biological difference. In contrast, family 491 has a large negative lod score, which could indicate nonlinkage. A test for heterogeneity of lod scores (7), however, was not significant, so that elimination of this negative lod score from the total cannot be justified. The possibility remains that this family may have a different type of specific reading disability with the locus being on another chromosome

A lod score above 3.0 (equivalent to prior odds of 1000 to 1) is normally considered sufficient to establish linkage, thus assigning a gene for specific reading disability to chromosome 15. Because of the complexity of the phenotype and the importance of the linkage studies in providing evidence of a genetic etiology in certain cases of specific reading disability, this study will be continued until a lod score of at least 5 is obtained. Confirmation by a second study is also required before a linkage is considered proven.

An opportunity to study the effects of one gene on information-processing has evolved from these studies. Moreover, the methods are applicable to many other problems in behavior genetics.

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References and Notes

- 1. J. M. Finucci, J. T. Guthrie, A. L. Child, H. Abbey, B. Childs, Ann. Hum. Genet. 40, 1
- J. M. Finucci, J. T. Guthrie, A. L. Child, H. Abbey, B. Childs, Ann. Hum. Genet. 40, 1 (1976); F. I. Lewitter, J. C. DeFries, R. C. Elston, Behav. Genet. 10, 9 (1980).
 B. Hallgren, Acta Psychiatric. Neurol. Scand. Suppl. 65 (1950); M. Zahalkova, V. Vrzal, E. Klobovkova, J. Med. Genet. 9, 48 (1972); A. L. Drew, Brain 79, 440 (1956).
 N. E. Morton, Am. J. Hum. Genet. 7, 183 (1955)
- 3. N. (1955).
- Ott, ibid. 26, 558 (1974).
- The Q-banding technique and subsequent de-staining is described by H. A. Lubs, W. H. McKenzie, S. R. Patil, and S. Merrick [in Methods in Cell Biology, D. Prescott, Ed. (Academic Press, New York, 1973), p. 345]. C-banding was done by the BaOH technique of O. J. Miller and L. Deavan (paper presented at the Workshop of Chromosome Banding, Institute for Pathobiolo-gy, Aspen, Colo., 13–18 July 1975).
 Paris Conference, Standardization in Human Cytogenetics. Birth Defects: Original Article
- Cytogenetics. Birth Defects: Original Article Series (National Foundation, New York, 1972), vol. 8, section 7; W. McKenzie, H. and A. Lubs, Cytogenetics 14, 97 (1975). N. E. Morton, Am. J. Hun, Genet. 8, 80 (1956). We wish to thank D. E. Goldgar for his assist-ance with the statistical analysis. Supported by NIH grants R01 HD 13899 and 7F32 NF05761.

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Infant Intermodal Speech Perception Is a Left-Hemisphere Function

Abstract. Prelinguistic infants recognized structural correspondences in acoustic and optic properties of synchronized, naturally spoken disyllables, but did so only when they were looking to their right sides. This result suggests that intermodal speech perception is facilitated by rightward orientation of attention and subserved by the left hemisphere.

Research on infants' capacities for intermodal perception has demonstrated that infants are sensitive to correspondences in the acoustic and optic properties that specify an event (1, 2). Infants may prefer a natural pattern of structural correspondence between the optic and acoustic dimensions of an event by which, in speech for example, an opening mouth is correlated with a rise in amplitude and with an upward shift in overall spectral structure and a closing mouth with the reverse. Alternatively, infants may simply prefer a temporal pattern of correspondence by which gross points of change in acoustic and optic structure are synchronized (1). If infants prefer mere synchrony, they should be satisfied with any arbitrary pattern of acoustic-optic correspondence; thus, in speech they might have no preference for syllable amplitude peaks synchronized with an open mouth over those synchronized with a closed mouth. But if infants prefer natural patterns of structural correspondence, they should look longer at the synchronized video monitor display of a woman producing articulatory patterns that specify the speech they are hearing than at an alternative, synchronized video display of the same woman displaying a different articulatory pattern. We therefore investigated the capacity of infants to recognize acoustic-optic correspondences in speech structure when the synchrony between an acoustic and two competing optic displays was maintained.

Our preliminary analyses suggested that when acoustic and optic speech displays specified the same disyllable, intermodal recognition was enhanced if in-

Table 1. First fixation times in seconds, averaged across six disyllables, to the left and right video display when the display matched or mismatched the audio CVCV. Mean fixation times are summed across 18 infants.

