Effects of handedness on the inhibition of reaction time in double stimulation situations

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Inhibitory effects of S1 on the RT to S2 in double stimulation situations were examined by 11 left-handed subjects from the viewpoint of hemispheric input/output couplings. In contrast with the right-handers, no effect of hemispheric input/output couplings was shown in the left-handed subjects. The results were discussed in relation to the differences between right- and left-handers in the hemispheric control of hand movements.

Key words: handedness, motor control, reaction time, laterality, cerebral dominance, inhibition (motor).

Honda (1981) showed that when a subject responds only to the second stimulus (S2) of paired stimuli successively presented with extremely short interstimulus intervals (ISIs), the reaction time to S2 (RT2) is delayed in comparison with reaction times in single stimulation situations, and that the size of the delay depends on hemispheric input/output couplings. The most interesting finding in this study was that the RT2 of the right hand (the left hemisphere) after presentation of S1 in the left visual field (the right hemisphere) was shown to be significantly longer than that of the left hand (the right hemisphere) after the presentation of S1 into the right visual field (the left hemisphere). The results were interpreted as showing that unilateral hemispheric activation produced by the projection of S1 interfered in an asymmetrical way with the activation in the opposite hemisphere produced in reaction to S2. Then the asymmetrical interhemispheric interference hypothesis was tentatively proposed based on neurological findings that right hand movements of the right-handers are exclusively controlled by the contralateral left hemisphere, while hemispheric control of left hand movements is rather bilateral (Cernacek & Podivinsky, 1971; Gazzaniga & Hillyard, 1971; Kutas & Donchin, 1974; Wyke, 1971).

The present study was conducted to examine the asymmetrical interhemispheric interference hypothesis for the asymmetrical inhibitory effect of S1 on RT2 described above, by analyzing the effect in relation to the subject's handedness. It is now well established that the hemispheres are to some extent asymmetrical in the function they perform, that

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is, the left hemisphere is dominant in verbal functions and the right hemisphere in nonverbal, visuospatial functions. However, the traditional concept of hemisphere specialization seems to be applicable only to right-handers. Hemisphere specialization of left-handers is, in general, thought to be rather ambiguous (Bryden, 1965; Curry & Rutherford, 1967; Humphrey & Zangwill, 1952; Hecaen & Ajuriaguerra, 1963; Orbach, 1967; Zurif & Bryden, 1969). This was also shown in recent studies on motor function (Kimura, 1973; Kutas & Donchin, 1974; Hicks, 1975). The asymmetrical inhibitory effect of S1 on RT2 in double stimulation situations demonstrated in our previous experiments (Honda, 1981) was obtained using right-handed subjects. If hemisphere specialization is indeed the basis for this effect, a different pattern of inhibitory effects in double stimulation situations will be obtained when left-handers are used as subjects.

Method

Subjects

Fifteen left-handed university students (10 males and 5 females) served as subjects. Their handedness was assessed by the Edinburgh Inventory (Oldfield, 1971). In addition, subjects were queried concerning visual acuity, the state of their birth, history of CNS or peripheral nerve disease, family handedness, etc.

Apparatus and Procedure

A red LED and four green LEDs were arranged horizontally on the inside of a black box, and used as a fixation point and visual stimuli, respectively. The fixation point was placed at the center, and continuously turned on. A subject was instructed to watch it through a viewing hood mounted on the side of the black box. The distance from the subject’s eyes to the fixation point was about 50 cm. Two green LEDs for S1 were attached at a visual angle of 3.0° horizontally on the left and right sides of the fixation point. Another two green LEDs for S2 were attached outside the S1s, at a visual angle of 3.5° from the fixation point. Under the black box, two micro-switches were placed 30 cm apart side by side, and used as reaction keys for the left and right hands.

