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The effect of viewing the moving limb and target object during the early phase of movement on the online control of grasping

Takao Fukui *, Toshio Inui

Department of Intelligence Science and Technology, Graduate School of Informatics, Kyoto University, Yoshida-Honmachi, Sakyo-ku, Kyoto 606-8501, Japan

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Abstract

Two experiments were conducted to investigate (1) during which phase of the movement vision is most critical for control, and (2) how vision of the target object and the participant's moving limb affect the control of grasping during that movement phase. In Experiment 1, participants, wearing liquid crystal shutter goggles, reached for and grasped a cylinder with a diameter of 4 or 6 cm under a shutting paradigm (SP) and a re-opening paradigm (RP). In SP, the goggles closed (turned opaque) 0 ms, 150 ms, 350 ms, 500 ms, or 700 ms after movement onset, or remained open (transparent) during the prehension movements. In RP, the goggles closed immediately upon movement onset, and re-opened 0 ms (i.e., without initially shutting), 150 ms, 350 ms, 500 ms, or 700 ms after the initial shutting, or remained opaque throughout the prehension movements. The duration of the prehension movements was kept relatively constant across participants and trials at approximately 1100 ms, i.e., the duration of prehension movements typically observed in daily life. The location of the target object was constant during the entire experiment. The SP and RP paradigms were counter-balanced across participants, and the order of conditions within each session was randomized. The main findings were that peak grip aperture (PGA) in the 150 ms-shutting condition was significantly larger than in the 350 ms-shutting condition, and that PGA in the 350 ms-re-opening condition was significantly larger than in the 150 ms-re-opening condition. These results revealed that online vision between 150 ms and 350 ms was critical for grasp control on PGA in typical, daily-life-speeded prehension movements. Furthermore, the results obtained for the time after maximal deceleration (TAMD; movement duration – time to maximal deceleration) demonstrated that early-phase vision contributed to the temporal pattern of the later movement phases (i.e., TAMD). The results thus demonstrated that online

* Corresponding author. Tel.: +81 75 753 3149; fax: +81 75 753 3292.
E-mail address: fukui@cog.ist.i.kyoto-u.ac.jp (T. Fukui).

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vision in the early phase of movement is crucial for the control of grasping. In addition to the apparatus used in Experiment 1, two liquid shutter plates placed in the same horizontal plane (25 cm above the experimental table) were used in Experiment 2 to manipulate the visibility of the target and the participant's moving limb. The plate closest to the participant altered vision of the limb/hand, while the more distant plate controlled vision of the object. The conditions were as follows: (1) both plates were open during movement (full vision condition); (2) both plates were closed 0, 150, or 350 ms following onset of arm movement (front-rear condition: FR); or (3) only the near plate closed 0, 150, or 350 ms following the onset of the arm movement (front condition: F). The results showed that shutting at 0 and 150 ms in the FR condition caused a significantly larger PGA, while the timing of shutting in the F condition had little influence on the PGA. These findings indicated that online vision, especially of the target object, during the early phase of prehension movements is critical to the control of grasping.

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1. Introduction

Two main research questions regarding the online control of goal-directed movements have been extensively investigated in the literature but have not been resolved. One is the rather classical problem of the 'temporal' aspect of vision, that is, "when does the influence of vision emerge in motor control?" (e.g., Beggs & Howarth, 1970; Keele & Posner, 1968; Vince, 1948; Woodworth, 1899; Zelaznik, Hawkins, & Kisselburgh, 1983). The other is the 'environmental' issue, which has to do with the relative importance of the various kinds of visual information for motor control. Although it is evident that there are several sources of visual information for guiding our actions in the environment, including visual feedback of the actor's own hand, vision of the target, and various environmental cues, it remains unclear which source of visual information is most important for motor control, and how each source influences the control of goal-directed movements.

As regards the first research question, Desmurget et al. (1999) demonstrated that the trajectory of the hand movement (i.e., *pointing* movement) could be monitored in real time from the very beginning of movement by means of transcranial magnetic stimulation (for a review see Desmurget & Grafton, 2000). As regards the online control of *grasping*, it remains uncertain during which phase of movement online vision is most crucial.

Prehension movements are typical actions in daily life, and are usually performed for a particular purpose. Jeannerod (1981, 1984) proposed that prehension movements consist of two main components: a transport component and a manipulation (grasp) component. In focusing on the behavioral aspects of the grasp component, fingers first open gradually and form the appropriate configuration for the target object to be grasped ('preshaping'), then open wider than the size of the target object up to a certain maximum (i.e., the peak grip aperture), to then enclose the object, and finally touch the object's surface. It has also been demonstrated that the peak grip aperture (PGA) is significantly larger when vision is absent during prehension (Jakobson & Goodale, 1991; Wing, Turton, & Fraser, 1986). Therefore, PGA has been regarded as indicative of the influence of online vision on grasping, although it remains unclear why an overshoot in hand aperture occurs or why PGA is larger when one cannot use