What Sign Language Reveals about the Critical Period for Language

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Early Language Acquisition and Adult Language Ability:

What Sign Language Reveals about the Critical Period for Language

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In 1806, Jean Itard wrote that adolescence was too late to learn language. He concluded this in a report to the government describing his two-year attempt to teach the famous Wild Boy of Aveyron to speak French. Itard called the boy Victor because the only sound to which he responded was the French [ɔɹ] (Itard, 1896/1962:29). Eventually Victor could communicate his desires to a limited degree with actions on objects, as in holding his bowl next to the porridge pot when he wanted more, but he never learned French despite intense and structured lessons (Itard, 1896/1962). The idea that language proficiency is linked to the age when the learning begins is known as the critical period for language and, as Itard's report demonstrates, is an old idea. Because Itard was the physician for the Institution Nationale de Sourdes-Muets, the world's first school for deaf children and the birthplace of one of world's largest sign language families (Zeshan, 2006), it is curious that he never tried to teach Victor sign language (Lane, 1976). The school was 40 years old by then and the historical record shows that French Sign Language was in full bloom (Van Cleve & Crouch, 1989). The idea that sign language is *language* was unheard of in the 1800s, however, and research uncovering its linguistic architecture would not begin for another hundred years (Klima & Bellugi, 1979; Stokoe, Casterline, & Croneberg, 1965).

Could Victor have learned French Sign Language even though he failed to learn spoken French? The question is whether there is a critical period for language acquisition that encompasses sign language. Because professionals who work with deaf children often appear to implicitly assume that there is a critical period for spoken but not sign language, the question is central to clinical and educational practice. The question is also fundamental to language theory because it requires that we understand the complex relations among language acquisition, brain maturation, and sensory-motor modality. Germane to our discussion is research that investigates age of acquisition effects on the outcome of language acquisition, both spoken language and sign language. The linguistic details of these studies are outside the scope of this chapter, but discussing the research in broad strokes allows us to see the larger picture of how age of acquisition affects the outcome of language acquisition. To foreshadow the conclusion, Victor would not have acquired French Sign Language even though he developed rudimentary, non-vocal communication using objects. The goal of this chapter is examine the reasons why. We begin by considering what a critical period is with respect to language.

<1> Critical Period Learning

A critical period is a phase during development when learning is most efficient. Critical period phenomena were first observed and documented for animal behavior at a number of levels, for example in chicks' identification and attachment to mother birds (Lorenz, 1965) or in cats' visual perceptual development (Wiesel, 1982). Although critical periods are sometimes characterized as being limits on learning, they represent a unique form of learning where an interaction between biology and environment produces quick and unconscious learning. Some researchers prefer to replace the term *critical* with adjectives such as *sensitive* or *optimal* to denote the facts that (1) learning can occur after a critical period and (2) that multiple sub-skills can be involved in a complex skill, each with its own temporal sensitivity in development (Werker & Tees, 2005).

Language acquisition is an example of a complex skill consisting of numerous sub-skills. Although scientists have observed and documented time-limited sensitivity over development for many types of learning, they disagree as to what the underlying mechanisms might be, both in terms of what causes the heightened sensitivity to a particular type of environmental input and why the sensitivity ends. One class of explanations proposes that environmental complexity directly affects the creation of neural networks (Greenough & Black, 1992), although this neural effect has not yet been found for language. Another type of explanation based on connectionist modeling proposes that early learning itself affects subsequent learning (Seidenberg & Zevin, 2005), especially with respect to second-language learning *vis à vis* the first-language, as explained below.

Infants and young children acquire the languages in their environment quickly and effortlessly. By contrast, most adults appear to struggle and learn new languages only with sustained and conscious effort. The neurosurgeon Wilder Penfield, who first mapped the language areas of the brain during surgeries designed to limit recurrent seizures, observed that the brain has strong biological biases for language in early life. He noted the overwhelming tendency of the anterior left hemisphere to control language, except in cases of injury to the left hemisphere when homologous regions in the right hemisphere then take control of language, but only if the injury occurs in early childhood (Penfield & Roberts, 1959). This suggests some level of plasticity for language in brain development that is only present in early life.

