

NOTES AND DISCUSSION

Influence of the Movement Parameter to Be Controlled on Manual RT Asymmetries in Right-Handers

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In this experiment we test whether the effects of manual asymmetries on movement preparation depend on the parameter (amplitude or direction) to be programmed. In two experiments, only the amplitude, or the direction, of aiming movements was constrained. Reaction and movement times were measured. Results show that RTs are always shorter for left-hand than for right-hand movements. There is an effect of target extent in the amplitude condition, but not in the direction one. RTs for ipsilateral movements are shorter than RTs for contralateral movements. These results are discussed in the light of the processes involved in setting the amplitude or direction of the movement and with regard to the competency of the two hemispheres regarding these processes. © 2000 Academic Press

Key Words: reaching; reaction time; manual asymmetries; direction/distance; humans.

INTRODUCTION

Manual asymmetries in the performance of a variety of motor tasks have generally been attributed to the relative proficiency of each cerebral hemisphere regarding specific operations of perceptual-motor processing (Todor & Smiley, 1985). Thus, manual performances for each hand depend on the aspect of the task under scrutiny. For instance, a right-hand/left-hemisphere advantage is usually reported for movement execution (e.g., Roy, Kalbfleish, & Elliott, 1994; Elliott, Lyons, Chua, Goodman, & Carson, 1995), whereas a left-hand/right-hemisphere advantage is observed for movement preparation (e.g., Elliott, Roy, Goodman, Carson, Chua, & Maraj,

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1993; Carson, Chua, Goodman, Byblow, & Elliott, 1995). This latter effect is supported by clinical evidence (Fisk & Goodale, 1985; Haaland & Harrington, 1989) as well as behavioral evaluation of normal subjects (Carson, Goodman, Chua, & Elliott, 1993; Elliott et al., 1993; Carson et al., 1995). Two main hypotheses have been proposed to account for this right-hemisphere advantage in movement preparation: it could depend on a superiority of the right hemisphere for the allocation of attention in space (Heilman & Van Den Abell, 1979) and/or on a better integration and forwarding, prior to movement initiation, of information about the position and orientation of an effector with respect to the target location (Carson et al., 1995).

However, authors working on manual asymmetries have often neglected to include in their models some well-established characteristics of movement programming. For example, it is well known that setting the direction and amplitude parameters of a voluntary movement rely on distinct processes (Rosenbaum, 1980; Favilla, Mening, & Ghez, 1989; Soechting & Flanders, 1989; as well as neurophysiological data from Fu, Suarez, & Ebner, 1993; Fu, Flament, Coltz, & Ebner, 1995). It is therefore conceivable that the programming requirements of the task may affect the asymmetry effects. The aim of the present study was to assess manual asymmetries in movement organization as a function of the movement parameter to be controlled. We compared reaction times (RT) of the two hands depending on whether the direction or the amplitude of the movement had to be programmed. Movement time (MT) was also recorded as a control variable.

MATERIALS AND METHODS

We have designed two experiments in order to evaluate the influence of the control of amplitude or direction on manual asymmetries. The direction of the required movement was manipulated in the first one, the distance in the second one.

Subjects

Ten male volunteers participated in the experiment. All were naive with regard to the goal of the experiment. They also all reported normal vision and were rated as right-handers (Bryden, 1977).

Experimental Set-up

Subjects sat in the dark in front of a table onto which the experimental apparatus was fixed. The design of the set-up was such that, depending on the experimental condition, only the direction or the amplitude of the movement was constrained. Figure 1 depicts the aiming surface, which consisted of eight horizontal angular targets (10°) on each side of the sagittal plane of the subject (Y). Each of these angular targets was further divided into six sectors by concentric circles centered on the so-called origin point, O. The radii of the circles delimiting the six sectors ranged from 17.5 to 47.5 cm, in increments of 5 cm. An LED was positioned in the center of each sector, and an electrical contact allowed the detection of the contact between the stylus and the sector (uncertainty ± 0.5 ms). An additional target, located at the

