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The time course for language acquisition in biologically distinct populations: Evidence from deaf individuals☆

Danielle S. Ross[a,*] and Thomas G. Bever[b]

[a] Department of Brain and Cognitive Sciences, University of Rochester, Meliora Hall, Room 360, Rochester, NY, 14627-0268, USA
[b] University of Arizona, USA

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Abstract

The present study provides evidence that individuals who have different patterns of cerebral lateralization and who develop along different maturational time courses can attain comparable levels of language proficiency. Right-handed individuals with left-handed family members (left-handed familials, LHFs) showed a shorter sensitive period for language acquisition than did right-handed individuals with only right-handed family members (right-handed familials, RHFs). The shorter sensitive period for LHFs may be due to a focus on non-linguistic, word-based conceptual information during language acquisition. RHFs may focus on grammatical relations during language acquisition, which matures later than lexical knowledge. This suggests that there may be different patterns of cerebral lateralization for language in all normal populations as a function of familial handedness.

Keywords: Sensitive period; Critical period; Familial handedness; Lateralization; Sign language; Deafness; Language acquisition; Neurolinguistics

1. Introduction

Although many studies suggest that a specialized neurological module in the left hemisphere of the brain is predominantly responsible for language (Broca, 1865; Lenneberg, 1967; Petitto et al., 2000; Poizner, Klima, & Bellugi, 1987), normal levels of language proficiency can be reached in biologically distinct populations with patterns of cerebral lateralization that differ from the norm (Bever, Carrithers, Cowart, & Townsend, 1989; Joanette, Lecours, Lepage, & Lamoureux, 1983; Luria, 1947). This raises two possibilities regarding lateralization and language development. First, it is possible that different neurological substrates develop along different maturational time courses and second, it is possible that there may be differences in how biologically distinct groups acquire language.

In order to examine the possibility that language develops along different time courses in populations with different patterns of cerebral lateralization, the present study compares the sensitive period functions for language acquisition in two populations of deaf individuals. The deaf population provides a unique opportunity to study the maturational course for language acquisition because of the wide variability in how many years of experience they have signing their primary language and when they are first exposed to their primary language.

The present study compares the sensitive period functions for the following biologically distinct populations of deaf individuals: (1) right-handed familials (RHFs: right-handed individuals with only right-handed relatives) and (2) left-handed familials (LHFs: right-handed individuals with at least one left-handed relative). Since differences have been shown in how RHF and LHF right-handers process language (Bever et al., 1989), it may be possible that these two groups develop along distinct maturational time courses and that they acquire language differently.

Demonstrating that such distinct populations can not only acquire language to normal levels of proficiency,

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* Corresponding author.
E-mail address: ross@bcs.rochester.edu (D.S. Ross).

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but that they develop along different time courses will provide important insight as to the biological substrates for language. It will provide strong evidence that language, although possibly predominantly dependent on a module in the left hemisphere for the majority of individuals *can* develop with alternate patterns of cerebral lateralization. In other words, a similar cognitive ability can result from various patterns of lateralization. This will provide evidence for the remarkable resilience and flexibility of the human brain and will provide important insight as to the relationships between cognition, brain, and behavior.

Before providing more details of the current study, some relevant background will be provided.

Lenneberg (1967) suggested that children acquire language naturally and to a native level of proficiency during a sensitive or "critical period." After this period, children may not acquire language to a native adult level of proficiency. The developmental process of those who are exposed to language after this sensitive period may be different than those who are exposed to language from birth. Subsequent research supports this hypothesis (Curtiss, 1977; Johnson & Newport, 1989).

