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Effects of Attention Focus on Adaptation Process for Body Sway Induced by a Tilting Room

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To examine the effects of attention focus on adaptation of body sway induced by a "tilting room", eighteen subjects were either asked to keep looking at a target (target-attention) or to maintain an upright position (body-attention). Body sway induced by the forward tilting room was measured with the force plate during the five trials for both groups. Analysis indicated the forward room tilting induced forward body sway like that of the moving room. Analysis of adaptation process across a series of trials showed the distance between mean body position from baseline and maximum body sway of both groups was significantly different over the series trials as follows: the subjects in the target-attention group swayed significantly more forward than the body-attention group in the third, fourth, and fifth trial. These findings indicate improved body sway under internal focus condition, compared to external focus condition in tilting room. The author concluded that instruction of attention to internal focus affected the context-dependent weighting of new input.

Key words : tilting room, instruction, body sway, attention, adaptation.

1. Introduction

The motion of the visual environment could either result from displacement of the visual scene with respect to a stationary observer or from the observer moving through a stable environment. Visually induced illusory perception of self-motion is consequence of integration between vestibular, kinesthetic, and visual information (Howard, 1986) and can be experienced during rail travel where the sight of another moving train frequently elicits the self-motion in opposite direction. Evidence indicating the importance of vision on postural control comes from research on perception of vection (Dichgans & Brandt, 1978). Vection is the sense of self-motion induced by moving environments for a stationary observer (for review see Dichgans & Brandt, 1978; Kano, 1991). Lee and his colleagues provided an interesting example of this self-motion (Lishman & Lee, 1973; Lee & Aronson, 1974; Lee & Lishman, 1975). They used a "moving room" in which subjects stood on an unmoving floor and were surrounded by three side walls and a ceiling that moved forward and backward. The direction of movement gave the subjects the illusion that they were moving in the opposite direction. As a consequence, subjects swayed forward or backward in response to the visual stimulation (Lee & Lishman, 1975), with some infants even falling over (Lee & Aronson, 1974; Bertenthal & Bai, 1989).

Issues of postural adaptation over time and repeated exposure have been examined in only a few reports. For example, Clement, Jacquin, and Berthoz (1983) found evidence for postural adaptation, with adults exhibiting a decrease in their amplitude of body sway across subsequent blocks of trials in response to roll vection (circularvection), but not to linear vection. Developmentally, Bertenthal and Bai (1988) proposed an adaptation to explain an observed decrease in body sway across a series of trials in a moving room.

How did those subjects decrease their body sway over a series of trials in a moving room? Based on a series of experiments, Nashner suggested an answer to this question (Forssberg & Nashner, 1982). The process of adaptation could be explained from two viewpoints, automatic postural adjustments and context-dependent reorganization of the weighting of inputs from the support surface and from the vestibular and visual systems (Forssberg & Nashner, 1982). As for cases in which visual information conflicts with other sensations, Forssberg and Nashner discussed the idea that the decrease in swaying indicated that the weighting of the new inappropriate visual input was being progressively reduced.

However, these authors did not focus on the strategies that the adults might have adopted in the adaptation process. The moving room brings about a conflicting situation between visual information and kinesthetic information. Therefore, adult subjects try to solve this conflict using the following strategies: i.e. they understand the conflict and pay attention to their own kinesthetic information, the fact that they themselves are not moving, or they close their eyes. Hoshikawa (1999) indicated the differences of strategies in the adaptation process after examining the effects of a tilting room on body sway across a series of trials. In his experiment, subjects were instructed to maintain an upright position in a "tilting room", and body sway was measured by a force plate. The results indicated that the forward-tilting room induced forward body sway as would a moving room. Based on analysis of strategy, subjects were divided into two groups, a "maintaining-standing strategy" group and "other-strategies" group. While subjects who used the maintaining-standing strategy swayed more in the first trial, they significantly reduced their body sway compared with the other group. Almost all subjects in the other group consciously tried to compensate their upright position, and they failed to weight the new input appropriately. These results suggested that the strategy affected the adaptation process for body sway induced by a tilting room.

Induced self-motion is a situation in which subjects watch an external object and do not pay attention to their own bodily sensations. For example, when one looks at a moving train from the opposite station platform, one experiences induced self-motion. From the viewpoint of attention, one pays attention to the external object. In this situation, one can reduce induced self-motion by paying attention to bodily sensations. The subjects' strategies (Hoshikawa, 1999) could be replaced two directions of attention, maintaining-standing strategy means that subjects paid attention to kinesthetic information from their own bodies (internal focus) and compensation strategy means that subjects focused on visual information from the outside (external focus). The finding of tilting room indicated improved postural sway under internal focus condition, compared to external focus condition (Hoshikawa, 1999).