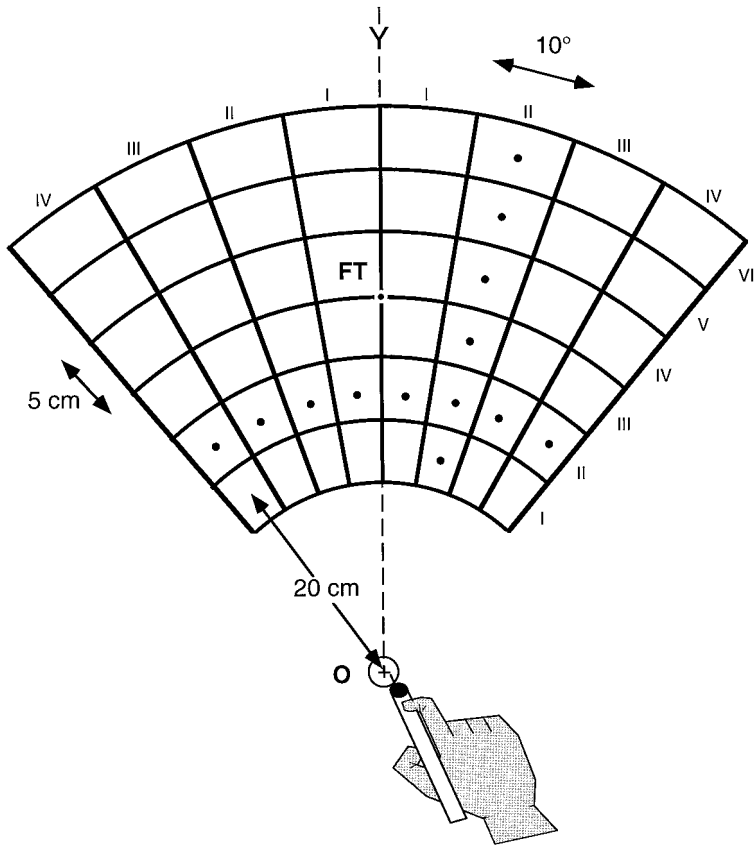


FIG. 1. The experimental set-up. The aiming table consists of eight angular targets, four on each side of the sagittal plane, each divided into six sectors by concentric circles. The subject is holding a stylus on the origin point O until a target pattern (a line or an arc of a circle) lights up. The fixation point FT is located in the center of the display.

very center of the set-up (on the y axis, at a distance of 32.5 cm from the origin), served as visual fixation point (FT) and preparatory signal.

Subjects were asked to hold an aiming stylus between their thumb and index fingers, while looking at the fixation point. Before movement initiation, the stylus had to rest on a metallic home plate fixed on the origin point O. The subjects held their head just above the home plate, which lay about 40 cm below eye level.

The subjects were asked to aim at, and touch, the target with the stylus as soon as the target pattern was lit. They were also asked to execute the movement as fast as possible; that is, with maximal velocity (± 2 standard deviations). Maximal velocity was determined for each subject during a learning session preceding the experimental session. Depending on experimental condition, the target was either an alignment of LEDs crossing the origin point O and oriented at 5°, 15°, 25°, or 35° to the right or to the left of the sagittal plane (direction condition) or a circular arc of origin O with a radius of either 20, 25, 30, 35, 40, or 45 cm (amplitude condition) (see Fig. 1). Precision tolerance was of $\pm 5^\circ$ for the direction stimuli and ± 2.5 cm

for the amplitude stimuli. In the amplitude condition, targets were labeled relative to their distance from the fixation LED (I to VI starting from O). In the direction condition, targets were defined as either contralateral or ipsilateral and numbered from I to IV with increasing eccentricity.