Direc- tion of gaze	Video display					
	Matches audio CVCV	Mismatches audio CVCV				
Left	66.0	59.3				
Right	81.2	67.0				

fants were watching the right, rather than the left, video display. When adults look to the right (or left) as they complete a task, their performance is facilitated if the task demands are better subserved by the hemisphere contralateral to gaze direction (3). Such results have been interpreted as evidence that attention, behaviorally manifested by gaze, may selectively activate the hemisphere contralateral to direction of gaze. We therefore expected that only rightward looking would significantly enhance recognition of acoustic-optic correspondences in speech structure.

Eighteen infants, eight males and ten females, 5 to 6 months of age ($\overline{X} = 5$ months, 25 days) participated in the experiment. We used three pairs of naturalproduced consonant-vowel-consolv nant-vowel (CVCV) disyllables, spoken with equal stress on both syllables: /mama lulu/, /bebi zuzi/, and /vava zuzu/. We enhanced the opportunity to detect acoustic-optic correspondences by making the articulatory dynamics of the contrasting video displays highly discriminable. To prepare the experimental materials, an adult female silently articulated each CVCV in synchrony with either the corresponding or the contrasting spoken disyllables of another adult female. The voice and the articulating face were recorded simultaneously to appear on one side of a 28 cm by 22 cm video monitor screen. The video recording procedure was then repeated so that the articulating face appeared on the other half of the split video screen, silently articulating the second CVCV in the pair in synchrony with the audio playback of the original disyllable. Deviations in acousticoptic synchrony were below the adult threshold for detecting asynchronies (4). The resulting recording of the acoustic signal synchronized with two competing articulatory displays was output to two video monitors.

The infant sat 46 cm from the video monitors on its mother's lap at the open end of a wooden box. The infant viewed a different articulatory display on the split screen of each monitor, one appearing through the right back window of the box and the other through the left. The

Table 2. Proportion of first fixation time, averaged over 18 infants, spent looking at right matches or mismatches, left matches or mismatches, and right or left matches.

Proportion of time	Disyllable						Over-
spent looking at	bebi	zuzi	mama	lulu	vava	zuzu	all
Matches versus mismatches							
Right	.59	.52	.62	.53	.52	.61	.57
Left	.54	.50	.54	.49	.49	.52	.51
Right versus left matches	.57	.57	.61	.52	.58	.59	.57

speech corresponding to one of the two video displays was played at equal loudness from speakers of both monitors. A camera placed centrally between the monitors taped the infant's visual responses. The mother looked over the roof of the box and could not see the video displays.

Infants were presented with each of the three CVCV pairs on four trials for a total of 12 trials. Each member of a CVCV pair occurred twice as an audio signal, with its matching video display occurring once on the left video monitor and once on the right. The trials were randomized under the constraint that no two trials with the same video output immediately follow one another. We used nine different randomizations and assigned two infants to each. Each trial lasted 20 seconds and consisted of 11 auditory-visual CVCV repetitions. Disyllable durations were about 1100 msec, separated by interstimulus intervals of about 800 msec. Successive trials began without interruption between trials. The experimental session lasted 4 minutes.

From video recordings of the child's face, independent observers recorded for each trial the duration in seconds of the first fixations to the right and to the left. We preferred first fixation over total fixation time because it is less vulnerable to contamination by factors such as attentional lapse. Interjudge reliability, based on a Pearson product-moment correlation coefficient for 41 randomly selected trials, was r = .96 for left-looking time and r = .98 for right-looking time.

The direction of the infants' first looks after trial onset was to the right side on 58 percent of the total trials (N = 216). The longest first fixation times were to matches, particularly on the right side (Table 1).

Because first fixation times varied across infants, we obtained proportions of first fixation time spent looking at acoustic-optic matches occurring on the right and the left side by each infant for each disyllable. We thus normalized for variability over subjects and disyllables and, at the same time, for any general preference for one side over the other. Proportions were computed by dividing the first fixation time spent looking at a match (right, left, or both sides) by the total first fixation time for that comparison, summed across two trials (Table 2).

The overall proportion of total (right and left) first fixation time spent looking at matches (X = 0.54) rather than mismatches was significant (z = 2.64,P < .004, N = 16, two ties; this and subsequent tests are one-tailed Wilcoxon matched-pairs signed-ranks tests). Table 2 summarizes the remaining results.

On the right side, the proportion of first fixation time spent looking at matches was significantly greater than for mismatches overall (z = 2.66,P < .004, N = 18) and for three of the six disyllables: mama, bebi, and zuzu (with respective values of z = 2.46, P < .007, N = 17, one tie; z = 1.94, P < .03, N = 17, one tie; z = 2.27, P < .01, N = 18). Proportions were greater than .50 for all six disyllables. On the left side, the proportion of first fixation time spent looking at matches was not significantly greater than for mismatches overall or on any of the six disyllables. Proportions were greater than .50 for only three of the disyllables.

