Collision Avoidance Affected by Walker's Head Direction in a Virtual Environment

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Abstract. We investigated participants' active response to avoid collision with an approaching walker in a virtual environment. The walker was approaching and then changed his direction leftward or rightward at a random timing. The walker's head rotated (yaw) leftward or rightward, or remained straight at 533ms before direction change of walking. Ten participants were asked to avoid collision by moving a mouse laterally to move own viewpoint. We found that participants' collision avoidance behavior was affected by head directions. They moved in the opposite direction to the other walker's head direction when the walker rotated his head. These results suggest that we utilize other people's head direction to avoid collision in active situation as well as static perceptual situation.

Keywords: Perception and action, Collision avoidance.

1 Introduction

We can perceive other people's walking direction very quickly and accurately. Its accuracy depends on spatial and temporal information such as presentation duration and body surface [1]. Ten to twenty point lights attached to body joints elicit biological motion perception such as walking and dancing [2]. The accuracy of direction perception of a point-light walker is lower than the gray-shaded computer graphics walker, but high enough [1][3]. Since human walker's gaze and head direction reflect the intended direction of walking [4], human observers utilize other people's eye direction [5] and head direction [3][6] to perceive the other's walking direction. These studies employed cognitive inferences [2] and perceptual judgments [3][6] of static participants, who were observing a walker approaching to the participant in a virtual environment. However, participants' active or behavioral response for approaching walkers has not been investigated. Active responses (actions) and passive perception (judgments) are differently induced by visual stimulation. Actions and manual control decreases visual illusions [7][8] and facilitates some aspects of visual perception [9]. Thus, illusory effects of head direction might be diminished by active responses.

2 Methods

Ten naive observers with uncorrected or corrected normal vision participated in the experiment after written informed consent. The experiment was approved by the Committee for the Human-subject Studies at Toyohashi University of Technology. The stimulus was created and controlled by a computer (DELL, Precision workstation T1600, Intel Core i3-2120 3.30GHz, NVIDIA Quadro FX3700), and projected on a rear-screen (248 wide x 186 high cm) by a 3CRT projector (Barco, Cine7/II, 1024 x 768 pixel, 60 Hz, 0.0077 - 9.404 cd/m^2). The experiment was performed in a darkroom.

In a virtual environment of a corridor (10m width floor and ceiling with 2.5m height left and right walls that were filled with random dots: 10 dots/ m^2), a walker (170 cm tall, Male) approached (2 steps/s, 2.94 km/h) to participants (Figure 1). The participants also moved ahead at the same speed. The other walker changed his direction randomly leftward or rightward (6.7 deg) at a random timing (1.67-2.67 s) after starting walking. The direction change took 300 ms. The walker's head rotated (yaw) leftward or rightward (20 deg), or remained straight at 533ms before direction change of walking. The head turn took 167 ms. These stimuli were presented on the rear-projection screen (63.60 x 49.88 deg in visual angle) and participants observed them at 200 cm viewing distance. All combinations of experimental conditions were repeated 20 times in random orders (Figure 2). Participants were asked to avoid collision by moving a mouse laterally to move their own viewpoint.

Fig. 1. Schematic of virtual environment. The corridor was made with four walls filled with random dots. Gray-shaded walker approached to the observer/participant.

Fig. 2. Experimental conditions. The rotation directions of head and the following direction changes of walker were combined for setting 6 conditions. The combination of the left (right) head turn and the left (right) walking direction change is the consistent condition of head and walking, while the combination of the left (right) head turn and the right (left) walking direction change is the inconsistent condition.

3 Results

We found that participants' collision avoidance behavior was affected by head directions (Figure 3). They moved in the opposite direction to the other walker's head direction when the walker rotated his head. In the conditions that the head yaw was consistent with the walking direction change, collision avoidance began in the correct direction (opposite direction to the walker) approximately 500 ms before collision avoidance action in the conditions without head rotation. In the conditions that the head yaw was inconsistent with the walking direction change, collision avoidance began in the wrong direction (same direction as the walker) approximately 500 ms before the no-head-rotation conditions, then was being returned to the correct direction after 500 ms of the first action.

Fig. 3. Experimental results. Lateral position of participant's viewpoint was plotted against time after head turn. Positive value of the vertical axis indicated the opposite direction to walking-direction change, thus the appropriate direction for collision avoidance.

4 Discussion

These results suggest that we utilize other people's head direction to avoid collision in active situation as well as static perceptual situation. Thus, the effect of head rotation on walker's perception is not a visual illusory effect, but rather it supports the notion that our perception of and action to other walkers are related to our social cognition or social perception. Directions of eye and head often reflect walker's intention of walking and path finding. Thus, human observers utilize others' gaze and head direction to perceive and infer others' behavior. This kind of perception and inference seems to be a rudimentary social communication and important for human as social mobile observers. The fact that human perceptual accuracy of other's gaze is very high also supports this notion [10]. Perceptions of other walkers' motion and gaze shift elicit brain activities at the regions relating to social cognition [11][12]. These findings also support the importance of other walker's perception to investigate our social cognition.

Our findings can contribute to design robot' walking motions that facilitate human perception or inference of robot's heading change naturally and automatically. We should put appropriate motions of robot's head and eyes at an appropriate timing before heading change.

Acknowledgments. This research was partly supported by Grant-in-Aid for Scientific Research (B) #22300076 and Grant-in-Aid for Challenging Exploratory Research #23650060 from MEXT Japan.

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