<1> Age of Acquisition Effects on Spoken Language Outcome

Scientific investigation of the critical period for language requires that we study individuals whose initial exposure to a language varies temporally over the course of human development. One source of information comes from children who experience atypical social isolation during early childhood, including feral children such as Victor, or severely abused children such as the well known case of Genie who lived without human contact for the first 13 years of her life (Curtiss, 1977). Genie was able to learn some spoken English with intense instruction, but she was unable to maintain her language in adulthood (Garmon, 1994). The multiple complications suffered by these rare cases, such as nutritional and emotional deficiencies, means that we must use caution in interpreting their difficulty with language acquisition because of these confounding factors.

The most common means of investigating age constraints on the outcome of language acquisition has been to measure the language proficiency of people who learn a second language, L2, at varying ages. Several studies have found a negative correlation between age of L2 acquisition and eventual L2 proficiency and/or significant differences in language performance between native and non-native learners. These effects have been found across an array of linguistic structures in morphology, syntax, and phonology, mostly investigating English as the L2, using a number of measurements of spoken and written language, including quality ratings by judges, error counts, memory tasks, and grammaticality judgments (Birdsong & Molis, 2001; Flege, Yeni-Komshian, & Liu, 1999; Johnson & Newport, 1989).

Although these findings confirm the widespread folk belief that learning a second language at a younger age leads to higher L2 proficiency compared to learning it at older ages, researchers disagree as to how the trend should be interpreted. At issue is whether the decline in L2 proficiency in relation to age provides evidence for a critical period for language. The data suggest that there is no terminal age when an L2 can no longer be learned. After the age of 8, the decline in L2 proficiency in relation to age continues throughout the lifespan into senescence (Hakuta, Bialystok, & Wiley, 2003). This finding is interpreted to mean that some factor other than a critical period causes the negative correlation between age of acquisition and L2 proficiency, such as cognitive aging. Moreover, age of acquisition is not the sole predictor of L2 proficiency. Many L2 learners attain near-native proficiency despite older ages of L2 acquisition. Factors such as the amount of education in the L2, and the linguistic relationship of the L1 and L2 also predict L2 outcome (Birdsong & Molis, 2001; Flege, Yeni-Komshian, & Liu, 1999).

When weighing the effects of age of acquisition on L2 proficiency, it is important to bear in mind that L2 learning entails, by definition, acquisition of a first language in early life. If there is a critical period for language acquisition, some researchers argue that it should affect acquisition of the *first* language, L1, rather than the L2, based on evidence from rare cases of social isolation in early childhood where the outcome of L1 acquisition is severely limited (Eubank & Gregg, 1999). However, these case studies do not provide straightforward evidence for a critical period due to the multiple and severe deprivations suffered by these children, as explained above (Mayberry, 1994).

<1> Age of Acquisition Effects on Sign Language Outcome

<2> Variation in age of acquisition of sign language

A major contribution of sign language research to cognitive science is the discovery that linguistic structure and processing transcend sensory-motor modality (Klima & Bellugi, 1979; Stokoe, Casterline, & Croneberg, 1965). Like spoken languages, sign languages are structured at the sentence (syntax), word (morphology), sub-word (phonology), and semantic (word and sentence meaning) levels. Unlike gesture or pantomime, but like spoken language, sign language comprehension requires the unpacking of meaning via the multi-layered and hierarchical structure of language. In other words, the meaning of sign language sentences does not come for free by simply looking at signs as if they were pictures. Rather, sign language comprehension requires knowledge of its linguistic structure. Linguistic structure is what young children acquire so readily in early life, leading some researchers to hypothesize that acquisition of linguistic structure is governed by a critical period (Lenneberg, 1967).

