COORDINATION CHANGE BETWEEN GAZE, HEAD AND HIP DUE TO EARLY EYE ROTATION DURING OPEN CUT MANEUVER

[1]Akifumi Kijima, [2]Koji Kadota, [3]Noriyuki Tabuchi, [4]Tomoyuki Matsuo and [4]Ken Hashizume
[1]Department of Health and Sport Sciences, Fukuyama Heisei University, [2]Osaka University of Health and Sport Sciences,
[3]Graduate School of Human Sciences, Osaka University, [4]School of Health and Sport Sciences, Osaka University
e-mail: kijima@heisei-u.ac.jp

INTRODUCTION

The integration of visuo-vestibular information achieved by eye-head synergy (vestibulo-ocular reflex), is presumed to play an important role in postural control, as it provides a frame of reference for a postural control system [1]. The frame of reference refers to the set of values to which each motor variable refers for planning their own movement. This hypothesis has been supported by previous data demonstrating that the eye-head rotation led to a change in the direction of gravitoinertial acceleration in curvilinear walking [2], or a trunk lateral rotation in a sudden direction change of locomotion (i.e., cutting maneuvers) [3]. However, previous studies have never confirmed that eye-head synergy solely integrates visuo-vestibular information and governs whole body movements.

Subsequently, we tested whether eye-head synergy occurs even when the gaze was experimentally constrained to rotate earlier than in a natural setting. If eye-head synergy exclusively acts to integrate visuo-vestibular information, an early rotation of the head would be emphasized, as it minimizes angular deviation between the eye and the head.

METHODS

Five healthy graduate students were asked to walk a distance of 1.95 m with 2 steps, and cut into one of two directions (60 degrees to the left and right) or step straight ahead. The direction of cut is indicated by a semicircular array with a radius of 0.93 m consisting of 16 LEDs, which was placed at the subjects' eye level.

In the control condition (CNT), the subjects were instructed to start walking straight toward the center of the circular LED array and then step onto the right mat with a cross-over step when the right 8 LEDs placed at 0 to 90 degrees lateral to the approaching direction were turned on. The left 8 LEDs indicated that the subject should step onto the left mat with an open step, and the 8 center LEDs indicated that they should step straight ahead. The timing of the LEDs' onset was controlled by the (left) heel strike of the first approaching step. Eight trials were made for each direction in a randomized order.

To investigate the effects of compulsorily induced lateral gaze rotation, we conducted 24 additional trials for the EHR (eye-head rotation) condition, in which 2 of 8 LEDs located in the cutting direction (i.e., at 54 and 66 degrees) were turned on or off at 0 or 0.5 s after the LEDs' onset. The subjects were required to report when these 2 LEDs turned on or off (e.g., "At first, LEDs turned on (off) and then off (on)"; "remained on (off)"). The lateral rotation of the head, shoulder, and hip as well as that of the left eye during the left open cut maneuver was measured using 4 infrared cameras (ProReflex motion capture unit, Qualysis Medical, Sweden) and a video-based eye-mark recorder (EMR-8, Nac Image Tech., Japan) at a sampling rate of 60 Hz. The lateral angular displacement of the gaze was calculated by summing the lateral rotation of the eye in the orbit and that of the head in space.

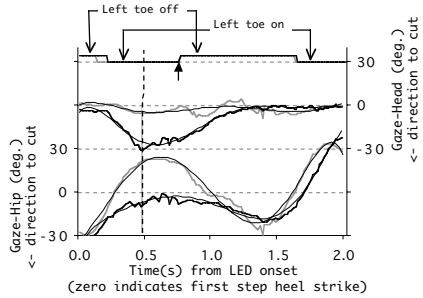

Figure 1: Deviation of angular displacement between Gaze-Head (middle) and Gaze-Hip (bottom) in CNT (gray) and EHR (black)
Thin line on each plot represents a curve fit by a polynominal. Rectangular plot shown on top indicates the timing of left toe contact on the ground. Small upward arrow indicates the timing of the open step onset. Vertical broken line at 0.5 s indicates the timing on which 2 LEDs turned on or off. Mean of 8 trials perfomed by a typical subject.

RESULTS AND DISCUSSION

In the EHR trials, the timing of the saccade onset was concentrated at 0.5 s after the LED onset in order to fixate on the 2 lighting LEDs placed in the cutting direction. The head rotation was not observed in this phase. The saccades in the CNT trials were immediately followed by head rotation, and the timing of those onsets ranged widely from 0.5 to 1.0 s after the LED onset. Thus, the manipulation undertaken in the EHR trials succeeded in guiding the earlier onset of saccade and disturbed eye-head synergy.

An angular deviation of the head relative to the gaze was kept approximately at 0 degree, that is, the eye-head synergy was maintained in every phase in the CNT trials, as reported in a previous study [2]. On the other hand, in the EHR trials, not the head, but the hip was aligned in the gaze direction when the eye fixated on the cutting direction at 0.5 s after the LED onset, following which the head rotated to align in the gaze direction (Figure 1). The results observed in the EHR trials indicate that not only eye-head but also gaze-hip coordination could be employed to integrate visuo-vestibular information.

These results suggest that it is also necessary to achieve the frame of reference for the open cut maneuver. Further, as suggested in a previous study about postural control [1], the strategy for this function is altered or compensated by body segments below the head due to the gaze constraint. We speculated that the earlier rotation of the head relative to the trunk presented in the previous analysis of cutting maneuvers [3] is a part of this dynamic nature of the mechanism to maintain a stable frame of reference.

REFERENCES

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