Importantly for the present study, recent research indicates that this hypothesis also applies to signed languages (Mayberry, 1994; Mayberry & Eichen, 1991; Newport, 1990). Five to ten percent of deaf signers are born to deaf parents in the United States and are exposed to American Sign Language (ASL) from birth (Gallaudet Research Institute, 2001; Rawlings & Jensema, 1977; Schein & Delk, 1974). The remainder of deaf signers, who are born to hearing parents, are often not exposed to sign language until later periods in their lives due to various reasons such as detection of deafness after early childhood, absence of services, lack of access to services, pedagogical decisions, and social/political reasons.[1] Deaf individuals who are exposed to sign language from an early age have been shown to acquire it in the same manner as do hearing children exposed to spoken language from an early age (Bellugi, 1988; Newport, 1990; Newport & Meier, 1985; Petitto & Marentette, 1991). Among other measures, aphasia data (Corina, 1998a, 1998b; Hickok, Klima, & Bellugi, 1996; Poizner et al., 1987) and PET scan studies (McGuire et al., 1997; Petitto et al., 2000) have also demonstrated that these individuals have the same tendency to be left-hemisphere dominant for sign language, as do hearing individuals for spoken language.

Like spoken language, the acquisition of ASL shows strong age of acquisition effects (Mayberry, 1994; Newport, 1990). For example, Newport (1990) has shown that although many deaf individuals who acquire ASL after early childhood (approximately age 12;0), referred to as "late learners" or "non-native signers," do become fairly proficient signers, on average, non-native signers have been shown to acquire ASL imperfectly. They often omit grammatical morphemes and make inconsistent errors in their productions of ASL (Newport, 1990; see also Emmorey & Corina, 1990; Mayberry & Eichen, 1991; Mayberry & Fischer, 1989). In short, for a child to acquire a language fully s/he must be exposed to that language during early childhood.

Studies of *right-handed individuals with left-handed family members* (LHFs) and *right-handed individuals with right-handed family members* (RHFs) provide evidence that normal levels of language proficiency can develop with different patterns of cerebral lateralization (Bever et al., 1989; Joanette et al., 1983; Luria, 1947). Joanette et al. (1983) found that LHF right-handers with left-hemisphere lesions recovered faster from aphasia than did RHF right-handers, and that LHFs with minor right-hemisphere lesions often suffered from minor aphasias. This provides evidence that LHFs process language in the right hemisphere more than do RHFs.

Bever et al. (1989) report that despite comparable levels of proficiency, LHF right-handers and RHF right-handers process English sentences differently. Bever et al. (1989) summarized several studies that demonstrate LHF right-handers are more sensitive to non-linguistic, word-based conceptual information during sentence processing. LHFs access individual word meanings during sentence processing more readily than do RHFs. For example, when subjects read sentences word-by-word in a self-paced task average reading times of LHFs were faster than those of RHFs. This complements the fact that RHFs read faster than LHFs when whole clauses are presented at once.

Iverson and Bever (1989) presented RHF and LHF right-handers with short essays auditorily, after which subjects answered written content questions. The content words were presented to one ear and the function words to the other. The words were presented in the correct order for grammatical sentences. This kind of presentation helped comprehension in LHFs (because it simplifies word segregation) and hindered comprehension in RHFs (because it interferes with their normal mode of processing). When all the words in the sentence were presented to the same ear, RHFs performed better than when they were presented in separate ears.

In the present study, we compare the maturational course for language acquisition for LHF right-handers and RHF right-handers by investigating whether the effects of years of experience and sensitive period functions differ between these two groups in deaf individuals. If differences in the maturational course between the two familial handedness groups are found, there may be consequences of such differences on performance during the acquisition process.

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2. Method

2.1. Subjects

Over 900 deaf college students (70 dB+ in the better ear) attending the National Technical Institute for the Deaf (NTID) were interviewed. Data from 238 of these students (124 males and 114 females) were included in the analyses for the present study. Two hundred and thirty-three subjects were born deaf and five subjects reported that their deafness was discovered no later than three months of age. One hundred and two subjects had at least one deaf relative, determined by self-report on the questionnaire (sibling, parent, aunt/uncle, grandparent). The cause of deafness for these subjects was considered genetic. In order to control for the possibility of any neurological changes associated with deafness caused by illness, the subjects who reported pre- or peri-natal illnesses such as meningitis or rubella and those whose deafness was caused by premature birth or birth trauma (such as anoxia) were not included in this study.