At a “Ready” signal by the experimenter, each subject placed the forefinger of each hand on the respective reaction keys, and 2 s after the signal S1 and S2 were successively turned on for 20 ms each. The visual stimuli were presented in the following four presentation conditions. (i) Condition L/R: S1 in the left visual field and S2 in the right visual field. (ii) Condition R/L: S1 in the right visual field and S2 in the left visual field. (iii) Condition L/L: S1 in the left visual field and S2 in the left visual field. (iv) Condition R/R: S1 in the right visual field and S2 in the right visual field. The ISI between S1 and S2 was either 100, 200, or 300 ms. The subject was required to make no reaction to S1, and to react only to S2 by pressing a reaction key with the ipsilateral hand. Thirty trials for each of 12 combinations of four presentation conditions and three ISI conditions, that is, a total of 360 trials were given to each subject in random sequence with an intertrial interval of 15 s. Subjects were given a rest time of 1 min every 30 trials. Thirty trials were rehearsed prior to the experiment. RT2s were measured to an accuracy of 1 ms by a digi-timer (IWATSU UG-6145).

Sixty trials for measurement of RTs in a single stimulation situation, divided into two sessions of 30 trials, were carried out before and after the experimental sessions described above. In this control condition, only S2 was presented in either the left or right visual field, and subjects were required to respond to it with the ipsilateral hand.
Results and Discussion

Handedness score of left-handed subjects assessed by the Edinburgh Inventory ranged from LQ -100 to LQ -44. One subject reported that he was attended with much difficulty at his birth. Two subjects showed large variance in their RTs, and one subject showed extraordinary slow RTs. Their data were excluded from the statistical analysis. As a result, data obtained from 7 male and 4 female subjects (LQ -100 to -70) were applied to statistical analysis. Only 1 of 11 subjects indicated left-handed relatives.

Figure 1 shows the mean RT2s obtained in this study. According to preliminary examination, no sex difference was present. Therefore, the following statistical analysis was done using grouped data from both sexes. RTs in the single stimulation situation showed no significant difference between the right and left hands. Differences between RT2s in double stimulation situations at the shorter ISIs (100 and 200 ms) and the RTs in the single stimulation situation were significant beyond the 1% level in every condition except at the ISI of 200 ms in Condition R/L. The delay of RT2 decreased as the ISI was raised, and no significant difference was shown between the RT2s at an ISI of 300 ms and RTs in the single stimulation situation.

In comparing the delay of RT2s among the four presentation conditions, we separated RT2s obtained when S1 and S2 were presented in the same visual field (Conditions L/L and R/R) and RT2s obtained when S1 and S2 were presented in the opposite visual field (Conditions L/R and R/L), since between these two groups of presentation conditions, there existed a difference in the distance between S1 and S2 (0.5° in Conditions L/L and R/R and 6.5° in Conditions L/R and R/L). It is probable, therefore, that subjects perceived S2 more clearly in Conditions L/R and R/L than in Conditions L/L and R/R. On the other hand, the two groups of presentation conditions had a distinct difference in S1-R (responding hand) compatibility. In Conditions L/L and R/R, subjects may have had a strong tendency to shift their attention toward the visual field where the two stimuli were presented than in Conditions L/R and R/L where the two stimuli were presented separately in the two visual fields. Thus, in the present study, RT2s seem to have been influenced by many factors due to stimulus configuration. Therefore, it is not meaningful to directly compare the RT2s in Conditions L/L and R/R with those in Conditions L/R and R/L.

In contrast with right-handed subjects, left-handed subjects showed no significant difference in RT2s between Conditions L/R and R/L. According to ANOVA, significance was shown in the main effect of ISI \( (F(2,20)=41.83, p<.01) \). The ISI x presentation condition interaction was significant \( (F(2,20)=8.58, p<.01) \). However the main effect of presentation condition was not significant. Subsequent ANOVA showed no significant difference
in RT2s between Conditions L/R and R/L at every ISI. Similar results were shown in Conditions L/L and R/R. The main effect of ISI and the ISI × presentation condition interaction were significant \(F(2,20)=59.65, p<.01; F(2,20)=4.01, p<.01\), but the main effect of presentation condition was not significant.

