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2. The results of this questionnaire survey have been replicated in another sample of 489 subjects (F. J. Evans, M. R. Cook, H. D. Cohen, E. C. Orne, M. T. Orne, paper presented at the American Psychological Association, Washington, D.C., 3 to 6 September 1976).
3. A. Rechtschaffen and A. Kales, Eds., *A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects* (Public Health Service, Government Printing Office, Washington, D.C., 1968).
4. All reported differences are significant ($P < .05$, two-tailed t-test).
5. Studies by I. Karacan, R. L. Williams, W. W. Finley, and C. J. Hursch [*Biol. Psychiatry* 2, 391 (1970)]; L. Maron, A. Rechtschaffen, and E. A. Wolpert [*Arch. Gen. Psychiatry* 11, 503 (1964)]; and W. B. Webb, H. W. Agnew, and H. Sternthal [*Psychonom. Sci.* 6, 277 (1966)] have shown that REM sleep typically occurs in naps of less than about 1½ hours only if they are taken early in the morning.
6. J. M. Taub, P. E. Tanguay, D. Clarkson, *J. Abnorm. Psychol.* 85, 210 (1976).
7. A third type of napper who naps in response to stress-induced insomnia has been identified. Although the nap has EEG characteristics similar to those of a replacement nap, it is not satisfying and tends to interfere with the subsequent night's sleep, thereby maintaining the sleep disturbance that initially led to the nap itself.
8. Hypnagogic reverie tends to occur during these light-sleep, drowsy periods.
9. Supported in part by U.S. Army Medical Research and Development Command contract DADA17-71-C-1120 and in part by a grant from the Institute for Experimental Psychiatry. Aspects of these data were presented at the 16th Annual Meeting of the Association for the Psychophysiological Study of Sleep, Cincinnati, Ohio, 3 June 1976. We thank B. E. Lawrence, W. M. Waid, S. K. Wilson, P. A. Markowsky, and H. M. Pettinati for their helpful comments during the preparation of this report; C. Graham, who introduced subjects to the study and, where necessary, appropriately allayed subjects' anxieties about their inability to nap in a laboratory setting; and B. R. Wells and A. L. Van Campen, N. K. Bauer, J. P. DeLong, E. F. Grabiec, J. E. Hamos, M. L. Korn, A. M. Myers, L. L. Pyles, and J. Rosellini, for technical assistance. We also wish to thank H. Gleitman, who allowed his class to volunteer for the questionnaire survey.
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20 August 1976; revised 26 January 1977

Cerebral Lateralization of Haptic Perception: Interaction of Responses to Braille and Music Reveals a Functional Basis

Abstract. *Normally, haptic perception of the left hand surpasses that of the right. But simultaneously playing music into the left (but not the right) ear reverses this superiority. This suggests that the left cerebral hemisphere has full haptic perceptual capability, which is subject to right hemisphere interference unless the latter's attentional mechanisms are engaged by contralateral peripheral stimulation.*

Systematic investigations have shown unequivocally that haptic discrimination in dextrals, whether blind or sighted, is far more accurate for the left than for the right hand. This is true whether the measure of discrimination involves (i) linguistic encoding, as in naming palpated Braille symbols (*1*) or letters of the alphabet (*2*), (ii) making tactual-visual matches (*3*, *4*), or (iii) tactual-tactual matches (*5*). Furthermore, left hand superiority is observed whether tactual stimulation is applied successively to either hand (*1*, *2*, *5*) or simultaneously to both (*3*, *4*).

Our investigation was conducted (i) to verify the assumption made in previous reports that left hand superiority reflects greater right hemisphere efficiency in haptic form discrimination, and (ii) to determine whether the relatively poor performance of the right hand in older children and adults is due to deterioration or to suppression of the haptic discriminative ability evident in early childhood (*2*, *4*).

To meet our objectives, we used a method capitalizing on sensory interaction within and across cerebral hemispheres. Incoming haptic information was pitted against music, a stimulus whose processing previously had been shown to be predominantly a function of the right hemisphere (*6*). The rationale was that, if left hand proficiency in haptic tasks results from right hemisphere dominance, then its performing a discrimination while music was being played into the left ear should stimulate competition for the same contralateral attentional mechanisms and produce diminished accuracy. Conversely, if music were fed into the right ear, intersensory rivalry for right hemisphere attentional mechanisms would be reduced, and performance with the left hand should be as good as in a control situation of no auditory input.

