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Manual reaction time asymmetries in human subjects: the role of movement planning and attention

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Abstract

Hemispheric asymmetries in spatial processing are generally considered to be responsible for the shorter reaction time (RT) of the left hand classically observed for right-handers when pointing at targets. Surprisingly, despite the special role which the right cerebral hemisphere is known to play in visual attention, the attentional hypothesis for hand movement preparation asymmetries is currently rejected. This study aims to test the respective roles of visual attention and movement planning in the left hand RT advantage for goal-directed movements. Two experiments were conducted with the same subjects, a simple visual detection task and a classical pointing task, using the same lateralized stimuli. Subjects used the left hand and the right hand alternatively in order to react to the stimuli. In the detection task, the reaction consisted of simply releasing a switch as quickly as possible after the appearance of a target, whereas in the pointing task, it consisted of performing lateralized reaching movements towards the same target. The main results of this study revealed left hand shorter RTs for both tasks, emphasizing the role which right hemisphere dominance for visuospatial attention plays in manual aiming asymmetries. Moreover, a direct comparison of the RTs obtained in both experiments showed that the specific cost of movement planning was lower when using the left hand, therefore also revealing right hemisphere dominance for movement planning.

Keywords: Manual asymmetries; Reaction time; Attention; Movement planning; Human

Manual asymmetries in the performance of a variety of motor tasks have generally been attributed to the relative proficiency of each contralateral cerebral hemisphere regarding specific operations of perceptual-motor processing [17]. Since many authors have demonstrated the specialization of the right hemisphere and its interconnected subcortical structures for spatial cognition [9,12], the left hand advantage in movement preparation inferred from a shorter reaction time (RT) has been interpreted as reflecting a greater degree of engagement of the right hemisphere in spatial processing [2,4,6,13,18,19].

However, many spatial functions contribute to the general dominance of the right cerebral hemisphere for spatial cognition. Among them, visual attention is especially important. Neuropsychological studies derived from hemispatial neglect [9,12], psychophysical studies [15,20] and brain imaging studies [8] have provided evidence of the special role played by the right cerebral hemisphere in visual attention. Recent electroencephalographic data has confirmed that the cerebral dominance of the right hemisphere is not only involved in complex pattern recognition, object identification or sustained attention, but also in simple visual reaction tasks [14].

Surprisingly, despite the special role which the right cerebral hemisphere is known to play in visuospatial attention, the attentional hypothesis for hand movement preparation asymmetries is currently rejected [6,13]. It is instead suggested that left hand shorter RTs may reflect the right hemisphere superiority for the spatial parameterization of movements, i.e. for the integration and feedforward of information about the position and orientation of the effector relative to the target and the environment, prior to the initiation of the movement. This hypothesis is mainly based on the observation that hemispheric asymmetries in pointing tasks depend strongly on the spatial requirements of the movement [2,4,6,13,18,19], and on experiments manipulating the degree of spatial uncertainty in pointing movements. However, from a behavioral point of view, it remains difficult to observe and/or to interpret visual hemifields together

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with hand RT differences on the basis of attentional asymmetries when dealing with pointing movements. Indeed, visuospatial attention and hand movement preparation are intimately linked [3,7,16] and several lateralized effects (related for example to task constraints, target side, response hand, etc.) can interact or be merged [20]. Moreover, there is a surprisingly weak number of studies of directional biases in visuospatial attention with normal subjects.

Accordingly, this study sets out to test the respective roles of visual attention and movement planning in the left hand RT advantage for goal-directed movements, by comparing two experiments involving a simple reaction task and a classical pointing task, respectively, both using the same lateralized stimuli.

