor command would affect space perception or not. The somatosensory reaching task was same as the visual reaching task except for the display method of target points. In this task, a subject didn't see visual targets but touched haptic targets. If the efferent copy of motor command affected space perception, the results of the somatosensory reaching task would be different between active and passive conditions.

Experiment 2

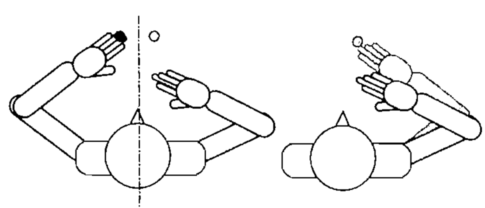

Figure 4: Display Methods of Targets in Proprioceptive Reaching Experiment.

Apparatus

The apparatus was same as Experiment 1 illustrated schematically in Figure 1. The haptic targets were displayed with small round seals on the surface of the X-Y motion table base. Subjects couldn't touch the surface as long as they were gripping the hook.

Procedure

Subjects were blindfolded. The haptic targets was displayed by two methods illustrated schematically in Figure 4.

(a) Haptic targets were located at the symmetrical position against median plane to the position to be pointed. Subjects touch the haptic target with the index finger of their left hand.

(b) The target points were displayed with the hook in passive movement condition. They memorized the position, then the hook returned to the initial position. The relocations were always done with random walk movements. Subjects could confirm the target positions whenever.

The other condition was same as Experiment 1.

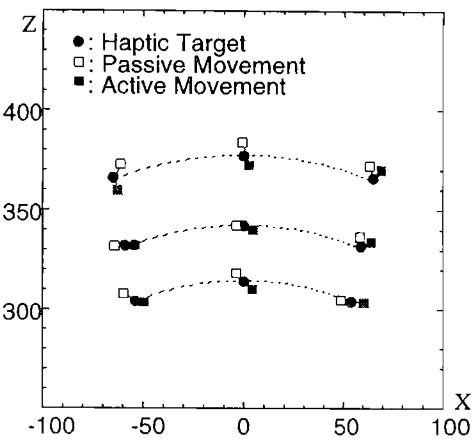

Figure 5: Reaching points for haptic Targets

Results

The display methods had no significant difference in their results. Therefore the results were integrated. A typical example of results is shown in Figure 5.

The constant errors were significantly smaller than the errors in Experiment 1, and had no significant difference between the conditions in active and passive movement. Therefore, in the condition of this experiment, the efferent copy of motor command would almost not affect the somatosensory space perception. Although kinds of sensory information were fewer in this experiment than in Experiment 1, Constant errors were smaller in this experiment rather than in Experiment 1.

These observations submitted that these constant errors in pointing accuracy came from the sensory integration process between the coordinate of eye and the coordinate of arm.

4. Reconsideration in Experiments of the adaptation for prismatic stimulation

In order to confirm the considerations in Experiment 1 and 2, it is necessary to confirm the independence of conversion processes to each organ to be controlled.

For the purpose, the third experiment was similar to previous perceptual-motor coordination experiments with the adaptation for prismatic stimulation. From the considerations in Experiment 1 and 2, in the active movement condition, subjects would adapt the conversion process from the coordinate of eye to the coordinate of arm. In the passive movement condition, subjects would adapt the conversion process from the coordinate of arm to the coordinate of eye.

In many previous experiments, subjects adapted with active movement much better than with passive movement. It meant that subjects adapted the conversion process from the coordinate of eye to the coordinate of arm in the active movement condition much better than in the passive movement condition.

Therefore, in our third experiment, we should confirm that subjects adapted the conversion process from the coordinate of arm to the coordinate of eye in the passive movement condition much better than in the active movement condition.

Experiment 3

Apparatus

The apparatus was same as Experiment 1 illustrated schematically in Figure 1. The prismatic stimulation was lateral 15dp toward right.

Procedure

The condition was almost same as Experiment 1. As the adaptation process, the pointing tasks were repeated to random points. Subjects pushed the button on the joy stick to know the pointing error. Then, the hook was relocated to correct position in active movement condition, and the image of LED was relocated to the position of the hook in passive movement condition. The requirement for the end of adaptation process was to point the targets continuous 3 times within the error of 1cm.

Three targets for measurement were presented on the horizontal plane on the eye height at the cross points at (0,11), (-10,11), (0,12) [degree] of the bipolar latitude and the vergence angle.

Results

A typical example of results is shown in Figure 6. In this figure, there is no display for the results of each movement task in the same movement condition, because subjects had already adapted to the task and the pointing errors were almost within 1cm.

These results confirmed that, in each movement condition, the same movement task adapted much better than the other movement. It meant not only that subjects adapted the conversion process from the coordinate of eye to the coordinate of arm in the active movement condition much better than in the passive movement condition, but also that subjects adapted the conversion process from the coordinate of arm to the coordinate of eye in the passive movement condition much better than in the active movement condition. Therefore, it submitted that the conversion processes to each organ to be controlled was independent from each other.

These observations submitted the difference between the phenomena with active and passive movements would come from the independence of conversion processes to each organ to be controlled.

5. Conclusion

In this report, psychophysical phenomena about active and passive movements were discussed through three perceptual-motor coordination experiments. These results submitted that the phenomenal difference of space perception between active and passive movements should depend on not efferent copy but intention on sensory integration.

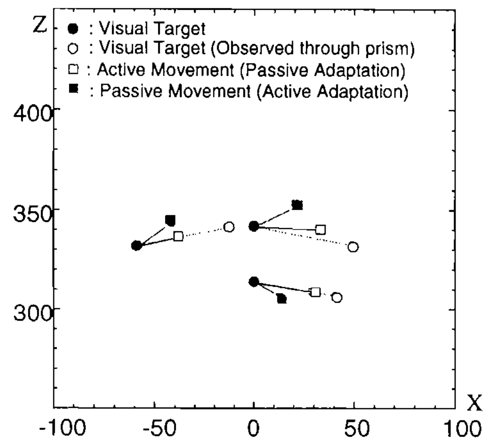

Figure 6: Reaching Points in Prism Adaptation Experiments

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