Exploring the dynamic engagement and disengagement of eye and hand in a naturalistic VR task.

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Abstract

Eye-hand coordination is a research topic of great interest since it is significant to important activities related to object interactions. Various studies have been conducted ranging from simple object manipulation (Ballard et al., 1995) to more complex natural activities including driving (Mars and Navarro, 2012), hand washing (Pelz and Canosa, 2001), or tea making (Land et al., 1999). These studies have shown that the eye fixations are mainly task-related and precede manual action by 1 second or less, indicating that vision can be understood as a planning mechanism for the following action. However, most of these tasks followed organized task structures and did not examine novel tasks that require ad hoc action planning and full-body movement where specific action locations might be hard to reach or non-ergonomic.

In the present study, we used a naturalistic virtual reality (VR) setting to investigate the complex interplay of gaze direction and hand movements while subjects performed a novel task. The virtual reality setting was used to overcome the deficiencies in precisely recording the changes in a real-life environment simultaneously with bodily interactions. We designed an experiment where subjects had to pick up and drop off objects on a life-size shelf with the goal of sorting the objects based on color and/or shape (Figure 1A). While subjects performed the tasks, we concurrently measured eye movement parameters such as gaze position and direction along with head and hand movements. We analyzed the horizontal and vertical angular positions of the head-centered gaze and hand for 4 seconds before and after object pick up (Figure 1B). Using cross-correlation functions, we assessed the delay between the eye and hand angular positions in the horizontal and vertical plane (Figure 1C).

Our results suggest that the eye signal precedes the hand by mean 0.45 seconds (SD=0.10) in the horizontal plane and mean 0.34 seconds (SD=0.12) in the vertical plane and is positively correlated (horizontal: rho=0.12, SD=0.02, vertical: rho=0.23, SD=0.06) before the action initiation. However, after the action was completed, the two signals are most anti-correlated, suggesting a disengagement of the eye and hand while the eye moves on towards planning another action. We also found that the time lag between the eye and hand movements was dependent on the spatial location where the action is performed. Interestingly, for hard-to-reach locations, such as the outermost rows and columns of the shelf, we found high variance in the time lag between the eye and the hand signals. Furthermore, we found that the strength of the correlation of the eye and the hand differed based on the spatial location of the action, indicating that ergonomic factors might be

involved in how eye movements are utilized to plan manual actions. Finally, the cross-correlation function revealed differing coordination strategies in the horizontal and vertical planes for the same shelf locations indicating that this coordination is much more complex in naturalistic settings.

In conclusion, our study shows that the oculomotor system prepares the motor system to act in the environment. The eye and hand movements show a clear dynamic of engagement before action initiation and disengaging soon thereafter. Furthermore, the latency between the eye and hand movements shows that the coordination happens in the moment and is primarily driven to perform the action and is not affected by ad hoc planning required for the novel tasks. Moreover, this coordination is sometimes noisy in the face of more complex settings where the ergonomic value of performing the action at specific locations might play an important role. In sum, the dynamic coordination of eye and hand movements is primarily driven to produce relevant action.

References

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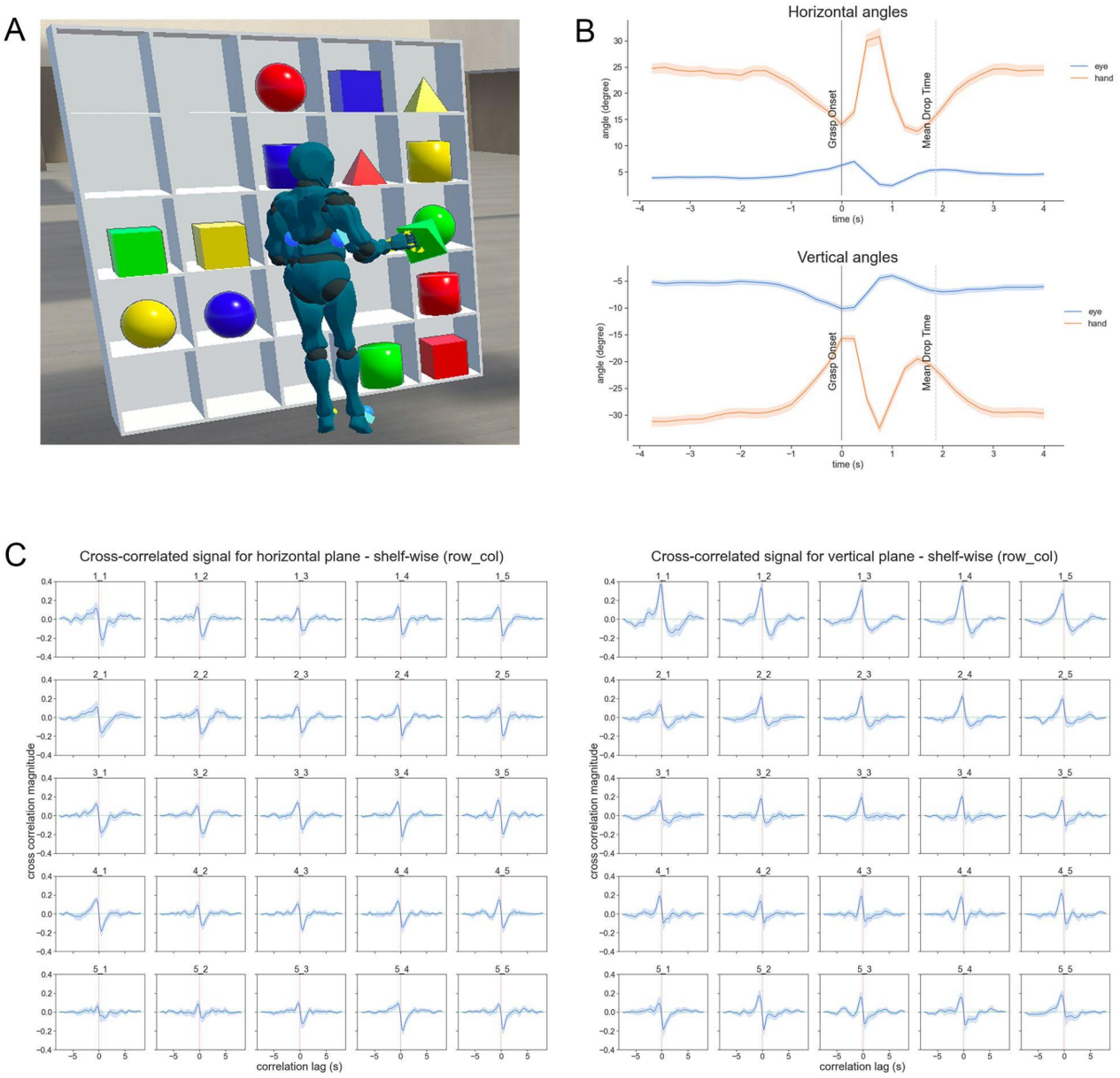

Figure 1. A) *Experimental Task. In a virtual environment, 32 participants sorted 16 different objects based on their color and/or shape while we measured their eye and body movements. All subjects performed 24 trials in total with no time limit.* ***B)*** *Time course of eye and hand angular positions in the horizontal and vertical plane. The shaded regions show a 95% confidence interval of the mean angular positions at each time-bin, pooled across all subjects. For the horizontal plane, decreasing angles correspond to a leftward movement, increasing angles to a rightward movement. For the vertical plane, decreasing angles correspond to a downward movement, increasing angles to an upward movement.* ***C)*** *Cross-correlation of the eye and hand angular positions in the horizontal and vertical plane made overall shelf 5x5 locations.*