Gender-Related Differences of Finger Tapping Consistency in the Lateralization of Concurrent Task Effects.

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There have been various studies which suggested gender-related differences in cerebral lateralization. In a neuropsychological point of view, McGlone (1980) has argued that the female brain in which language is represented bilaterally is more symmetrical than the male brain. Consequently, damage to either hemisphere should produce a mild language impairment in females, but damage to the left hemisphere should produce severe aphasic syndrome in males since females would be less lateralized than males in speech functions. A prediction of McGlone's findings is that the incidence and severity of aphasia in females should be less than in males.

A number of studies, however, have not obtained this result. For example, Kimura (1983, 1987), employing pathological subjects with either the anterior or the posterior cortex, found that aphasia was much more common after anterior lesions than after posterior lesions in females whereas aphasia was more frequently caused after posterior lesions. Kimura's data further suggested different organization within left-hemisphere between males and females; speech function was very much dependent on the anterior region for women but aphasia resulted from damage to various sites of the brain for men.

In the review of the literature about the sex differences in cognitive functions, MacCorby and Jacklin (1974) found that girls have greater verbal ability than boys and that female superiority increases with age. Since the general view on the lateral specialization is that more lateralized the hemispheric function is to either left or right more specialized and more better the function is, females should show larger asymmetrical effects in cognitive tasks. Healy, Waldstein, and Goodglass (1985) supported Kimura's assumption in the cognitive experiment which compared a verbal discrimination task performance with a verbal production performance. These findings lead to the assumption that an interaction effects of sex difference by language production or

reception might be revealed in cognitive laterality tasks. Clearly, however, any adequate model, battery, or theory of language function must consider such difference, if they exist.

The present study used the dual-task procedure to test the possibility of a task related sex difference in cerebral lateralization. Kinsbourne and Cook (1971) first found that vocalizing disrupted the concurrent balancing of dowel rod with the right hand but not the left in the right-handed subjects. As controlling speech and moving the right hand require left hemisphere involvement whereas controlling of speech and moving the left hand involve opposite hemispheres this effect was attributed to the lateralization of speech to the left hemisphere. Kinsbourne and Hicks (1978) further assumed that interference within a hemisphere should be greater than interference between hemispheres and proposed the functional cerebral space which came from a model for overflow transfer and interference effects in human performance.

In the dual-task paradigm, asymmetric interference are measured either in terms of tapping rate or in terms of tapping inconsistency. These measures would be expected to increase under conditions in which subjects were instructed to tap as rapidly as possible or as consistently as possible while engaging in a secondary task (Hiscock, 1982; McFarland & Ashton, 1978). Comparing the two measures in finger tapping, Hiscock, Chessman, Inch, Chipuer, and Graff (1989) concluded that interference effects were largely symmetric when measured in terms of variability or consistency although the right hand was affected more than the left hand in both variability and rate. The present experiment, however, employed tapping consistency as the index of interference because the difference of the right- and the left-hand performance is less in the single-task control condition than tapping rate.

As to the gender-related differences, female subjects should be more interfered than male subjects under the speech production condition with right-hand tapping if females are more lateralized than males with respect to language production. It should be also presupposed that similar interference should occur in both male and female performance under the speech reception condition if no sex-related difference exists in language reception.

Method

Subjects. Thirty, right-handed university students (15 males and 15 females) participated in the experiment. All subjects were professed right-handers, verified by completion of a handedness questionnaire (Oldfield, 1971) modified by the author.

Stimulus. For language production condition, 15 sets of nonverbal stimuli, which consisted of 40 colored pictures of familiar objects on the white background, were presented onto a 23.0 x 15.0-cm CRT screen in front of the subject. For language reception condition, 15 paragraphs, each defining a different psychological term, were selected from a technical book of psychology (Adachi & Shiomi, 1985). Mean paragraph length was 130 letters and paragraphs were matched for difficulty and length. Each paragraph was presented onto the same CRT screen as in the language production condition, written from left to right in black color on the white background.

Apparatus. A telegraph key was used for finger-tapping and a polygraph (San-ei Polygraph 360 system) and a cassette data recorder (TEAC R-60) were used to record subjects' tapping performance. Pulse sounds for tapping tempo were generated by a microcomputer (NEC PC-9801VM0), which also controlled the timing of stimulus presentation. A CRT (NEC PC-KD851) was used to present cognitive stimuli during the experimental session. The recorded tapping data were analyzed off-line using a microcomputer (NEC PC9801E) with a digital input-output system (IO-Data-Equipment PIO-9022A) and an analogue-to-digital converting system (Canopus Electronics ANALOG-PRO).

Procedure. Subjects were tested individually in session lasting about 35 minutes. The experimental procedure was divided into two sessions. In the practice session subjects were taught to tap a telegraph key at a rate of 120 bpm with each index finger. A pulse sound generated by a microcomputer was used as the training signal. Subjects were instructed to tap the telegraph key with their index finger while adjusting the tapping rates to the pulse sounds presented through the speaker which was put right ahead of the subject.