In the motor skill learning, a series of recent studies of Wulf and colleagues (Shea & Wulf, 1999; Wulf, Hoess,& Prinz, 1998; Wulf & Prinz, 2001), compared the effects of instructions that direct the learner's attention to the external effects of their movements (external focus of attention) with instruction which focus their attention on the movements themselves (internal focus of attention). The results of these studies consistently demonstrated that motor skill learning could be enhanced by an external compared to an internal focus of attention. Moreover, McNevin and Wulf (2002) examined whether the attentional focus adopted on a supra-postural task had an influence on postural control. They instructed subject to minimize movements of the finger (internal focus condition) or to minimize movements of the sheet (external focus condition). They concluded that their findings indicated improved static balance responses under external focus conditions and compromised static balance response under internal focus conditions. Wulf, McNevin and Shea (2001) explained their findings by a "constrained action hypothesis", according to which trying to consciously control one's movements constrains the motor system by interfering with automatic motor control processes that would "normally" regulate the movement.

Although there were differences between tasks, there was a contradiction between the findings of Hoshikawa (1999) and Wulf *et al.* Therefore, the purpose of this study was to examine the effects of attentional focus on body sway induced by a tilting room. From the viewpoint of Hoshikawa, internal focus could be important for standing still, while from the viewpoint of Wulf, external focus could be important. Before the following experiment was carried out, the author had a hypothesis. In the adaptation process, the subjects who are instructed to maintain their upright position would pay attention to their own bodies, and they would be able to reduce the effects of a tilting room across a series of trials. The subjects instructed to look at an object, however, would attend to external sensation and would not be able to reduce the effects of a tilting room across a series of trials. This study used a tilting room (Hoshikawa, 1999) that rotated on an axis in line with the subject's ankle joints because the moving room used by Lee (Lee & Aronson, 1974; Lee & Lishman,1975) requires a huge amount of laboratory space.

2. Method

Subjects

The subjects were 18 undergraduate students of Kyushu University. Subjects were ranged between 20 and 22 years of age. All reported normal or corrected vision without any vestibular and neurological disorders.

Material and apparatus

The apparatus consisted of a small room, 180 × 180 × 90 cm, with the floor and one wall removed. Three walls (both sides and front) and the ceiling of this room could tilt up to 12 degrees forward or backward from upright position along a rotation axis in line with subjects' ankle joints. In order to emphasize the pattern of optical flow, the interior of the three walls and ceiling were covered with a black and white checked pattern (10 × 10 cm). The luminance of the front wall was 15 cd/m^2. The degree of tilting was measured by a potentiometer fixed at the rotation axis. The speed of tilting was 0.007-0.008 rad/sec. using an air jack made for this experiment.

The subjects stood on a force plate (Sanei Sokki, No.1G02) placed toward the open end (rear wall) of the tilting room (Figure 1). The subject's foot were parallel and 10 cm apart and the line of os naviculares of each foot (the center of gravity) wes set along the center of the force plate. Signals from the force plate were supplied separately in the three moments: x (left-right), y (forward-backward) and z (up-down). Signals from a trigger (push button), tilting degree (potentiometer) and signals from the force plate were amplified by an electroencephalograph (Nippon Koden, EEG5213), and recorded by a data recorder (Sony, A-614). The recorded data were transformed using an analog/digital converter (Canopus Electrics, ADX-98H), and analyzed by a computer (NEC PC-9801UX). The sampling rate for the signals from the force plate, potentiometer, and trigger was 100 Hz.

Procedure

Subjects were told that the purpose of this study was to examine their postural stability. Subjects were asked to close their eyes before entering the laboratory expect for the following two sessions: the baseline session (measurement of each subject's body position in the usual standing posture) and the experimental session of five trials. In the baseline session, subjects were asked to maintain an upright position for 1 min. and look at a thumbtack (1 cm in diameter) fixed in the front wall at eye level. The mean body position in this session was called the "baseline".

In the experimental session, subjects were divided into two groups: target attention (hereafter referred to as TA) group and body attention (hereafter BA) group. The subjects in the TA group were instructed to look at the thumbtack fixed on the front wall at eye level. The subjects in the BA group were given the same instructions, and were additionally instructed not to move forward or backward or to the left or right, but maintain an upright position. These instructions were repeated before every trial. The body sway was recorded during the following three periods: standing still for 10 sec. before the room was tilted (pre-tilting), standing still for about 30 sec. as the room was tilted forward (during tilting) and standing still for 10 sec. after the room was tilted (post-tilting). While the room was put back into position between trials, subjects were asked to close their eyes.