Eleven right-handed male volunteers participated in both RT experiments. Each subject's handedness was determined using the Handedness Inventory of Bryden. They were seated in darkness, their head fixed 30 cm from a 28×38 cm vertical black screen, with their eyes at exactly the same level as the center of the screen (marked by a 0.5 cm-diameter white dot). Subjects were instructed to gaze at this central fixation point (CFP) throughout the procedure. White targets (5.5 cm-diameter) appeared randomly to the left or the right of the CFP, either near or far from the CFP (10.5 cm/19.3° and 15.5 cm/27.3°), and with a random delay varying from 300 to 1200 ms after the emission of a warning tone. In Experiment 1 (EXP1), subjects were asked to react as quickly as possible to target appearance by simply releasing with the index finger a highly sensitive switch, located on the sagittal axis, distance 30 cm from the screen and 20 cm below its center (lifting condition). In Experiment 2 (EXP2), a small switch was placed on the extremity of the index finger, and subjects pointed as quickly as possible towards the illuminated target, starting from the CFP (pointing condition). Trials were rejected when movement endpoints did not respect the accuracy criterion (5.5 cm-diameter). Subjects were informed that a maximum of 5% error was allowed. EXP1 and EXP2 were performed in a counterbalanced order. For each experiment, a total of 128 trials divided into four sessions (two for each hand) presented in a counterbalanced order across subjects were performed (16 trials for each condition of hand × side × distance). Complete results are presented in Table 1 and Fig. 1.

A 2 Hand (left (LH) and right (RH)) × 2 Visual Field (left (LVF) and right (RVF)) × 2 Distance (near and far) ANOVA with repeated measures on the last three factors was applied to RT data for each experiment. Post-hoc analyses (Newman–Keuls) were performed when necessary.

EXP1 revealed shorter left hand RTs ($F(1,10) = 5.25$, $P < 0.05$). The main effect of Visual Field ($F(1,10) = 14.6$, $P < 0.01$) was that it showed shorter RTs for LVF targets. However, the interaction of Hand × Visual Field ($F(1,10) = 43.84$, $P < 0.001$) revealed that only the LH-LVF condition (217.3 ms) was different from all others (222.8, 223.6 and 222.1 ms for LH-RVF, RH-LVF and RH-RVF, respectively, $P\text{s} < 0.001$).

EXP2 also revealed that RTs were shorter for the left hand (258.3 vs. 265.1 ms for LH and RH, respectively, $F(1,10) = 20.22$, $P < 0.01$) and when targets were located near to rather than far from the central dot ($F(1,10) = 24.55$, $P < 0.001$; 258.3 vs. 265 ms, respectively). The interaction of Hand × Visual Field ($F(1,10) = 13.71$, $P < 0.01$) revealed ipsilateral advantages: each hand provided shorter RTs when pointing in its own hemifield (Table 1, all conditions are different from each other, $P\text{s} < 0.05$ – except LH-RVF vs. RH-LVF).

Finally, in order to estimate the specific cost of movement planning, we considered the difference between RTs obtained for each subject in EXP2 and EXP1 (ΔRT). The same statistical analysis revealed that Hand has a major effect ($F(1,10) = 7.43$, $P < 0.05$) and showed that ΔRT was shorter for LH than for RH (38.2 vs. 42.2 ms, respectively). An effect of Target distance was also observed (37.3 vs. 43.1 ms for near and far targets, respectively; $F(1,10) = 17.17$, $P < 0.05$).

The main results of this study emphasized that LH exhibited shorter RTs than RH in both experiments, whether movement planning was required or not. This clearly indicates that manual RT asymmetries cannot be solely attributed to movement planning processes as currently suggested [6,13,19]. Given the special role which the right hemisphere

Table 1
Mean values and standard-deviations of RTs (ms) obtained in EXP1 (simple detection task, lifting condition) and EXP2 (manual aiming task, pointing condition)[a]

	Left hand				Right hand			
	LVF		RVF		LVF		RVF	
	Near	Far	Near	Far	Near	Far	Near	Far
EXP1	216 ± 16	218 ± 16	223 ± 15	223 ± 17	223 ± 19	224 ± 18	222 ± 17	222 ± 19
EXP2	252 ± 24	259 ± 22	258 ± 20	263 ± 20	264 ± 23	271 ± 23	259 ± 24	266 ± 24
ΔRT (EXP2-EXP1)	36 ± 17	41 ± 13	35 ± 16	41 ± 12	41 ± 15	47 ± 15	37 ± 14	44 ± 14

[a] The difference between RTs obtained in the two experiments and an estimation of the specific cost of movement planning are also reported (ΔRT). Data are presented according to the hand used (Left, Right), the side of appearance of the visual stimulus (LVF, RVF) and the distance of the target from the CFP (Near, Far).

