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Author(s): Hari, Riitta & Jousmäki, Veikko

Title: Preference of Personal to Extrapersonal Space in a Visuomotor Task

Year: 1996

Version: Final published version

**Please cite the original version:**

Hari, Riitta & Jousmäki, Veikko. 1996. Preference of Personal to Extrapersonal Space in a Visuomotor Task. *Journal of Cognitive Neuroscience*. Volume 8, Issue 3. 305-307. ISSN 0898-929X (printed). DOI: 10.1162/jocn.1996.8.3.305.

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# Preference of Personal to Extrapersonal Space in a Visuomotor Task

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## Abstract

■ The speed of visually triggered movements depends, among other things, on the time needed for visuomotor transformations. We show that it takes on average 20–40 msec less time to respond to visual stimuli when they are projected on the

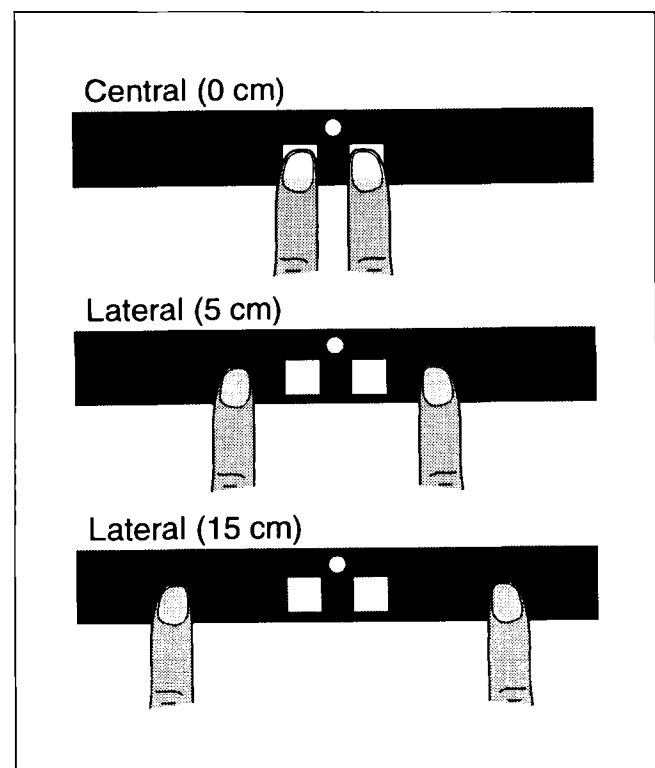
reacting fingers than a few centimeters away from them. The result implies significant preference of the personal space to the extrapersonal space for stimuli used in the initiation of visually triggered movements. ■

Motor reactions guided by visual stimuli involve automatic transformations from sensory to motor coordinates, and thereby require accurate information on the positions of the body parts with respect to the stimuli. The human brain continuously computes such positions, based on input from all sensory modalities, and maintains awareness of the surrounding space. Processing of visual input used for visuomotor transformation is considered separate from that leading to visual perception (Jeannerod & Rossetti, 1993) and may differ for different compartments of the extrapersonal space (Hyvärinen, 1982).