One hundred and thirty-six students could not attribute their deafness to any known cause. This was also determined by self-report on the questionnaire. For such subjects, there was no family history of deafness and no other cause of deafness could be determined. The cause of deafness for these subjects was considered genetic because: (1) modern diagnostic techniques can determine most causes of deafness that are due to illness, thereby eliminating most subjects whose etiology is due to illness from the group whose etiology is unknown and (2) studies that have thoroughly investigated groups of deaf individuals whose etiology was considered unknown have concluded that for most of these subjects deafness is likely due to genetics (Fraser, 1974; Newton, 1985).

The subject's ages ranged from 18;0 to 50;0 years. The average age of both RHF and LHF subjects overall was 21;6. The average age of the RHF group was 21;8 and that of the LHF group was 21;4. All subjects had seven or more years of sign language experience.

2.2. Data collection

Information about familial handedness and language background was obtained through interviews based on a questionnaire by 11 deaf research assistants. The deaf research assistants, using a questionnaire consisting of 33 items, conducted the interview in one of three ways: (1) the interviewer signed each question clearly, one-on-one, with the deaf student, (2) the interviewer signed each question clearly to a small group of deaf students, and (3) the interviewer asked the student to read and complete the questionnaire him/herself. The interviewer then checked the questionnaire to ensure that all questions had been comprehended correctly. The interviews were conducted in these three ways to ensure maximum comprehension.

2.3. Measures reported

2.3.1. Dependent measures

Sign language. The "Sign Language Placement Interview" (SIPI) (Caccamise, Poor, & Holcomb, 1992) was used to assess proficiency in ASL. This interview is a standard measure used at NTID to assess sign language proficiency. The score is based on an informal interview, with the purpose of determining in which of several sign language courses the student should be placed. The interviewer rates the student's signing skill on a scale from one to five with a rating of five being the most advanced in ASL (see Table 1). The students' SIPI ratings were obtained, with the students' written permission, from their communication profile in a large database maintained at NTID.

English. English proficiency was assessed using the Michigan Test of English Language Proficiency, Form G (Peterson, Upshur, Palmer, & Spaan, 1968). This is a written test consisting of 100 multiple-choice questions. There are three parts. Part one assesses knowledge of English grammatical structures such as basic morphology, tense, function words, and word order. Part two assesses knowledge of English vocabulary. Part three assesses reading comprehension. The students' scores on this test were obtained, with the students' written

Table 1
SIPI rating system (Caccamise et al., 1992)

Ratings	Description
5	*Bilingual ASL/Signed English*. Highly skilled in both ASL and meaning-based Signed English[a]
4	*Advanced Sign Skills*. Highly skilled in meaning-based Signed English with appropriate use of some grammatical features of ASL
3	*Intermediate Sign Skills*. Has good control of basic sign vocabulary items and appropriate use of some grammatical features of ASL
2	*Basic Sign Skills*. Able to express and comprehend simple sentences using everyday sign vocabulary
1	*No or Minimal/Survival Sign Skills*. No sign skills or able to produce some basic signs and/or fingerspelling

[a] "Signed English" in this context refers to pidgin-like signing which includes lexical items of ASL with a high degree of the grammatical structures of English (e.g., English word order, English prepositional phrases not used in ASL, and basic English idioms) with a small degree of some simple grammatical structures of ASL (e.g., simple verb inflections).

permission, from their communication profile in a large database maintained at NTID.

2.3.2. Independent measures

Age of acquisition of sign language. Age of acquisition of sign language is defined as the age at which the subject reported first being exposed to sign language. The subjects are divided into two age of acquisition groups: 0–7 years and 8+ years.

Number of years of signing experience. Number of years of signing experience was calculated as the subject's chronological age minus his/her age of acquisition of sign language. The subjects are divided into two years of experience groups: 7–14 years and 15+ years.

Familial handedness. Familial handedness was also based on self-report on a questionnaire. Familial handedness was determined by the dominant writing hand of immediate, biological relatives (siblings, parents, aunts/uncles, grandparents). *Right-handed familials* (RHFs) are right-handed individuals with only right-handed relatives. *Left-handed familials* (LHFs) are right-handed individuals with at least one left-handed relative (sibling, parent, aunt/uncle, grandparent).

