LATERALIZATION, LANGUAGE LEARNING, AND THE CRITICAL PERIOD: SOME NEW EVIDENCE

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New evidence is presented that modifies Lenneberg's (1967) proposed critical period of language acquisition. The development of lateralization is complete much earlier than puberty and is thus not a barrier to accent free second language learning by adults. Rather, the development of lateralization may correspond to normal first language acquisition. Also, the case of Genie, a girl who endured 11 years of enforced isolation, shows that some first language acquisition is possible after the critical period, although mechanisms outside of the left hemisphere may be involved. Genie's slow but steady progress also implies that adult achievement in learning second languages should not be pre-judged.

In Biological Foundations of Language, Lenneberg suggests that natural language acquisition "by mere exposure" can only take place during a critical period, lasting from about age two to puberty. Before two, language acquisition is impossible due to maturational factors, while natural acquisition of language after puberty is blocked by a loss of "cerebral plasticity" supposedly caused by the completion of the development of cerebral dominance, or lateralization of the language function. It is this biologically based critical period, Lenneberg suggests, that is responsible for the fact that "automatic acquisition from mere exposure to a given language seems to disappear after this age (puberty)" and "foreign accents cannot be overcome easily after puberty" (Lenneberg 1967:176). Scovel (1968) has in fact suggested that if such a critical period exists, it is futile for foreign language teachers to attempt to rid their older students of their accents.

This paper will report on areas of current neurolinguistic research that modify and shed new light on Lenneberg's notion of a critical period. First, evidence will be presented that the de-

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The development of interassociation

A critical period for the development of interassociation is from 2 to 5. After this age, the ability to learn new associations diminishes. This is supported by studies that show a decrease in the number of new associations learned after the age of 5. The development of interassociation is complete by the age of 16.

Table 1

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Lessons</th>
<th>Age Range</th>
<th>Total Pairs of Numbers of Lessons</th>
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<tbody>
<tr>
<td>Besser 1965</td>
<td>20</td>
<td>9 to 12</td>
<td>143</td>
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<tr>
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Table 2

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The effectiveness of different pairs of numbers in children's learning is tested by the percent change in their performance before and after the intervention.

The development of interassociation is complete by the age of 16. The critical period for the development of interassociation is from 2 to 5. After this age, the ability to learn new associations diminishes. This is supported by studies that show a decrease in the number of new associations learned after the age of 5. The development of interassociation is complete by the age of 16.
The result of a recent report by the National Research Council (1969) is that the development of the right hemisphere in the first two years of life is critical. It is during this period that the right hemisphere develops rapidly in terms of its ability to process non-verbal information such as facial expressions, gestures, and spatial relations. This rapid development of the right hemisphere is important because it is believed that the right hemisphere is more sensitive to spatial and Gestalt configurations, which are crucial for tasks such as problem-solving and spatial reasoning. The report also highlights the importance of early intervention in cases where there is a delay in the development of the right hemisphere, as it may have implications for cognitive and emotional development.
functions in the left). White (1961) mentions a left hemispherectomy performed on a young man who received "trauma" to the left hemisphere at nine. Apparently, removal of the left hemisphere did not affect language at all. No case history or handedness data was available, however.

In addition, Lansdell (1969) reported on 18 cases of right hemisphere speech preceded by left lesions; in 14 of the cases the injury clearly took place before age five. In one case the age of onset was six. In another, the only detail provided is that seizures began at sixteen (the injury could have been earlier), and in a third, childhood brain damage was suspected. Only one case out of 18 cannot be accounted for by the lateralization-by-five hypothesis—a case of right hemisphere speech with lesion at ten (who might have been originally right dominant).

Striking evidence that transfer may be impossible after five is provided by Rasmussen in discussion following Zangwill (1964). Five cases of left damage in right handed (and thus most probably left dominant) children are reported. Each child experienced and recovered from aphasia. Transfer of dominance, revealed by right hemisphere performance on the Wada test, occurred in the three children who were five or under at the time their lesion was incurred (two, three, and five), but not in the children who were seven and eight years old at the time of the lesion.

While transfer seems to be at best rare after five, data is scarce and the possibility still remains that complete transfer is possible until puberty; the plasticity necessary for successful language acquisition may be connected to interhemispheric plasticity. Note, however, that the lesion, dichotic listening, and testing data place the completion of the development of lateralization much earlier than puberty. If transfer were possible until puberty, t'As would imply that lateralization and transfer are not directly related. It is logically possible that the right hemisphere can retrain itself to do language despite its full specialization for other functions (this possibility was independently suggested by Richard Harshman and Eric Lenneberg).