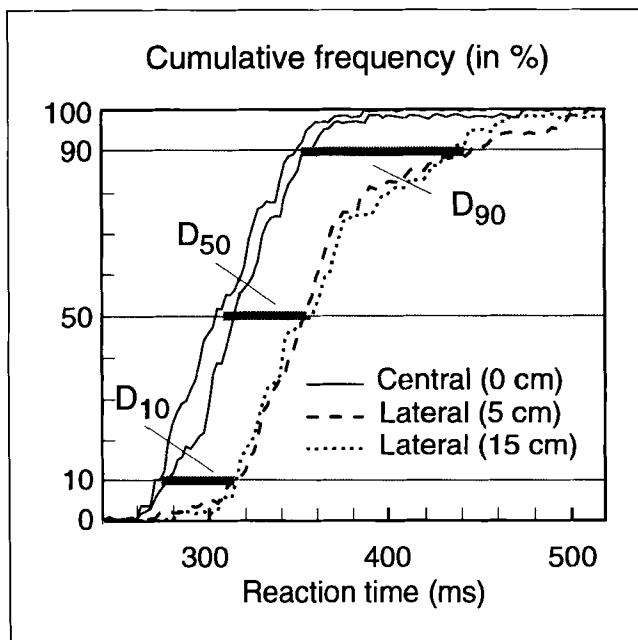
While testing visual stimuli for a study of cortical visual functions we encountered an apparently new perceptual phenomenon: It seemed more comfortable and straightforward to respond with finger lifts to visual stimuli when the stimuli were projected on the fingers than slightly away from them. We tested this phenomenon systematically in eight right-handed adults (mean age 33 years, four females). Stimuli were presented to the left or right visual field in random order with interstimulus intervals of 2.5–3.5 sec and the subject reacted to them as fast as possible by lifting the index finger of the same side. The stimuli were always presented to the same locations and the subject fixated on the same point (Fig. 1) but the reacting fingers were either 0, 5, or 15 cm lateral to the stimuli in different conditions. The 0-cm ('central') task, in which the stimuli fell on the back of the subject's index fingers, was commonly considered the most straightforward. As one subject stated: "It is, of course, much easier to react when the lights fall on the fingers since then you do not have to think which finger to move."

Figure 2 shows the cumulative reaction times (RTs) of one subject in all conditions. RTs were consistently longer when the fingers were outside the stimulus loca-

tions, but did not differ significantly between the two lateral positions. The great similarity of the two RT distributions for the central positions, performed as the first



**Figure 1.** The experimental setup. The stimuli were projected with a mirror onto a cardboard strip placed on the subject's lap in a dimly lit room. The subject fixated on the dot in the middle. The stimuli ( $2.5 \times 2.5 \text{ cm}^2$  light squares viewed from 55–60 cm) were presented randomly either to the left or the right visual field. The subject lifted the index finger on the side to which the stimulus was presented.



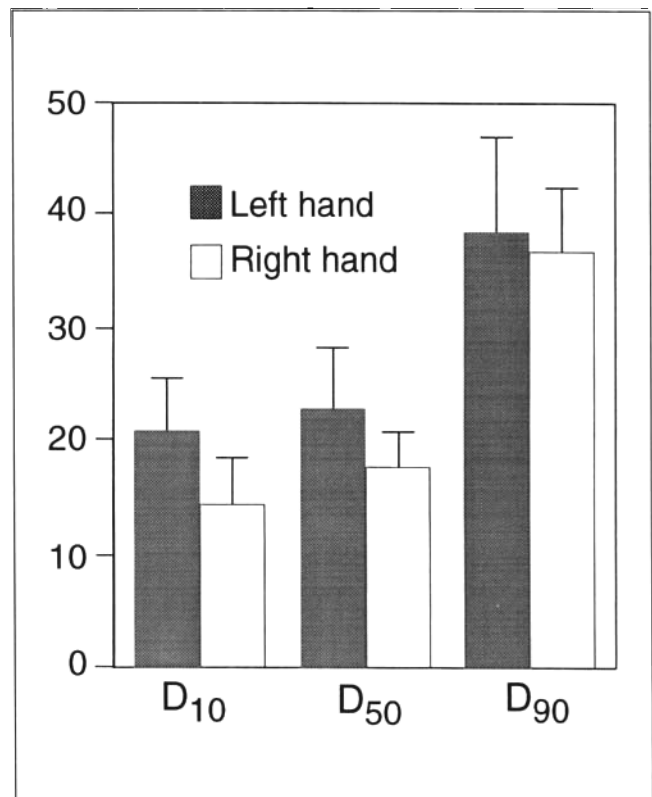
**Figure 2.** Cumulative frequency distributions (in percentage) of RTs in one subject; the measurement started and ended with the central (0-cm) condition. Altogether 60 correct responses were recorded for each finger in each condition. Determination of  $D_{10}$ ,  $D_{50}$ , and  $D_{90}$  is indicated.

and the last task of the session, rules out learning or fatigue effects as the cause of the observed differences.