Procedure

Each experimental session consisted of two series of trials, one for direction stimuli and one for amplitude stimuli. During the directional series, the subjects had to point in the direction defined by the alignment of lit LEDs, without any amplitude constraint. During the amplitude series, they had to aim at the distance corresponding to the lit circular arc, without any direction constraint. In other words, the subjects were free to set the unconstrained parameter of the movement by setting a default amplitude under the direction condition and a default direction under the amplitude condition. The subjects performed four blocks of trials under each experimental condition, two with the right hand and two with the left hand. Within a block, trials appeared randomly. Right- and left-hand blocks were alternated for each subject, and the order of blocks was counterbalanced between subjects.

At the beginning of each trial, the preparatory signal blinked for 2 s and then stayed lit for a variable period of time (300 to 1200 ms). The subjects were then required to fix their gaze onto the preparatory LED. This preparatory signal was turned off, and the target LEDs were simultaneously switched on. Subjects were asked to react and execute the movement as fast as possible upon detection of the target signal. Before the experimental session, they were asked to perform about 100 training trials at maximal velocity. Thus, maximal velocity was determined for each subject. During the experimental session, trials for which RT or MT were 2 standard deviations, or more, above maximal velocity were discarded and presented again at the end of the session. The data from subjects making more than 10% of errors were not analyzed. An error is defined as a movement missing the target or performed 2 *SDs* under maximal velocity.

Reaction times (the delay between target presentation and movement onset) and movement times (the time elapsed between the onset and the end of the movement) were measured using the electrical contacts. A trial was considered valid if the precision was within the above-mentioned tolerance ($\pm 5^\circ$ or ± 2.5 cm). The number of errors relative to the total number of trials was recorded. Average data were compared for each of the two dependent variables (RT and MT). In the direction condition, a 2 hands (left and right) \times 2 sides (ipsilateral and contralateral) \times 4 eccentricities (I, II, III, and IV) design was used. In the amplitude condition, the design was 2 hands (left and right), \times 6 extents (I, II, III, IV, V, and VI).

RESULTS

Direction Condition

Reaction times. Data analysis revealed a main effect of hand, RTs being shorter for left-hand movements than for right-hand movements [262 ± 20 vs 287 ± 43 ms; $F(1, 9) = 5.55, p < .01$]. RTs were more variable for right-hand movements than for left-hand movements. There was also an effect of side [$F(1, 9) = 29.7, p < .0004$], showing that RTs for movements to the ipsilateral side (271 ± 37 ms) were shorter than RTs for movements to the contralateral direction (278 ± 34 ms). There was no effect of eccentricity on RTs.

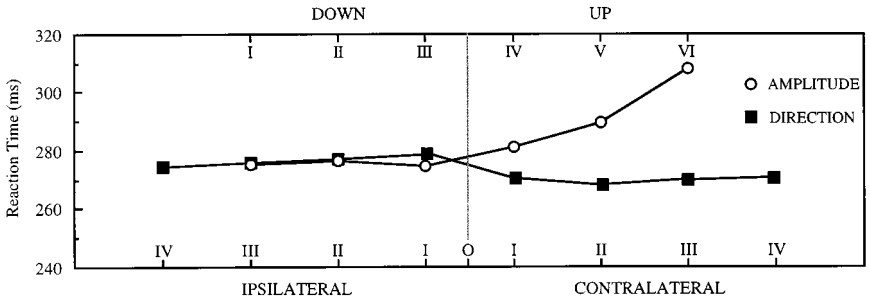


FIG. 2. Effect of target distance on the reaction time in the amplitude (open circles) and direction (solid squares) conditions. In the direction condition, targets are either ipsilateral (on the left) or contralateral (on the right) relative to the aiming segment. In the amplitude condition, targets are called "down" if they are located between the subject and the fixation point and "up" if they are beyond the fixation point.