3. Results

The results are presented in two main sections: (1) replication of previous findings and (2) new findings. The new findings are presented for age of acquisition of sign language and for years of signing experience.

3.1. Replication of previous findings

A number of common findings in the literature were replicated for the two groups of deaf individuals.

3.1.1. No differences in proficiency with normal exposure

As shown in Fig. 1, with normal exposure to language (i.e., in early childhood: 0–7 years), no differences in SIPI scores between RHFs and LHFs were found, which has previously been seen in the literature (Bever et al., 1989; Ross & Bever, 1996).

3.1.2. Age of exposure to sign language

Replicating a common finding in the literature (Newport, 1990), we found a negative correlation between age of exposure and current level of sign language proficiency ($r = -.21$, $p < .001$).

3.1.3. Years of sign language experience

We also repeated another finding in the literature. Years of signing experience may be related to sign language proficiency (see Mayberry & Fischer, 1989). In the current study, a positive correlation between years of

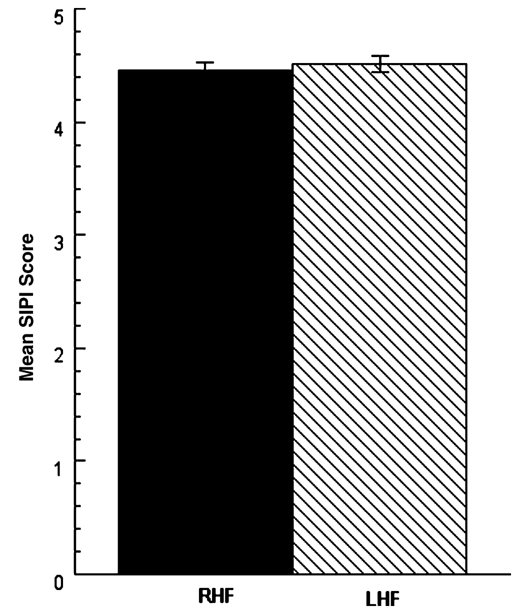

Fig. 1. Sign language proficiency for RHFs and LHFs (age of exposure: 0–7).

experience and current level of proficiency was found ($r = .32$, $p < .0001$).

3.2. New findings

3.2.1. Age of exposure to sign language

t tests comparing the means for the two age of exposure groups for RHFs and LHFs were performed. As shown in Fig. 2, for LHFs a significant difference between mean SIPI scores for the two age of exposure groups was found ($t = .362$, df 102, $p < .008$). The mean SIPI score for LHFs age 0–7 years was 4.51 and the mean SIPI score for LHFs age 8+ years was 4.00. No significant difference was found between these groups for RHFs.

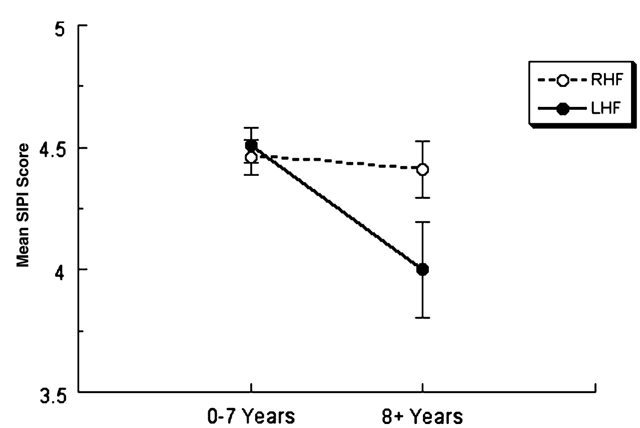

Fig. 2. Sign language proficiency for RHFs and LHFs as a function of age of acquisition of sign language.