On the right side, the number of infants who spent more than half of their first fixation time looking at matches versus mismatches was significant, on a binomial test, for two disyllables (mama, 13/18, P < .05; zuzu, 14/18, P < .02),but no corresponding tests for left-side looking were significant.

In a right-left comparison, the proportion of first fixation time spent looking at acoustic-optic matches was significantly greater on the right side than on the left side overall (z = 2.02, P < .02) and for three out of the six disyllables: mama, *bebi*, and *zuzu* (respectively, z = 1.87, P < .03, N = 17, one tie; z = 1.68, P < .05; N = 18; z = 1.96, P < .03,N = 18). Proportions on the right side were greater than those on the left for all six disyllables (Table 2).

One potential source of bias-a preference for an optic articulatory pattern irrespective of the acoustic pattern that accompanied it-might have influenced these results. To check for this, Spearman rank-order correlation coefficients

were computed for preferences for a video display when the audio signal matched the video display and when it did not. We computed correlations for right and left sides combined as well as for each side separately. A significant positive correlation would have indicated that infants preferred to look at a particular articulatory pattern irrespective of the CVCV to which they were listening; none of the correlations was significant.

Because infants looked significantly longer at synchronized video displays of a woman articulating a disyllable synchronized and matched with what they were hearing than at an alternative display synchronized but not matched with what they were hearing, their preference was for acoustic-optic correspondences in structure, not for mere synchrony. Moreover, they displayed this preference only when attending to the right side.

These findings demonstrate (i) sensitivity of infants to natural structural correspondences, rather than merely temporal ones, between the acoustic and optic properties of articulation and (ii) mutual facilitation of two left-hemisphere functions: rightward orientation of attention (3) and intermodal speech perception. Taken with the well-known dominance of the left hemisphere in the motor control of speech for adults (5) and in speech perception for both adults (6) and infants (7), these results suggest that the normal infant's capacity to begin reproducing native language speech sounds in prelinguistic babbling (8), may rest on a predisposition of the left hemisphere to recognize the sensorimotor connections between the auditory structure of speech and its articulatory source.

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References and Notes

- 1. E. Spelke, Dev. Psychol. 15, 626 (1979).
- E. Spelke, Dev. Psychol. 15, 626 (1979).
 and A. Cortelyou, in Infant Social Cognition: Empirical and Theoretical Considerations, M. E. Lamb and L. R. Sherrod, Eds. (Erlbaum, Hillsdale, N.J., 1981), pp. 61–84; B. Dodd, Cognit. Psychol. 11, 478 (1979).
 M. Kinsbourne, Acta Psychol. 33, 193 (1970); in Attention and Performance V, R. M. A. Rabbitt

and S. Dornic, Eds. (Academic Press, London, 1974), pp. 81–97; H. Lempert and M. Kinsbourne, *Neuropsychologia* **20**, 211 (1982).

- Temporal discrepancies in audio-video speech events must reach 131 msec before they can be detected by adults [N. Dixon and L. Spitz, *Perception* 9, 719 (1980)]. In our study, temporal discrepancies between corresponding events on any two video displays did not exceed 48 msec. Furthermore, there were no significant differences in seven adults' perceptual judgments of temporal discrepancies between acoustic-optic matches versus mismatches for any of the six disyllables. We assumed that infants' sensitivity would not be superior to adult's on this task The procedures have been detailed in a paper presented at the 2nd International Conference for the Study of Child Language, Vancouver, B.C., 9 to 14 August 1981.
- B. Milner, in *The Neurosciences: Third Study Program*, F. O. Schmitt and F. G. Worden, Eds.

(MIT Press, Cambridge, Mass. 1974), pp. 75-89.

- (M11 Press, Cambridge, Mass. 19/4), pp. 75–89.
 M. Studdert-Kennedy and D. Shankweiler, J. Acoust. Soc. Am. 48, 579 (1970).
 D. L. Molfese, R. B. Freeman, D. S. Palermo, Brain Lang. 2, 356 (1975); C. T. Best et al., Percept. Psychophys. 31, 75 (1981).
 B. de Boysson-Bardies, L. Sagart, N. Bacri, J. Child Lang. 8, 511 (1981). 7.
- B. de Boysson-Bardies, L. Sagari, N. Bach, J. Child Lang, 8, 511 (1981). We thank A. Liberman and B. Repp for critical comments and J. Monroe and B. Repp for statistical advice. Supported in part by NICHD postdoctoral fellowship HD-05407 to K.M., by a grant from the Jane Hilder Harris Foundation to Cornell University Medical College and by 9 Cornell University Medical College, and by NICHD grant HD-01944 to the Haskins Laboratories
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and lumbar specializations by differential

cell death (5). In order to see whether

this same process might apply to the

local differentiation of areas of the neo-

cortex, we compared the amount and

pattern of early cell degeneration in vari-

ous cortical areas to their eventual cell

number and pattern of laminar special-

posterior neocortex, defined by the crite-

ria of Caviness and modified from Krieg

We examined five areas of hamster

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Local Differences in the Amount of Early Cell Death in **Neocortex Predict Adult Local Specializations**

Abstract. The amount of early cell loss in five neocortical areas was inversely related to adult numbers of neurons in those areas. Differential cell death predicted particularly the thickness of the upper cortical laminae; it was not related to neuron numbers in the lower laminae. Cell loss thus determines some features of local neocortical differentiation.