Movement times. There was no effect of hand on MTs, although MTs for the right hand were slightly shorter than those of the left hand (121 ± 23 vs 130 ± 20 ms). The ANOVA revealed a main effect of side, movements to the ipsilateral side being faster than movements to the contralateral one [$F(1, 9) = 138.95$, $p < .0001$] (see Fig. 2). There was also a main effect of eccentricity [$F(3, 9) = 3.42$, $p < .031$], and, more interestingly, a side by eccentricity interaction [$F(3, 27) = 16.94$, $p < .0001$], showing that the more ipsilateral, the faster the movement. Finally, there was a trend for a difference between left- and right-hand movements when aiming on the ipsilateral side (hand \times side interaction: $F(1, 3) = 4.7$, $p < .058$): the advantage of the right hand was greater on the ipsilateral side than on the contralateral one.

Amplitude Condition

Reaction Times. Analysis of data revealed a main effect of hand, RTs for the left hand being shorter than RTs for the right hand [277 ± 29 ms vs 291 ± 32 ms; $F(1, 9) = 5.42$, $p < .0449$]. There was also an effect of extent [$F(5, 9) = 20.99$, $p < .0001$]. RTs increased with the distance of the target, but only from the IVth target on. Indeed, post hoc analysis showed differences between targets V and VI and all other targets ($ps < .05$). There was no differences in RTs for targets I, II, III, and IV (see Fig. 3).

Movement Times. The ANOVA revealed an effect of hand, as movements performed with the right hand were faster than movements of the left hand [144 ± 41 ms vs 169 ± 37 ms; $F(1, 9) = 21.89$, $p < .0012$]. It revealed also an effect of extent [$F(1, 5) = 100.84$, $p < .0001$] as well as an interaction of the two factors [$F(5, 45) = 3.02$, $p < .0197$]. Concerning the effect of extent, all conditions were different from one another (all $ps < .003$), MT increasing with the distance from the home plate. The interaction between

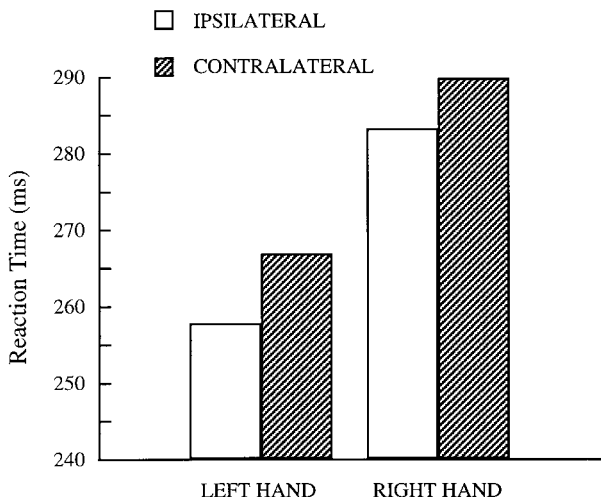


FIG. 3. Effect of the aiming field on the reaction time in the direction condition. For either hand, RTs are longer when the target is located in the contralateral field than when it is located in the ipsilateral one.

hand and extent showed that the difference in MTs for the right and left hands increased with the distance of the target.

DISCUSSION

The aim of the present study was to evaluate whether manual asymmetry effects are differentially affected by the movement parameter (direction vs amplitude) to be programmed. Two experiments were designed, in which only the amplitude, or the direction of aiming movements, was constrained. Reaction time and movement time were measured. As movement times served as control variable, they are discussed first. As expected, movement times of the right hand were always shorter than those of the left hand. It is well established that the preferred hand benefits from overpractice in aiming tasks. In the present experiment, subjects were required to execute the movement at maximal speed (MTs ranged from 113 to 135 ms in the direction condition and from 118 to 201 ms in the amplitude condition). Therefore, it is very likely that the difference in MTs reflects biomechanical and/or muscle adaptations to the preferred use of the right arm. Unsurprisingly, the more distant the target (amplitude), and the more complex the coordination required (ipsilateral vs contralateral movement), the longer the movement time.