The relationship of lateralization and language learning

If the development of lateralization is complete by around five and is thus not connected to Lenneberg's critical period, does it have any relationship to language learning? Krashen and Harshman (1972) (also Krashen 1972) argue that first language acquisition itself, also complete by around five, may be related to the development of lateralization. See Chomsky (1969) and Hatch (1969) for evidence that the five year old has not yet attained full compe-


tence in his language. Note that fairly subtle testing procedures were necessary to expose these previously undetected gaps, which for the most part involve exceptions to rules. The fact remains that the five year old has certainly mastered the fundamentals of his language. Either the two processes may go hand-in-hand, or, as Krashen and Harshman suggest, language acquisition may involve and depend on the previous lateralization of certain functions (this view is explicated and supported in Krashen 1972). Thus, the development of lateralization may represent the acquisition of an ability rather than the loss of an ability.

FIRST LANGUAGE ACQUISITION AFTER PUBERTY: THE CASE OF GENIE

The case of Genie, an adolescent girl who endured 11 and a half years of extreme social and experiential deprivation, is the most direct test of the critical period seen thus far. Genie emerged from isolation at the age of 13 years, eight months, with little if any linguistic competence and no linguistic performance, and was thus faced with the task of first language acquisition with a post pubescent brain (for details concerning Genie's personal history and the conditions of her confinement see Curtiss, Fromkin, Krashen, Rigler, and Rigler forthcoming). Despite this, and despite previous negative reinforcement for speaking (the result of her having been punished for making any noise whatever), Genie has shown slow but steady progress in language learning over the past two years. At the time of this writing, Genie can understand and produce three and four word sentences expressing negation, locative relations, SVO relations, possessives, and modification (for details of Genie's syntactic and phonological competence, see Curtiss et al. forthcoming, and Curtiss, Krashen, Fromkin, Rigler, and Rigler 1973).

Neurolinguistic research with Genie has thus far revealed two related findings; dichotic listening tests have shown that Genie is processing language in her minor, right hemisphere, and psychological testing, conducted by Dr. D. Rigler of Children's Hospital, Los Angeles, has shown that she performs surprisingly well in tests that involve skills that are normally dependent on right hemisphere mechanisms.

With the assistance of Lloyd Rice and Sarah Spitz of the UCLA Phonetics Laboratory, special dichotic tapes were prepared for Genie, one consisting of words familiar to her and the other consisting of familiar environmental sounds.

Genie was first tested monaurally (one ear at a time) and
scored 100% in each ear. As is reported elsewhere (Krashen, Fromkin, Curtiss, Rigler, and Spitz 1972), Genie manifested an extreme left ear advantage for verbal material, the left ear doing perfectly and the right ear performing at a chance level. Both the direction and degree of ear difference are very unusual. Since Genie is right handed, a right ear advantage was expected. Also, the ear difference usually found in dichotic listening is not large and statistical tests are generally necessary to show significant differences. Ear differences as extreme as found with Genie have been found thus far only in split-brain subjects (subjects who have undergone surgery for the control of epilepsy that involved cutting the nerve fibers connecting the two hemispheres—Milner, Taylor, and Sperry 1968) and in hemispherectomized subjects (Berlin, Lowe-Bell, Porter, Berlin, and Thompson 1972, and Curry 1968).

For environmental sounds Genie showed the expected moderate left ear advantage, pointing to right hemisphere processing. In a recent study, Krashen and Spitz have shown that environmental sounds may yield a right ear advantage when presented under certain conditions to male subjects and no ear difference for female subjects. This result is not inconsistent with the hypothesis that Genie is using her right hemisphere for both verbal and nonverbal processing, since she did show a left ear advantage. Nevertheless, efforts are now being made to determine cerebral localization of other functions in Genie.

### TABLE 3

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Stimuli</th>
<th>RE</th>
<th>LE</th>
<th>Study</th>
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<tbody>
<tr>
<td>normals</td>
<td>words</td>
<td>60%</td>
<td>52%</td>
<td>(Curry, 1968)</td>
</tr>
<tr>
<td>Genie</td>
<td>words</td>
<td>15%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>split-brains</td>
<td>words</td>
<td>91%</td>
<td>22%</td>
<td>(Milner et al. 1968)</td>
</tr>
<tr>
<td>hemispherectomies (right)</td>
<td>words</td>
<td>99%</td>
<td>24%</td>
<td>(Berlin et al. 1972)</td>
</tr>
<tr>
<td>normals</td>
<td>env. ads.</td>
<td>27%</td>
<td>29%</td>
<td>(Curry, 1968)</td>
</tr>
<tr>
<td>Genie</td>
<td>env. ads.</td>
<td>65%</td>
<td>93%</td>
<td></td>
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</tbody>
</table>

In other reports (Krashen et al. 1972, Krashen, Fromkin, and Curtiss 1972), it is argued that Genie may have begun language acquisition before her confinement with her left hemisphere. Through disuse the left hemisphere is now no longer able to fulfill its original linguistic function, and Genie may now be using her right hemisphere to learn language. This explains the direction of her results, the left ear advantage. The degree of ear difference may be due to the "atrophied" left hemisphere language areas preventing the flow of impulses arriving at the right ear from reaching the right hemisphere (Figure 1).