That the signer's mind must use the linguistic structure of sign language to understand and produce it has been amply demonstrated in psycholinguistic experiments (for a review see Emmorey, 2002). Neurolinguistic research has further shown that the brain treats sign language like spoken language. Consistent with Penfield's early observations of how the brain represents spoken language (Penfield & Roberts, 1959), researchers have since discovered that anterior regions of the left hemisphere are responsible for sign language processing in deaf and hearing signers, and not regions which process non-linguistic visual information (for a review see Corina & Knapp, 2006). Damage to these classic language regions cause aphasia in signers comparable to aphasia in speakers (Poizner, Klima, & Bellugi, 1987). Thus language structure and processing are amodal; the mind and brain treat sign language as language because it is language.

Given what is now known about the nature of sign language, it follows that children's acquisition of it from birth is similar to that of spoken language acquisition with respect to the timing and content of linguistic milestones (Anderson & Reilly, 2002; Mayberry & Squires, 2006; Reilly, 2006). Although sign and spoken language show parallel developmental trajectories when the acquisition begins at birth, most deaf signers are first exposed to sign language at ages well after birth. The crucial question is whether variation in age of acquisition affects sign language proficiency in adulthood. If so, then the question becomes whether such effects are similar to, or different from, those observed for L2 learning of spoken languages described above. Before turning to this body of work, it is important consider why age of sign language exposure is heterogeneous among deaf signers.

A small percentage (less than 10%) of deaf children are born to deaf parents, and this subset of the population is likely to be exposed to sign language from birth. For the remaining 90% of deaf children, sign language acquisition begins at various ages. No single factor underlies this variation, even in cases where the deaf child lacks functional spoken language. For example, the child may not have been enrolled in school until an older age, especially if the family lived in a rural area. A school that used sign language may not have been in close proximity to the family, and the parents may have been reluctant to send the child away to school or move. Alternatively, the family may have insisted that the child remain in an oral program, despite a notable lack of functional language, in the hope that the child would eventually develop spoken language with more time and instruction. Teachers and administrators often share these beliefs. Inaction in exposing a deaf child without functional language to sign language often reflects the assumption that exposing the child to sign language is “giving up” on spoken language, even though this is a mistaken idea. The deaf child’s growing maturity and inability to function at school or home without language is often the catalyst for the decision to educate the child with sign language.

These varying circumstances create heterogeneity in the age of sign language exposure within the deaf population. At the same time, these diverse circumstances of sign language acquisition mean that no underlying pathology covaries and/or worsens with age of sign language acquisition aside from human development with incomplete or sparsely developed language. The cognitive consequences of human development in the face of limited linguistic interaction with the environment have only begun to be investigated (Mayberry, 2002; Schick, de Villiers, de Villiers, & Hoffmeister, 2007).

Another factor in the heterogeneity of sign language acquisition among deaf individuals is whether it is acquired as a first or second language. Some deaf individuals learn sign language as an L2 after successful acquisition of spoken language, but for other deaf individuals age of sign language acquisition is more representative of L1 acquisition. This occurs when deaf individuals begin to learn sign language with little or no functional language. Acquiring sign language at older ages with little or no functional language is common among deaf children, although no currently available data describe the frequency of the phenomenon. Some of this L1 language delay is educationally induced for reasons explained above. Indeed, only among deaf signers do we find individuals who are otherwise intact and were lovingly cared for as children but nonetheless acquired little or no language in early childhood.

<2> Experimental studies of age of acquisition effects

Similar to the L2 research summarized above, several studies have found a negative correlation between age of acquisition and sign language proficiency. Among college-age students, accuracy of narrative and sentence recall declines as a linear function of ASL acquisition between the ages of birth and 15 years (Mayberry & Fischer, 1989). The negative correlation between age of ASL acquisition and sentence recall accuracy persists in adults who have had 20 to 40 years of ASL experience (Mayberry & Eichen, 1991), as shown in Figure 1. Similar results have been obtained using a battery of ASL tasks (Newport, 1990) and a sign monitoring task (Emmorey, Bellugi, Friederici, & Horn, 1995). These results show that age of acquisition affects language outcome independent of sensory-motor modality, consistent with what we now understand to be the amodal nature of linguistic structure and processing.