Regarding RTs, our results show an effect of hand in the two experimental conditions. RTs were always shorter for left-hand than for right-hand movements. However, given the location of the fixation point and the pattern of

target illumination, the two conditions were different with regard to target detection. In the direction condition, information relative to the target was lateralized, whereas it was not the case in the amplitude condition. In other words, in the direction condition, only the contralateral hemisphere received the information, whereas in the amplitude condition, both hemispheres could "see" the target.

Our results show an effect of target extent in the amplitude condition, but not in the direction condition. This effect is only observed for the targets located beyond the fixation point in the amplitude condition, RTs being different for the targets located within the central visual field (I, II, III, and IV) and for those lying outside (targets V and VI) (Fig. 2). Thus, it is very likely that the effect is due to the ocular saccade necessary to foveate the target in positions V and VI. On the contrary, no difference related to target eccentricity was observed in the direction condition; that is, when amplitude was not constrained. Presumably, there was no need for foveation, and therefore no difference related to the distance from the target to the fixation point. Whereas foveation appears necessary to determine the distance of the target relative to the body, peripheral retinal information appears to be sufficient to ascertain target orientation (Paillard & Amblard, 1985; Blouin, Teasdale, Bard, & Fleury, 1993). In other words, direction can be programmed rather automatically from the oculocentric information received through the peripheral retina (Blouin et al., 1993; Vanden Abeele, Delreux, Crommelinck, & Roucoux, 1993), whereas programming the amplitude requires a translation of target location information into egocentric coordinates, a process depending on central vision and thus on foveation. Such results confirm that the two programming processes rely on different perceptual analyses.

However, even if direction and amplitude controls depend on different processing pathways, similar asymmetry's effects are observed in either condition. Indeed, there is always an advantage of the left hand. In the direction condition, the ANOVA revealed an effect of side, showing that RTs are shorter for ipsilateral stimuli than for contralateral ones. This advantage of ipsilateral stimuli is usually interpreted as indicating that visuomotor processing happens in a single hemisphere (Di Stephano, Morelli, Marzi, & Berlucchi, 1980; Fisk & Goodale, 1985; Velay & Benoit-Dubrocard, 1999). According to these authors, the longer RTs recorded for contralateral movements are due to the time taken by the interhemispheric transfer of information required when one hemisphere receives the information while the other produces the response. In other words, when the movement does not require regulation of amplitude, whichever the hemisphere receiving the stimulus, it is competent enough to determine the direction of the movement. Thus, the left-hand advantage observed in the direction condition indicates that the left hemisphere is able to process this parameter, although less efficiently than the right hemisphere. The superiority of the right hemisphere could be of attentional origin, as proposed by several authors (Elliot et al., 1993; Hodges,

Lyons, Cokell, Reed, & Elliott, D 1997). However, we cannot exclude a contribution of a biomechanical artifact related to the greater complexity of contralateral movements to this side effect (Carey, Hargreaves, & Goodale, 1996). An experiment is presently in progress in our laboratory in which the receiving and emitting hemisphere for movements of identical biomechanical constraints is controlled.

Finally, clinical studies have concluded that the right hemisphere plays a special role in the processing of visuospatial information prior to movement initiation (e.g., Fisk & Goodale, 1985). Specifically, direct connections with the right hemisphere might benefit the left hand in situations in which on-line corrections are not critical to accurate performance, whereas accurate proactive visuospatial processing is necessary. If our hypothesis is correct, the exclusive right-hemisphere involvement in the early stages of visuospatial processing would concern computing the distance of the target relative to the body. That is, the increased RT observed in the amplitude condition for the right hand might be due to the interhemispheric transfers needed when the movement is programmed within the left hemisphere while processing related to target localization and involving central vision depends on the right hemisphere. The previously mentioned experiment, in which the hemisphere receiving the stimulus and emitting the response is controlled in the amplitude condition, should enable us to validate this model of asymmetry for movement preparation.

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