RT2s were not significantly different between Conditions L/L and R/R at every ISI.

In the left-handed subjects, there was no significant difference in a delay of RT2 between Conditions L/R and R/L. This is not consistent with the results in the right-handed subjects, in which the RT2 in Condition L/R was significantly longer than that in Condition R/L at the ISI of 100 ms (Honda, 1981). This asymmetrical delay of RT2s shown in right-handed subjects was explained in terms of interhemispheric interference. That is, when S1 is presented to the left visual field, it causes a “hold” response of the ipsilateral left hand, since a subject is required not to respond to S1 but to respond only to S2 which is presented immediately after the S1. The hemispheric control of the left hand is bilateral in right-handers, then the hemispheric inhibitory tendency corresponding to the “hold” response of the left hand occurs in the ipsilateral left hemisphere as well as in the contralateral right hemisphere. As a result, the subsequent overt response to S2 with the right hand is strongly inhibited. On the other hand, S1 presentation in the right visual field produces a “hold” response of the right hand which is exclusively controlled by the contralateral left hemisphere. An inhibitory tendency is, therefore, restricted to the left hemisphere, and the right hemisphere’s activation for the left hand’s response is not disturbed. As a result, inhibition of response to S2 with the right hemisphere (left hand) is rather small.

When S1 and S2 are presented to the same visual field (Conditions L/L and R/R), responses to S2 are emitted from the hemisphere where an inhibitory tendency has already been produced by S1 presentation. Thus, these two conditions show the same degree of inhibition.

As expected, the left-handers showed a different pattern of inhibitory effects in double stimulation situations. Since the hemisphere specialization of left-handers is rather ambiguous compared with right-handers, the symmetrical delay in RT2s shown in left-handed subjects of the present study is thought to reflect an ambiguous specialization in hemisphere control of limb movements in left-handers. It seems that, in contrast with right-handers, in left-handers each hand receives neural commands for movement control from both the hemisphere. In addition, the contralateral hemispheric control seems to be superior to the ipsilateral one. According to this hypothesis, the present results in left-handed subjects may be interpreted as follows. When S1 was presented in the right or left visual field, it caused a “hold” response of the ipsilateral hand. Then an inhibitory tendency for the “hold” response occurred in both the hemispheres, resulting in nonsignificant difference in delay of RT2s between Conditions L/R and R/L. In addition, the delay in RT2s was rather small, since the contralateral hemispheric control for the responding hand is superior to the ipsilateral one. Although at the present stage the above-mentioned explanation remains tentative, the results seem to suggest that the hemisphere control of hand movements of left-handers is quite different from that of right-handers.

References
The coding dimension in cross-modal matching tasks

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The purpose of this study was to investigate the coding dimension in cross-modal and intramodal matching (CMM and IMM). The CMM and the IMM tasks required subjects to decide whether visual and/or auditory stimuli occurred on the same or different (opposite) side of a fixation point. The study examined the effect of an additional stimulus (S1+ or S2+) presented simultaneously with either of the two matched stimuli (S1 or S2). S1+ yielded longer reaction times (RTs) in CMM but not in IMM, whereas S2+ had an delay effect when S2 was auditory. The results suggested that the matching dimension might be different depending on the tasks.

Key words: cross-modal matching, coding dimensions, translation, reaction times, delays, direction, competitions, visual dominance.

Connolly and Jones (1970) proposed a model of cross-modal matching (CMM) based on their discovery that the variance of two CMM of visual and kinesthetic length were larger than those of two intramodal matching (IMM). An essential feature of the model is that on CMM, the translation between the two modalities takes place prior to information being stored. On the other hand, in a discrimination task of auditory and/or visual direction, Auerbach and Sperling (1974)