Figure 1 about here

Another question is whether age of acquisition differentially affects the outcome of an L1 as compared to an L2. One study investigated the accuracy of ASL sentence recall in deaf L2 and L1 learners who were matched for years of experience and age of ASL acquisition (Mayberry, 1993). The deaf L2 learners were born with normal hearing, which they lost in late childhood due to viral inflections; they learned ASL in immersion settings when they became deaf. By contrast, the deaf L1 learners were first exposed to ASL at the same ages as the L2 learners, but were deaf from birth and had little or no functional spoken language when they began to acquire ASL. The L2 learners recalled the ASL sentences with significantly greater accuracy than the delayed L1 learners, as Figure 2 shows (Mayberry, 1993).

Figure 2 about here

These findings demonstrate that age of acquisition has far greater effects on the outcome of the L1 compared to the L2, suggesting that the scope of the critical period for language acquisition pertains to the first rather than the second language. A corollary implication is that L1 acquisition in early life facilitates later L2 learning. If early acquisition of spoken language facilitates later acquisition of sign language, the question is whether the reverse situation is true. Does early learning of a sign language facilitate subsequent acquisition of spoken language?

The question was investigated by comparing the English syntactic processing of four groups of adults with contrasting types of L1 experience in early childhood (Mayberry & Lock, 2003). One hearing group served as the control and consisted of native English speakers. The second hearing group consisted of L2 learners of English who were immersed in it in school when they immigrated to Canada in early childhood; their native languages were Urdu, Spanish, German, and French. The third group was born deaf and exposed to ASL from birth; they subsequently learned English as an L2 in school at the same ages as the hearing L2 learners. It is important to highlight the fact that two different types of English L2 learners participated in the study: one hearing group whose early L1 was a spoken language other than English, and one deaf group whose early L1 was sign language. The fourth group was also deaf but began to learn ASL and English in school at the same age as the other groups. However, their school enrolment marked their first experience with fully perceivable language, that is, they entered school with little or no previously acquired functional language.

Both groups of L2 learners, regardless of whether they were hearing or deaf, or whether their first language was spoken or signed, performed at near-native levels across the English syntactic structures tested, as Figure 3 shows (Mayberry & Lock, 2003). These results are consistent with above described studies investigating the effects of age of L2 acquisition on spoken language, namely that L2 learners can sometimes attain near-native levels of L2 proficiency. The results show that this is true even when the L1 is an early acquired sign language, as was the case in this study. These results also replicate the previous finding that delayed L1 acquisition impedes language proficiency in adulthood: the deaf delayed L1 learners entered school with little functional language. A dearth of language acquisition in early childhood has deleterious effects on the outcome of all subsequent language learning in later life, on sign language and written and read language; neither the L1 nor the L2 are acquired to near-native levels in adulthood.

Figure 3 about here

In another experiment, the English task was changed from grammatical judgment to sentence-to-picture matching. Despite the added nonverbal context of pictures, the delayed L1 learners, all of whom had normal nonverbal IQ, performed at low levels on several English structures including conjoined, passives, and relative clauses. Replicating the results of previous experiments, the two L2 groups, one hearing and one deaf, again performed at near-native levels. Thus, three experiments in two languages (ASL and English) show, first, that age of acquisition effects are robust and persist into adulthood for L1 acquisition. Second, the results show that L1 acquisition in early life supports and facilitates subsequent L2 learning independent of sensory-motor modality (Mayberry, 2007).