![Figure 1. Dichotic listening model for Genie.](image)

The environmental sounds results indicates that for Genie both linguistic and non-linguistic processing is taking place in the right hemisphere; thus Genie is not merely one of those individuals with "reversed" laterality (language in the right and non-language in the left).

Dr. D. Rigler has observed that Genie's behavior on psychological tests can be meaningfully comprehended when performance on two kinds of tests is distinguished: those that involve analytic or sequential use of symbols, such as language and number, and those that involve perception of spatial configurations or Gestalts. On the first group of tests (Peabody Picture Vocabulary Test, Columbia Mental Maturity Test) Genie's performance is consistently in the low range, presently approximating an age of two and a half to three years. Compared with her behavior on admission to the hospital, this represents a growth of about one and a half years over a two year period. On configurational tests (the Street Test, the WISC Performance Tests) her performance lies somewhere between eight years and the adult level, depending on the test. The rate of growth on these tests has been very rapid.

Both the dichotic listening and psychological testing results are consistent with the hypothesis that Genie is using her healthy right hemisphere for both verbal and nonverbal functions; what are generally considered right hemisphere functions (perception of the environment, spatial relations) thrive quite well, while Genie's
hemisphere is not as successful with what are considered left hemisphere functions. Note that this is consistent with reports of existing but deficient right hemisphere speech in adults (Smith 1966, Hiller 1954, Kinsbourne 1971).

Thus, while the normal development of lateralization may not play a role in the critical period, lateralization may be intimately involved in a different way; the left hemisphere must perhaps be linguistically stimulated during a specific period of time for it to participate in normal language acquisition. If stimulation does take place during this time, any language acquisition must depend on other cortical areas and will proceed less efficiently due to the previous specialization of these areas for other functions.

SUMMARY AND CONCLUSION

The main points of this paper are (1) the developmental course of lateralization is not associated with Lenneberg's proposed critical period, since lateralization is complete far earlier than puberty. Available evidence does not as yet preclude the possibility that limitations of interhemispheric transfer are associated with the critical period (although the demonstration that transfer is possible until puberty does not demonstrate the existence of a critical period), and (2) first language learning is definitely possible after puberty, although this language learning may not be as rapid or efficient as normal first language acquisition and may depend on cortical mechanisms outside the left hemisphere.

Completion of lateralization thus does not mean the establishment of an absolute barrier to language acquisition. Hill (1971), for example, cites cross-cultural studies that question the inevitability of foreign accents in second languages learned after puberty. Genie's continuing progress in first language acquisition, moreover, should encourage second language learners, the vast majority of whom possess healthy left hemispheres. Until we see Genie's limitations, the capacity of adult second language learners should not be pre-judged.

REFERENCES

presented at the 47th meeting of the Linguistic Society of America.
Atlanta, Ga.: December, 1972.
Krashen, S., V. Fromkin, S. Curtiss, D. Rigler and S. Spitz. 1972. Lan-
guage lateralization in a case of extreme psychosocial deprivation.
Journal of the Acoustical Society of America 52,174. (Abstract), also
Landsell, H. 1969. Speech and age at brain injury. Journal of Comparative
and Physiological Psychology. 734-736.
and Son.
MacFie, J. 1961. Intellectual impairment in children with localized post-
infantile cerebral lesions. Journal of Neurology, Neurosurgery and
Psychiatry 24,361-365.
McCarthey, quoted in Osgood and Miron (eds.). 1963. Approaches to the
study of aphasia. Urbana, Ill.
Milner, B., L. Taylor and R. Sperry. 1968. Lateralized suppression of
dichotically presented digits after commisural section in man. Science
161, 184-186.
versity Press.
Scovel, T. 1969. Foreign accents, language acquisition, and cerebral domi-
nance. Language Learning 19,245-254.
Smith, A. 1966. Speech and other functions after left (dominant) hemis-
pherectomy. Journal of Neurology, Neurosurgery and Psychiatry 29,467-
471.
White, H. 1961. Cerebral hemispherectomy in the treatment of infantile
Zangwill, O. 1964. The current status of cerebral dominance. Research
Publications—Association for Research in Nervous and Mental Disease.