The mammalian neocortex is a structure of fundamental homogeneity on which local variations are imposed. These variations are of two types. The first is the number of cells in any unit volume perpendicular to the cortical surface. For example, a comparison of the number of neurons in a cortical column of defined width across six cortical areas in five species showed that, in monkey and man, the primary visual cortex had on average twice the number of cells per column as that in other cortical areas (1). In a study with conclusions supporting cortical homogeneity in number, the medial neocortex of rodents was excluded from the original analysis because of the obviously fewer number of cells in this area (2).

The second major variation in cortical areas is the relative number of cell types in the cortex-the several classes of pyramidal and stellate cells. Directly related is the particular type of afferent and efferent connectivity each cell type subserves. The differences can be major; for example, several of the subareas of cingulate and frontal cortex lack laver 4. while the primary visual and somatosensory areas have a highly developed layer 4. These local differences form the basis for the classical and much of the modern attempts to subdivide the neocortex (3,4).

In another neural structure, the vertebrate spinal cord, neurons along the length of the cord appear to be generated initially in roughly equal amounts and reach their eventual brachial, thoracic,

(3): area 17, striate cortex; area 18b, parastriate cortex; areas 29d and 29b, cingulate cortices; and area 27 (also called 29a), variously termed cingulate, retrosplenial, retrohippocampal, or presubicular cortex (4). These areas include both the visual cortex and the thin medi-

ization

al cortical areas described by Bok (2) and exclude areas of extreme cortical concavity or convexity, where accurate estimation of numbers in any unit volume perpendicular to the cortical surface is difficult. The hamster is a particularly useful animal for this study, because the main period of neuronal death in the structures we examined occurs postnatally. Although cortical areas are not as differentiated in a hamster as in a gyrencephalic mammal, they are adequately differentiated, and the problems of compensation for gross cortical curvature can be avoided. A three to one range in cell number per unit column (Table 1), and a complete range of granular to agranular organization are found in these five areas.

To quantify adult cell numbers in the

five cortical areas, a complete count of neurons in a column 200 µm wide, 30 µm deep, and height dependent on cortical area was made (magnification, $\times 500$) from samples of both the right and left side of each of four hamsters. All tissue was processed identically: hamsters were killed with an overdose of urethane, perfused with 10 percent Formalin-saline. The brains were embedded in albumin, frozen, cut in 30-µm coronal sections, mounted, and stained with cresyl echt violet. Coronal sections were chosen for counting in which the plane of section deviated less than 1 percent from perpendicular to the cortical surface. Samples were taken at points of minimal cortical curvature in the coronal plane, as measured by the ratio of the inner and outer perimeters of the cortex. For areas 27, 29b, and 18b, the perimeters differed by less than 5 percent, and no additional correction for curvature was necessary. For areas 17 and 29b, whose perimeters differed by 20 and 30 percent, respectively, at the points sampled, it was assumed that the external layers were thinned and the internal layers thickened by equal amounts by the curvature. Thus for these two cortical areas it was assumed that the total area in each lamina is conserved as it is stretched or compressed; the measured depth and the neuron number were thus modified accordingly (2). This method of correction compensates adequately for moderate amounts of curvature such as those described here; for larger convexities, cortical depth significantly increases. Finally, neuron counts were corrected for frequency of encounter by cell size by the method of Abercrombie (6).

Cortical areas in the newborn hamster were defined by reference to the areas in adult hamster. Coronal sections of the developing neocortex were anchored with respect to a variety of reference points, including the posterior extent of the caudate nucleus, the rhinal fissure; the hippocampal transitional zone, and the corpus callosum. The cortex was then subdivided with reference to the adult coordinates. These cortical areas are large with respect to the total amount of cortex present, and small errors in the placement of boundaries are unlikely to cause major errors in the accuracy of counts of entire areas. Postnatal days 5, 6, 7, 8, and 10 were examined, with up to three animals used per day per cortical area. These days were chosen because prior surveys revealed little cell death before day 5 or after day 10. By day 5, adult laminae are distinguishable, and migration of cortical neurons to the external laminae is terminating (7).