<2> When L1 exposure is delayed until adolescence: Effects on language outcomes

Experimental studies of groups of deaf adults show that the scope of the critical period for language pertains to the L1 and that a lack of language acquisition in early life impedes the ability to learn language throughout life. The few available case studies of deaf individuals' L1 acquisition begun in adolescence corroborate the main findings of these experiments. First, the rate of delayed L1 acquisition is significantly slower than that of timely L1 language acquisition. Second, adult language proficiency is significantly limited in comparison to early L1 acquisition or later L2 acquisition.

Two studies longitudinally followed the spoken L1 acquisition of a deaf adolescent and an adult who had no exposure to sign language. In one study, the spoken Spanish acquisition of an adolescent boy was observed once he obtained hearing aids (Grimshaw, Adelstein, Bryden, & MacKinnon, 1998). After four years, he acquired limited vocabulary, could combine single words with gestures, but produced only a single two-word utterance. Another study followed the spoken English acquisition of a woman whose hearing loss was not identified until she was 31 years old. After 10 years of hearing aid use and spoken English instruction, she was reported to have a vocabulary of approximately 2,000 words and a grade 2-3 reading level, but her spoken utterances were described as being ungrammatical (Curtiss, 1988). The slow rate of delayed L1 acquisition observed in this adolescent and adult contrasts sharply with the rate of L1 acquisition in young deaf and hearing children. Early child language acquisition is characterized by voracious vocabulary learning (Anderson & Reilly, 2002; Bates & Goodman, 1997). By the age of 6 years old, hearing children can comprehend as many as 14,000 words and most grammatical structures of their language (Clark, 2003).

Another study longitudinally observed the L1 acquisition of ASL begun at age 13 by two deaf adolescents who had received no special services in their home countries prior to immigrating with their families to North America (Morford, 2003). After 31 months of ASL exposure, both adolescents had replaced the bulk of their gestures with ASL signs. No vocabulary assessment was made, but comprehension tasks given after 7 years of exposure showed both adolescents to suffer from severe comprehension deficits in ASL (Morford, 2003). These comprehension deficits caused by delayed L1 acquisition corroborate the experimental findings summarized above (Mayberry, 1993; Mayberry, Lock, & Kazmi, 2002).

Deaf individuals who are not exposed to language in childhood are not completely devoid of communication with those in their surroundings. Deaf children who acquire little functional, spoken language in early childhood have been observed to gesture for communicative purposes with their families, a phenomenon called *homesign* in ASL. Detailed analyses of homesign show that deaf children combine points with iconic gestures in a rule-governed fashion to name things in their environment, make comments, and make their needs known to some extent (Goldin-Meadow, 2003). This line of research shows that the deaf child creates the gesture system and, although they understand it, hearing parents do not appear to use it with the deaf child instead of speech. Homesign has been documented to occur cross-culturally among deaf children who have otherwise not acquired a spoken or sign language (Goldin-Meadow, 2003). Homesign was the means of communication used by the two adolescent L1 learners of ASL studied by Morford (2003). Although homesign displays many language-like features, it does not appear to function as early L1 acquisition in the critical period phenomenon. The deaf delayed L1 learners who participated in the experimental and case studies described here did not attain near-native levels of ASL proficiency despite years of using it even though they had used homesign as young children.

Together the results of these diverse studies indicate the effects of critical period for language to be three-fold. (1) Early L1 acquisition leads to native-like language proficiency in adulthood. (2) Early L1 acquisition supports and facilitates subsequent L2 learning, often leading to near native-like L2 proficiency in adulthood. (3) A lack of early L1 acquisition impairs the ability to learn language throughout life, that is, L1 acquisition that begins uncommonly late in human development leads to limited language proficiency for any language in adulthood.