Four practice trials were executed (2 for the right hand [R] and 2 for the left hand [L]), each of which consisted of 120 bpm pulses and lasted 3 minutes. The order of practice trials was either RLRL or LRLR. The interval between practice trials was one minute.

In the experimental session the subject was asked to tap as consistently as possible

at the 120 bpm rate without the reference sounds while simultaneously trying to name pictures aloud or remember silently as much of a paragraph as possible. Each subject accomplished twenty-four trials, which lasted 20 seconds respectively. The trials were organized into four blocks representing different combinations of the tapping hands and the secondary tasks. The order in which these blocks were performed was counterbalanced among the subjects of each sex. Within each of the four blocks, the subject performed six trials in a predetermined random order. It was emphasized that subjects should not switch their attention between the tapping task and the secondary task and should pay attention to both tasks simultaneously.

In the control condition, no secondary task was imposed on tapping and the subject continued tapping for 20 seconds until the stop cue was presented. The other two experimental conditions were the situation where subjects were engaged in a secondary task while tapping constantly. In the language production condition the subjects was asked to start vocalizing the color name and the object name of each stimulus as rapidly as possible (e.g. "yellow dog", "red fish"). In the language reception condition the subjects was required to read the paragraph silently, trying to memorize the contents of the paragraph as much as possible.

Results

A 3 x 2 x 2 ANOVA with one between group factor (sex) and two within group factors (condition and tapping hand) was accomplished on the mean tapping consistency. The data used in the analysis of variance were the deviations from the tapping criterion, which were converted into mean absolute values from 120 bpm. In scoring the data, the number of tapping was calculated at the period from 5 seconds to 20 seconds in order to eliminate the fluctuation at the initiation of tapping although each trial lasted 20 seconds. Four tapping scores at each condition of either hand were averaged to represent the subject's mean performance.

In the analysis of simple main effects two factors reached a significant level, that is, overall language production interfered with tapping more severely than language reception ($F[1, 42] = 5.39$, $p < .05$); the left-hand tapping was more constant than the left-hand tapping ($F[1, 42] = 4.98$, $p < .01$). Two of the 3 interaction between two factors were significant (the sex x condition : $F[2, 42] = 5.62$, $p < .01$; the condition

x hand : $F[2, 42] = 7.35$, $p < .01$; the sex x hand : $F[1, 42] =$, n.s.). Analysis of variance also yielded a significant interaction effect for the sex x hand x condition ($F[2, 42] = 7.11$, $p < .01$). Thus, all the main effects should be interpreted in relation to the significant sex x hand and condition x hand interaction.

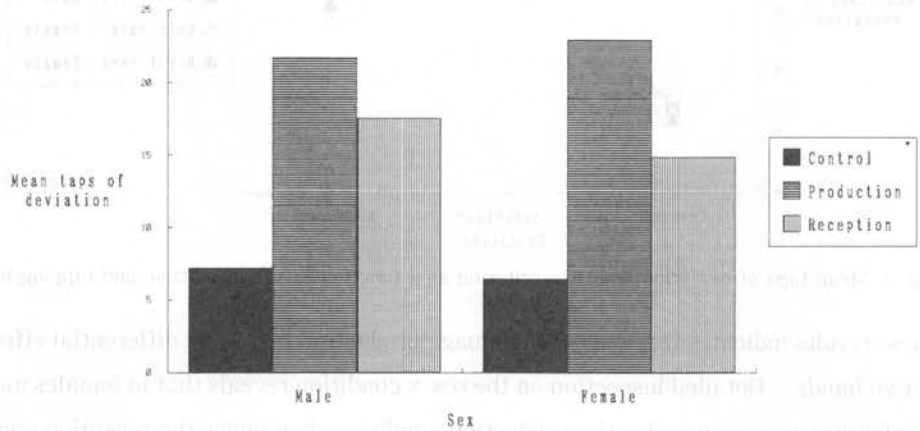

Fig. 1. Mean taps of deviation from the criterion as a function of sex and condition.

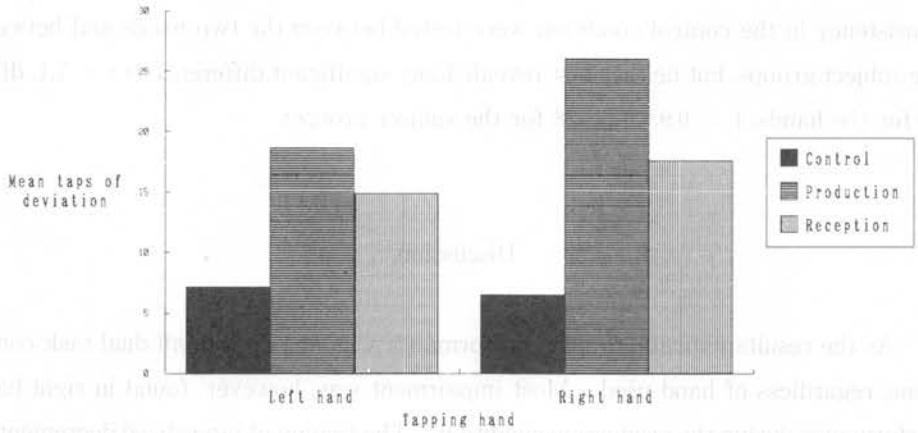

Fig. 2. Mean taps of deviation from the criterion as a function of tapping hand and condition.