In the mean data for all eight subjects, shown in Figure 3, the median (50th percentile) RTs were  $21 \pm 5$  and  $18 \pm 3$  msec (mean  $\pm$  SEM; left and right hands, respectively) shorter in the central than in the two lateral conditions. The corresponding 90th percentile differences ( $D_{90}$ ) were  $38 \pm 8$  and  $37 \pm 6$  msec, respectively. All differences ( $D_{10}$ ,  $D_{50}$ , and  $D_{90}$ ; determined as differences between the mean of the two lateral conditions and the mean of the repeated central conditions) were statistically highly significant ( $p < 0.005$ , two-tailed paired  $t$  test). Significantly larger values for  $D_{90}$  than  $D_{50}$  and  $D_{10}$  reflect differences in the RT distributions: the lateral conditions included a relatively larger number of delayed responses, implying that in those tasks the subjects occasionally had difficulties in transforming the visual stimulus locations to proper motor action.

Three control experiments were carried out. First, two subjects, with the largest central vs. lateral differences in the main task, kept their hands in the central position while the stimuli were presented 5 cm above the fingers on the response panel. The responses were delayed like those in the lateral positions. Thus the observed RT differences in the main task could not reflect just differences in hand separation.

In the second control experiment, three subjects had to react to left- vs. right-ear tones with the hand of the same side, keeping similar eye fixation as in the main experiment. These audiomotor responses did not differ



**Figure 3.** Mean ( $\pm$  SEM) RT differences  $D_{10}$ ,  $D_{50}$ , and  $D_{90}$  for all subjects, shown separately for the left and right index fingers.

in any systematic way between the central and lateral hand positions. Thus the faster visuomotor RTs in the central position were evidently not due to the shorter distance of the fingers to the fixation point and to foveal vision. Moreover, in a third control experiment the visual stimuli were separated by 10 cm, and the reacting fingers either by 5 cm (located symmetrically between the stimuli and on level with them) or by 10 cm (stimuli projected on the fingers). Both conditions were replicated once. The RTs ( $D_{50}$ ) were 12–20 msec shorter in the three subjects studied when the stimuli were applied on the fingers. Thus the foveal proximity of the fingers in the central condition of the main experiment cannot be responsible for the observed shortening of the RTs.

In all the above experiments, the head and eye positions, known to affect visuomotor coordination (Jeannerod & Rossetti, 1993), were stable and the only change was in the position of the reacting fingers. The results showed that, in such conditions, the motor reactions to visual stimuli falling on the reacting fingers are 20–40 msec faster, and are felt by the subjects to be more automatic, than responses to stimuli a couple of centimeters away in the extrapersonal space. Previous visual reaction time studies have missed this effect evidently because the subjects in such tasks typically react to stimuli presented on a screen, not on their body.

The present findings can be considered to reflect

spatial stimulus–response compatibility in the sense that some stimulus–response pairings were easier to form and faster to process than others (cf. Umiltà, 1994). However, the observed effect was much more specific than spatial stimulus-compatibility RT effects reported in the literature. Our findings also clearly differ from the “Simon effect,” in which the spatial location of the stimulus, although irrelevant to the task, still affects the response speed (Umiltà, 1994).

One explanation for the observed phenomenon is that motor programs are activated more easily by visual stimuli on the reacting body parts than in the immediate extrapersonal space. In other words, visual stimuli away from the body seemed to need a time-consuming extra processing step—like coordinate transformation from environmental stimulus locations to body coordinates (Andersen, 1988; Jeannerod & Rossetti, 1993)—whereas the same action occurs more automatically in the personal space.

Signals from different sensory modalities converge on the parietal lobe, which is considered to maintain a representation of space in body-centered coordinates, necessary for guiding movements in the extrapersonal space (Hyvärinen, 1982). One would thus expect abnormalities in the described RT measures in patients with a distorted body scheme after parietal lobe lesions. On the other hand, the present task might involve visual cells activated in arm-centered coordinates. Such neurons have been recently found in the prefrontal cortex of

monkey (Graziano, Yap, & Gross, 1994) and have been suggested to have an important role in hand–eye coordination in the near extrapersonal space.

### Acknowledgments

Supported by the Academy of Finland. We thank S. Salenius, L. McEvoy, S. Williamson, and V. Virsu for discussion and comments on the manuscript.

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