Observations of sensory interaction also formed a basis for determining left hemisphere capability for haptic pattern perception. We speculated that in adults the ability to discriminate form with the right hand was retained, but that its expression was thwarted by intervention from the more dominant right hemisphere. We believe that hemispheric dominance does not necessarily imply superior processing power; it may signify only a lower threshold for arousal of specific areas in a hemisphere by particular stimuli, accompanied by reciprocal inhibition of homologous parts of the opposite hemisphere (*7*). On the basis of this assumption we hypothesized that simultaneous presentation of music to the left ear, which would occupy right hemisphere attentional mechanisms, should effect its functional disengagement, permitting the left hemisphere to process uninterrupted tactual information received by the right hand. We expected, then, an improvement in right hand performance as compared to that in control conditions. We predicted that bimodal stimulation of the left hemisphere, on the other hand, would lead to a decrement in right hand performance or to no change, depending on whether the lower limit of performance had been reached under the control condition.

Twenty-four right-handed female and 24 right-handed male college students in an introductory psychology course were randomly assigned to one of six conditions: RH-RE and RH-LE, in which discrimination by the right hand was accompanied by music played into the right and left ear, respectively; RH-No, a control condition, in which right hand discrimination was carried out in the absence of any auditory input; and LH-LE, LH-RE, and LH-No, in which discrimination by the left hand was accompanied by left ear, right ear, and no auditory stimulation, respectively.

The haptic discrimination task consisted of a subject's identifying, while blindfolded, the match of a standard Braille symbol (*8*) which appeared in a comparison series of ten Braille patterns. Both the standard stimulus and the comparison stimuli were mounted in the upper left corners of two different platforms (12.5 by 10 by 3.75 cm). Subjects used their index fingers to palpate the symbols with light, small circular movements in a left to right direction. Retracing of the standard stimulus was not permitted once a comparison series was begun. Practice trials consisted of fingering serially a string of 20 randomly selected Braille patterns with the hand to be used in the experiment. The experiment itself was composed of six different matching tasks that were presented in sequence ten times. Scores were the average number of errors made on each trial and could range from 0 to 6. To maximize the probability that matches were made solely on a tactual basis, the experimenter at no time mentioned the names of the alphabet counterparts of the symbols.

The musical selections were tape recordings of classical orchestral works (*9*). Classical rather than contemporary music was chosen to minimize verbal associations or covert verbalization of lyrics. Control subjects who performed tactual discriminations without simultaneous auditory stimulation (LH-No and RH-No) donned earphones, and they were told that the earphones would muffle extraneous sounds.

Data (means and standard deviations) for performance under each of the six conditions (Table 1) were submitted to a mixed design analysis of variance (hand, ear, sex, the between subjects variables, and the trials within). Females significantly outperformed males ($P = .035$): the error scores for left and right hands were 2.88 and 3.69 for men and 2.32 and 2.82 for women. Significant left hand superiority across sexes was observed ($P = .052$), and the main effect of trials, signifying improvement with practice, was also significant ($P < .001$). The main effect for ears was not significant.

Table 1. Number of errors under the six conditions of the experiment; S.D., standard deviation.

Condition	N	$\bar{X}$	S.D.
LH-No	8	2.16	1.40
LH-LE	8	3.29	1.58
LH-RE	8	2.35	1.28
RH-No	8	3.64	1.70
RH-RE	8	3.88	1.89
RH-LE	8	2.30	1.24

The hand-ear interaction was highly significant ($P = .004$), and that between hands and ears over trials approached significance ($P = .076$). None of the other statistical interactions proved significant. Dunnett's test (*10*) revealed that presentation of music to the left ear significantly improved right hand performance to the level obtained under the LH-No condition ($P < .005$). In contrast, no statistically significant difference was observed between the RH-No and RH-RE conditions. Performance of the left hand in the LH-RE group did not depart significantly from that of LH-No subjects. When music was fed into the left ear (LH-LE), however, its performance deteriorated ($P < .05$).

Improvement in tactual performance with trials varied with hand-ear combination. There was virtually none under the conditions of bimodal stimulation of the same hemisphere (LH-LE and RH-RE). When bimodal stimulation was applied to contralateral hemispheres (RH-LE and LH-RE), proficiency in tactual form perception increased at about the same rate as under the most favorable situation (LH-No).