3.2.2. Years of experience signing

As can be seen in Fig. 3, a significant difference between mean SIPI scores for the two years of experience groups was found for both RHFs and LHFs (RHFs: $t = .196$, df 132, $p < .006$; LHFs: $t = .348$, df 102, $p < .02$). For RHFs the mean SIPI score for the group with 7–14 years of experience was 4.18 and the mean SIPI score for the group with 15+ years of experience was 4.56. For LHFs the mean SIPI score for the group with 7–14 years of experience was 4.14 and the mean SIPI score for the group with 15+ years of experience was 4.52.

3.2.3. English proficiency

Age of acquisition and years of experience are inextricably bound in the present study due to the young age of the subjects. Years of experience potentially have a differential effect on sign language proficiency depending on proficiency in a first language (Mayberry, 1993; Mayberry, Lock, & Kazmi, 2002). That is, for deaf signers who were first exposed to sign language later in childhood, and who do not have near-native or native proficiency in a first language (i.e., English) years of sign language experience will generally have little effect on how well they acquire their second language (i.e., ASL). Conversely, for those who acquire English as their first language to at least a near-native level of proficiency before being exposed to sign language, many years of experience can result in near-native or native levels of proficiency in signing their second language (Mayberry, 1993; Mayberry et al., 2002).

For the present study, in order to determine whether proficiency in their first language (i.e., English) was related to the effects of age of acquisition and/or years of experience for the two familial handedness groups, ANOVAs and t tests were performed between all familial handedness groups, age of acquisition groups, and years of experience groups. No significant differences were found for English proficiency as measured by the Michigan Test of English Language Proficiency, Form G (Peterson et al., 1968) between any of these groups.

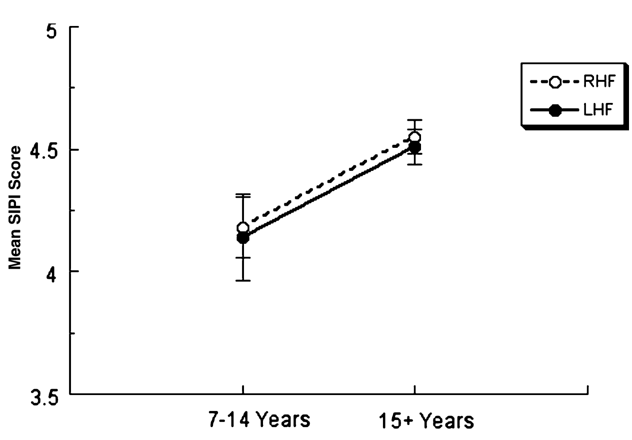

Fig. 3. Sign language proficiency for RHFs and LHFs as a function of years of signing experience.

4. Summary of results

To summarize, when RHF and LHF individuals are exposed to language in early childhood, comparable levels of proficiency are attained. However, differences in the age of acquisition (sensitive period) function between RHFs and LHFs were found. LHFs showed a steeper age of exposure function than did RHFs, indicating a shorter sensitive period for LHFs. Years of experience had an effect on both RHF and LHF groups. The more years of experience for both groups, the higher their SIPI score. No differences were found between any of the groups for proficiency in English.

5. Discussion and conclusions

The present study supports the view that with normal exposure (i.e., during early childhood) language proficiency in biologically distinct populations with different patterns of cerebral laterality is comparable to those with more usual lateralization patterns. Thus, the view that language is entirely dependent on a single kind of neurological substrate (e.g., an anatomical module in the left hemisphere) is not supported. We have demonstrated that biologically distinct populations that vary systematically with regard to patterns of cerebral lateralization develop language along different time courses. We have provided strong evidence that language, although possibly predominantly dependent on a module in the left hemisphere for the majority of individuals *can* develop with different patterns of cerebral lateralization and along different maturational time courses.