Fig.1 and Fig.2 show these interactions between two factors and Fig.3 shows the significant interaction between three factors. It is demonstrated that the secondary verbal task, whether the task is productive or receptive, impaired performance of both hands used in tapping. Moreover, tapping by the right hand was more hindered in the language production condition than in the language reception condition whereas tapping by the left hand sustained almost the same impairment in the two conditions.

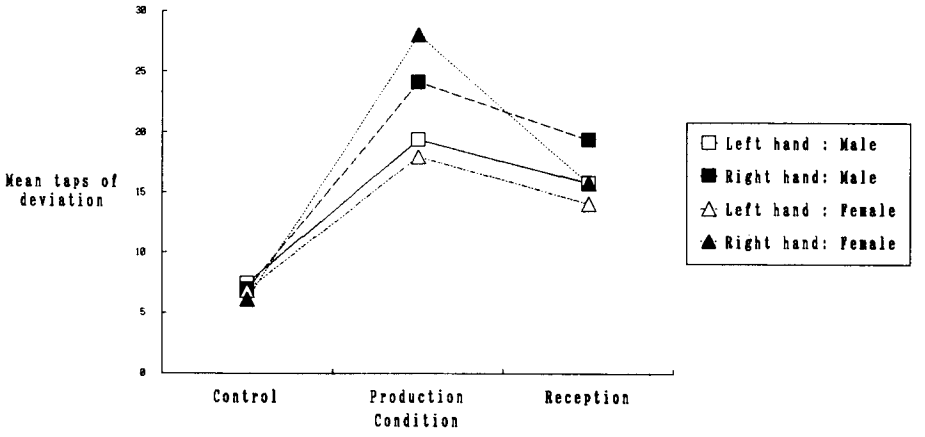

Fig. 3. Mean taps of deviation from the criterion as a function of sex, condition, and tapping hand.

These results indicates that only the language production tasks had differential effects on two hands. Detailed inspection on the sex x condition reveals that in females more interference was seen under the production condition than under the reception condition whereas in males similar interference occurred under the two conditions.

To confirm the equality of base line of performance, differences of tapping consistency in the control condition were tested between the two hands and between the subject groups, but neither test revealed any significant differences ($t = 1.1$, $df = 29$ for the hands; $t = 0.9$, $df = 28$ for the subject groups).

Discussion

As the results indicate, tapping performance was impaired in all dual-task conditions, regardless of hand used. Most impairment was, however, found in right-hand performance during the production condition. The finding of lateralized decrement of tapping in the language production condition can be regarded as an evidence that both outputs are motor and both are controlled by the left-hemisphere when the right-hand is performing in the language production. This finding indicates that actual activation of the motor control system for speech production is important. Consequently both tasks are competing for limited resources of motor control systems in the left hemisphere when this hemisphere is controlling the two motor outputs of speech and tapping by the right-hand.

In the silent reception condition the effect was much smaller. This result supports the traditional claim that lateralized interference is susceptible to the condition where verbal production is required and the vocalization rather than cognitive verbalization is important to the dual-task effect. As Hellige and Longstreth (1981) pointed out, it is plausible to assume that language per se has nothing to do with the asymmetrical interference effect in the dual-task situation. It seems, however, that the absence of selective interference in the reception condition is partly due to its less loading on the main task. The generalized interference effect, which reflected significant impairment in both hands, was seen in this condition although Hiscock (1986), in his methodological review, claimed that more demanding tasks produced generalized effects. Therefore, it is difficult to conclude whether this secondary task is either lateralized or not in the left cerebral hemisphere.

On the basis of the present data, the notion of gender-related differences in the cerebral lateralization has been partly supported since differential task effects were seen between the female and the male subjects. However, there have been some laterality studies which does not obtain any results of gender-related differences in the dual-task experiment. For example, Seth-Smith, Ashton, and McFarland (1989) found no evidence for such differences with either speech production or reception conditions.

In Seth-Smith et al. view, since sex difference are learned, sex differences in cortical mediation of language functions are overwhelmed when subjects were similar in their education. This explanation is an exceptional view because most laterality studies assume that lateral asymmetries in cognitive tasks are manifested from innate functional differences between the left and right cerebral hemispheres. Future research will hopefully clarify some problems with interpreting the results.

Summary

Dual-task procedures were used to examine gender-related differences in hemispheric lateralization. University subjects performed a finger-tapping task with each hand. On some trials a unimanual tapping task was paired with a secondary verbal task (a language production or a language reception task). Changes in tapping consistency were measured relative to the corresponding single task control condition. Both language reception and language production decreased the consistency but

reception interfered more severely with tapping than production. The right hand was more affected than the left hand in both instances. Task-related sex differences were found, that is, pattern of lateralized interference in tapping under the language production condition indicated more left- than right-hemispheric involvement for females, while bilateral involvement was shown for both males and females under the reception condition.

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