The poor performance of the LH-LE group, in which right hemisphere perceptual mechanisms were engaged by music, confirms that the sinistral accuracy observed in the LH-No and LH-RE groups is associated with right hemisphere dominance. The implication of right hemisphere dominance in tactual form perception is consistent with conclusions reached in studies of visual (*11*) and nonlinguistic acoustic (*6*) pattern discrimination (*12*).

Right hand performance in the RH-LE conditions, which approximated the best performance of the left hand, indicates that the left hemisphere of adults retains the ability to discriminate tactual patterns and suggests that its expression in the RH-No and RH-RE groups is disrupted by the right hemisphere. Music to the left ear, in occupying the right hemisphere's attention, functionally disengages it from the left hemisphere, permitting the latter to carry out, uninterrupted, processing of stimulation originating in the right hand (*13*). We propose that, when the right hemisphere is unoccupied, ipsilaterally conducted tactual information, which, although inadequate to enable precise discrimination, nevertheless activates the attentional mechanisms of that hemisphere, with consequent interruption of processing in the opposite, nondominant hemisphere. This interpretation is consistent with the view that the corpus callosum not only transmits information between homologous areas of the two hemispheres but also provides, under certain conditions, the basis for reciprocal inhibition between them (*7*).

The statistically significant hand-ear interaction further shows that the effects of bimodal stimulation depend not only on difficulty level of the perceptual tasks (*14*) but also on the functional asymmetry of the hemispheres. In our study, detectable interference by the auditory stimulus of tactual perceptual processing occurred only in group LH-LE, in which the dominant perceptual mechanisms associated with each stimulus reside in the same hemisphere (*13*). In contrast, facilitation of tactual performance was observed in the RH-LE condition, in which the auditory stimulus distracted the attention of the dominant hemisphere, thereby reducing rivalry with the nondominant hemisphere, which received the tactual information. Neither intersensory facilitation nor interference was occasioned in the LH-RE group, in which tactual processing by the dominant hemisphere proceeded in the absence of intrahemispheric competition, and the RH-RE group, in which the suppressive effects of the nonoccupied dominant hemisphere were sufficiently great that tactual performance could not further be depressed by ipsilateral auditory stimulation in the left hemisphere.

The superior tactual discriminative ability of women was of interest in view of reports that sinistral superiority for haptic perception emerges earlier in boys than in girls (*2, 4*). The generally greater haptic ability of adult females suggests that, while maturation of the right hemisphere in girls lags behind that of boys, development continues to a later age with the result that a higher asymptote is eventually attained.

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7. Such a possibility is suggested by M. Kinsbourne, in *Hemispheric Disconnection and Cerebral Function*, M. Kinsbourne and W. L. Smith, Eds. (Thomas, Springfield, Ill., 1974), pp. 239 and 260. A similar case for left hemisphere intervention in right hemisphere linguistic processing has been made by Nebes, but he views it as a result rather than a cause of the latter's poor performance [R. D. Nebes, *Psychol. Bull.* **81**, 1 (1974)]; see also J. E. Bogen, *Bull. Los Angeles Neurol. Soc.* **34**, 191 (1969).
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12. Notable exceptions are studies by D. Kimura [*Neuropsychologia* **4**, 275 (1966)] and W. F. McKeever and M. D. Huling [*Percep. Motor Skills* **31**, 201 (1970)] in which the two hemispheres were equally able in discriminating solid line nonsense figures. McKeever and Huling, however, did find a right hemisphere advantage with dotted designs that are analogous to the Braille patterns used in our study. It may be as Kimura [D. Kimura, in *Hemisphere Functions in the Brain*, S. J. Dimond and J. G. Beaumont, Eds. (Elek, London, 1974), p. 25] suggests, spatial positioning of the dots rather than configuration is the feature being discriminated. This is a possibility in the present work, since one of the comparison stimuli was patterned like the standard and differed from it only in its orientation (reversed and rotated 180°).
13. The results obtained by M. Kinsbourne and J. Cooke [*Q. J. Exp. Psychol.* **23**, 341 (1971)] in their study of the effects of concurrent verbalization on dowel balancing can be similarly explained. They found that verbalization improved balancing with the left index finger but interfered with right finger performance. In line with our explanation, we can argue that verbalization, in occupying the left hemisphere, prevented its intrusion in the activities of the right brain. In contrast, concurrent verbalization would impair right finger balancing because of the dual burden imposed upon attentional mechanisms of the left hemisphere.
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27 October 1976; revised 1 March 1977