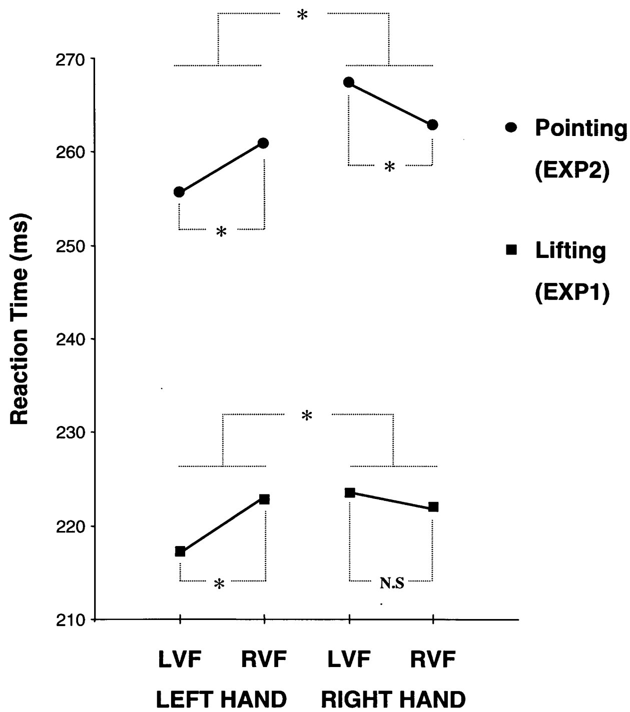

Fig. 1. Comparison of the RTs obtained in the simple detection task (lifting condition) and the manual aiming task (pointing condition) according to the different inter-hemispheric conditions (left (LVF) and right (RVF) visual fields and left and right hands). Statistical data are reported in the figure (*$P < 0.05$; N.S., non-significant difference).

is known to play in visuospatial attention [9,14,18], we suggest that the left hand could benefit from its more direct connections with it.

Accordingly in EXP 1, LH shorter RTs could be solely attributable to visuospatial attention. More precisely, a general alertness advantage in the right hemisphere would enable a faster detection of stimuli in the LVF [15]. This could explain why, comparing both uncrossed conditions, LH in the LVF revealed shorter RTs than RH in the RVF. Moreover, this could also explain why crossed-uncrossed differences were not observed for the right hand: RVF advantage could have been compensated for by the time needed to transfer visual information to the left hemisphere. These results are quite similar to those obtained in studies using the Poffenberger paradigm [10] which also reported weaker crossed-uncrossed differences for the right hand [1,11]. This pattern is classically interpreted as reflecting a faster right-to-left than left-to-right interhemispheric transfer of information[1,11]. We suggest that attentional asymmetries may also concur with this pattern.

In EXP2 however, as visuospatial attention and hand movement preparation are known to be intimately linked [3,7,16], their respective effects on LH shorter RTs are impossible to differentiate. Nevertheless, RT differences between EXP2 and EXP1 can be considered as resulting specifically from movement planning processes. It appeared that ΔRT was smaller for the left than for the right hand. In addition, other effects specific to visuomotor planning processes and reminiscent of numerous pointing studies were observed: faster ipsilateral RTs and increasing RTs with movement amplitude [4,5,18]. Taken together, these results strongly suggest that LH RT advantage could be attributed to a right hemisphere superiority for movement planning, partly supporting the former hypothesis [2,6,13,19].

We conclude that both visuospatial attention and movement planning processes account for manual RT differences in aiming. More precisely, a right hemisphere specialization for both visuospatial attention and for movement planning contributes to manual asymmetries in goal-directed movement preparation.

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