3. Results

Because one subject in the TA group swayed more significantly than other subjects, she was not included in the analysis. As the signals from the force plate were output as moments (i.e., the product of distance by load),

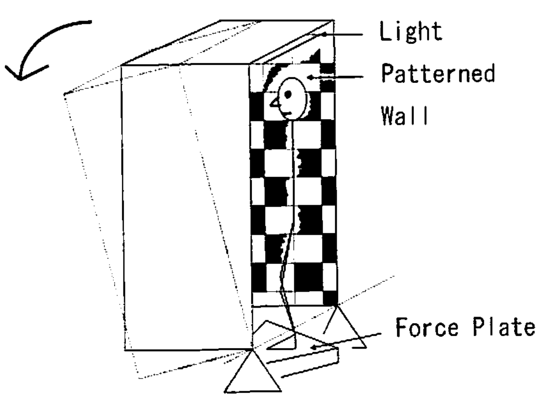

Figure 1. Schematic drawing of tilting room apparatus.

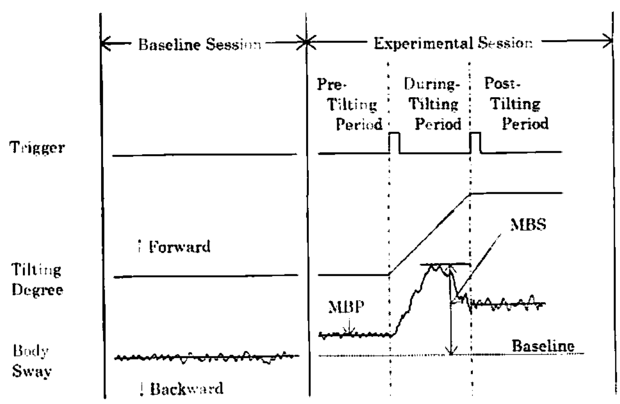

Figure 2. Example of typical sampling of trigger, degree of tilting, and forward body sway in the baseline session and the experimental session (one trial). MBP: Mean body position from the baseline in the pre-tilting period. MBS: Maximum body sway from the baseline during tilting.

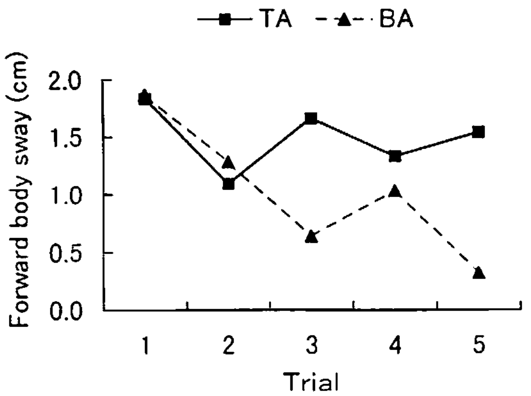

Figure 3. The different patterns of adaptation: the MBS in two instruction groups across a series of trials.

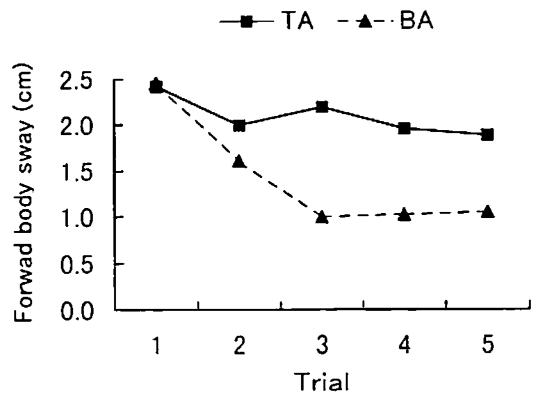

Figure 4. The different patterns of adaptation: the distance between MBS and MBP in two instruction groups across a series of trials.

they were affected by the subjects' weight. To determine the distance of movement of the center of gravity, the y-moment output from the force plate was divided by z-moment. Two measures were used in the analysis: the maximum body sway (MBS) from the baseline during tilting and the mean body position (MBP) in the pre-tilting period. Figure 2 indicates an example of typical sampling in MBS and MBP.