Although age of acquisition and years of experience are inextricably bound in the present study, the results are interpreted in terms of sensitive period, rather than simply years of experience. First, our results show that although both familial handedness groups were affected in the same way by years of signing experience, they were affected differently by age of acquisition of sign language. Second, proficiency in English may be a possible confound for some students who learned to sign after the age of 8;0. That is, proficiency in their first language, English, may predict the effects of years of experience on a second language, ASL (Mayberry, 1993; Mayberry et al., 2002). However, the students' levels of proficiency in English did not differ systematically between the two age of acquisition groups and the two years of signing experience groups for RHFs or LHFs. Thus, although first language proficiency (English) as it relates to years of experience and age of acquisition of a second language (ASL) may have added variability to the data, it does not appear to have confounded the results of the present study in a systematic and predictable manner. Finally, previous findings using older subjects and from which the effects of years of experience and age of acquisition were extrapolated (Mayberry & Eichen, 1991; Newport, 1990) have shown that age of acquisition determined sign language proficiency, rather than years of experience.

Although further study is necessary to discover the exact nature of the lateralization patterns in RHFs and LHFs, we offer the following hypotheses. Several authors have suggested that children have different first language learning styles (Bates, Bretherton, & Snyder, 1988; Bever et al., 1989; Bloom, 1973; Nelson, 1973; Peters, 1983). Bever et al. (1989) suggest that "...LHF right-handed children may approach language behavior initially as a problem of mastering the words, while RHF right-handed children may focus initially on the acquisition of grammatical relations." (Bever et al., 1989, pp. 348).

Consistent with this view, we have shown that LHFs appear to have a shorter sensitive period for language acquisition than do RHFs. As suggested by Bever et al. (1989), the reason for this difference may be that RHFs acquire language through initially focusing on grammatical or syntactic relations, whereas LHFs may initially focus on the meanings of words in the process of language acquisition. Since children experience a rapid increase in vocabulary very early in childhood (between two and six years of age), this may shift their sensitive period to an earlier time in childhood compared to RHFs. Similarly, significant increases in language proficiency most likely occurs later in RHFs than LHFs because children are ready maturationally to acquire grammatical relations later than they are word meanings. This thereby lengthens the sensitive period for RHFs as compared to LHFs.

Finally, these differences in sensitive period for language acquisition and perhaps language learning style should also alert researchers to a systematic variation in subject populations and should therefore be taken into consideration for language acquisition studies. Our own future research on the time course and style of language acquisition will focus on experimental studies of specific grammatical structures and word learning in RHFs and LHFs that will confirm and further clarify the preliminary findings in this study.

In summary, we have provided strong evidence that comparable levels of proficiency on a cognitive ability can be attained by individuals who develop along different time courses and who have very different patterns of cerebral lateralization. Therefore, the view that language depends entirely on a single kind of neurological organization must be modified. The different sensitive periods and possible learning styles of RHF and LHF individuals should be taken seriously by researchers as systematic subject variables.

In conclusion, the present study has significant implications for the general consideration of the biological basis for language and related debates on linguistic nativism. First, in our study and in Bever et al. (1989), roughly 40% of explicit right-handers are LHFs, according to our measures. Thus, one cannot view LHFs as "abnormal." Familial left-handedness is highly likely to be a biologically coded variable for explicit right-handers, not obviously a socially transmitted one. Thus, any differences must have a deep biological source. Bever et al. (1989) suggest a simple (and testable) hypothesis: the neurological representation of lexical knowledge is more widespread in LHFs. This follows from the classic view of Luria (1947) and others that LHFs are less completely lateralized for language, and hence have greater right-hemisphere involvement in language behavior. Many models of the difference between the hemispheres suggest that the right hemisphere has prodigious ability to store associative information (Beeman & Chiarello, 1998a, 1998b; Brownell, Gardner, Prather, & Martino, 1995; Chantraine, Joanette, & Ska, 1998; Chiarello, Liu, & Faust, 2001; Joanette, Goulet, & Hannequin, 1990). This could lead to a greater representation of specific lexical knowledge in the right hemisphere of LHFs and hence, more points of access for lexical knowledge. On this view, the biological difference between LHFs and RHFs is not in the fundamental capacities that make language possible: it lies rather, in the relative emphasis during acquisition on learning words, which intrinsically focuses LHFs more on lexical knowledge and less on syntactic knowledge. Over developmental time, the result may be an adult with apparent differences in cerebral lateralization, but which stem from the same fundamental biological substrate for language.

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