Using two-way ANOVA of 2 groups and 5 trials, MBS was significantly different across trials ($F(4, 60) = 3.60$, $p<.05$). The MBS in the first trial was significantly longer than that in fifth trial ($q(5, 60) = 4.67$, $p<.05$). Figure 3 indicates the adaptation patterns over the five trials. Moreover, there was significant interaction between groups and trials in the MBS ($F(4, 60)=2.98$, $p<.05$). The results of the test of the simple main effect on the MBS between two groups for each trial showed that the subjects in the TA group swayed significantly more forward than the BA group in the fifth trial ($F(4, 60) = 2.80$, $p<.05$). MBS across the series of trials was different in the BA group ($F(1, 75) = 16.39$, $p<.01$). Using Tukey's test, MBS in the first trial was significantly longer than that in the third and fifth trial ($q(2, 75) = 4.69$, $p<.01$, and $q(2, 75) = 5.92$, $p<.01$, respectively). MBS in the second trial was significantly longer than that in the fifth trial ($q(2, 75) = 3.69$, $p<.05$). In the TA group, MBS in the first trial was significantly longer than that of the second trial ($q(2, 75) = 2.85$, $p<.05$).

Again, using two-way ANOVA of 2 groups and 5 trials, the distance between MBS and MBP was significantly different across trials ($F(4, 60) = 12.75$, $p<.001$). The results of Tukey's test show that the distance of MBS from MBP in the first trial was more forward than in other trials (df=5, 60, $p<.01$, with q = 5.73, q = 7.73, q = 8.64, q = 8.82, respectively, for the four trials). Figure 4 indicates the adaptation patterns of the distance of MBS from MBP across five trials. Moreover, there was significant interaction between groups and trials in the distance between MBS and MBP ($F(4, 60)=4.66$, $p<.01$). As a result of the test of the simple main effect between two groups for each trial, the subjects in the TA group swayed significantly more forward than the BA group in the third, fourth, and fifth trial ($F(4, 60) = 7.06$, $p<.01$, $F(4, 60) = 4.35$, $p<.01$, $F(4,60) = 3.49$, $p<.05$).

4. Discussion

Results of this study indicated the subjects in BA group decreased body sway compared to that in TA group, and agreed with the finding of Hoshikawa (1999) that the difference of strategies brought about different patterns of adaptation. Present finding indicated the inconsistency of the findings of Wulf *et al.* that indicated improved static balance response under external focus conditions and compromised static balance response under internal focus condition. One possible reason for the contradiction was suggested by the difference between each experimental tasks' demand. McNevin and Wulf (2002) used supra-postural task that subjects were instructed to stand still while lightly touching a hanging sheet with their fingertips closing their eyes. Although, the dependent measure of McNevin and Wulf (2002) was body sway measured by stabilometer, there was no significantly difference of body sway between two groups, only they indicated that frequency of responding (fast Fourier transformation) was greater under the external focus condition, compared to the internal focus conditions. Moreover, Wulf *et al.* (2001) examined the difference of instruction using dynamic balance task with subjects instructed to either focus on a marker (external focus) or on their feet (internal focus), and indicated that the external focus group produced generally smaller balance errors than did in the internal focus group. Although, present experiment was the same condition of Wulf *et al.* because the subjects who were instructed to direct attention either to the target or to their body, Wulf *et al.* used a dynamic balance task in which the subjects asked to keep the platform in the horizontal position, compared to keep standing still under present study. Therefore, it could be concluded that the difference of tasks brought about contradiction between findings of this study and Wulf.

Another possible reason was the usage of terms of "external" and "internal". While, in this study, subjects were asked to maintain standing still in BA group, Wulf's subjects were asked to focus on their feet (Wulf *et al.*, 2001). There was a difference of the subject's motor control process. Subjects in present study directed attention to their body in order to keep standing posture instructed to keep standing still. On the other hand, subjects in dynamic balance task (Wulf *et al.*, 2001) had to process a dual task in which subjects were asked to keep balance on the platform and to keep direct attention to their feet. Therefore, their subjects were interfering with automatic motor control process that was proposed in "constrained action hypothesis".

There remains some doubt about why instruction did not affect body sway in the first trial or mean body sway across trials, but did affect the process of adaptation of body sway. Based on Nashner's finding and results of this study, it was concluded that subjects used some strategy in the tilting room in order to perform context-dependent reorganization of the weighting of inputs from support surface, and from the vestibular and visual systems. Because subjects in the TA group paid attention to external objects, they depended more on visual information than on kinesthetic information, and they did not reduce body sway induced by the tilting room. Subjects in the BA group who depended more on kinesthetic information than visual information, on the other hand, could reduce body sway because they focused on bodily sensation of standing still. Therefore, the effects of instruction were indicated only after repeated experiences of subjects across a series of trials.

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Footnote

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