The critical period phenomenon described here may explain the frequent clinical anecdotes from several countries, including the USA, Canada, Norway, Denmark, and Sweden, that young deaf children who have acquired sign vocabulary are more successful with cochlear implants than those with no sign vocabulary. Early language acquisition facilitates subsequent language acquisition cross-linguistically (Mayberry, Lock, & Kazmi, 2002). The first stage of language acquisition is vocabulary learning. Computer modelling shows that the amount of language input and size of early vocabulary affects the organization of semantic categories across the early lexicon (Borovsky & Elman, 2006). Vocabulary acquisition in sign may thus help the young child with a cochlear implant identify the meaning of distorted acoustic stimuli and bind it to already acquired word meaning and semantic categories. This is an area where research is needed due to the substantial rise in the number of deaf children receiving cochlear implants (see Marschark, Sarchet, Rhoten, & Zupan, this volume; Pisoni, Conway, Kronenberger, Henning, & Anaya, this volume).

Preliminary research suggests that delayed L1 acquisition has significant neural consequences as well. The degree to which the classic language areas of anterior left-hemisphere are activated during sign language processing are negatively correlated to the age at which the L1 was acquired in childhood (Mayberry, Klein, Witcher, & Chen, 2006).

<1> Sign Language Skill and Reading Development

Given that early L1 acquisition facilitates subsequent L2 learning to near-native levels, but late L1 acquisition impedes it, the next question is whether this critical period phenomenon relates to reading development in the deaf population. Some, but not all, theories of reading development posit that the reader must be able to speak the language represented in the written text in order to comprehend it. In these models, recognizing word meaning occurs only after written letters have been mentally transformed into the speech sounds they represent. Such theories predict that readers who are deaf and do not speak well will have difficulty reading. Note that this prediction is at odds with the research findings summarized above where early and robust language acquisition supports other kinds of language acquisition independent of sensory-motor modality. Early spoken language acquisition supports later sign language acquisition and vice versa, including written representations of spoken language. Indeed, this line of research suggests an alternative explanation for low, median literacy levels in the deaf population. If L1 acquisition in early life scaffolds subsequent L2 learning, then it should support L2 reading too, even when the L1 is ASL and the L2 is English. Many deaf individuals have weakly developed language skills in any language for all the reasons described above. The question is how such weakly developed language skill relates to reading achievement.

To answer the question, adult deaf signers were classified as having either strong or weak ASL skills as measured by grammatical judgment and narrative comprehension tasks (Chamberlain & Mayberry, 2008). The two groups of signers were also given standardized reading tests. The results were striking. There was a bimodal distribution of reading achievement between the two groups with no overlap, as Figure 4 shows. Average English reading achievement for the group with strong ASL skill was between the grade 10 to college level depending upon the particular reading test. By contrast, the average reading achievement of the group with weak ASL skill was between grade 3 and 4 (Chamberlain & Mayberry, 2008). Thus, sign language proficiency is a strong predictor of reading achievement among deaf signers, just as language proficiency has been found to be a strong predictor of reading achievement in the hearing population (Dickensen, McCabe, Anastasopoulos, Peisner-Feinberg, & Poe, 2003). Note that the average reading level of the signers with weak ASL skill was identical to the median reading achievement reported for the deaf school-aged population in the USA, namely between grades 3 to 4 (Traxler, 2000). This provides preliminary evidence that delayed L1 acquisition may be a significant factor in the attenuated reading achievement in the deaf population (Chamberlain & Mayberry, 2008).

<1> Implications of the Critical Period for Language

This review of research investigating age of acquisition effects on L1 and L2 outcomes allows us to reconsider the question of whether Victor could have become proficient in French Sign Language in the early 1800s had the idea to use it occurred to Itard. Victor was believed to be about 12 years old when Itard began to teach him French (Frith, 2003). Itard described the boy as having no gestures and no language but eventually, after being socialized, spontaneously using objects to communicate some of his needs (Itard, 1896/1962). Toddlers use objects to communicate with their caretakers and then begin to use their hands and arms to point at objects and people before they speak their first words (Bates, 1979). This means that Victor achieved a pre-linguistic level of communication. The research summarized here completes the picture by suggesting that Victor would not have become proficient in French Sign Language because he had grown into adolescence without having acquired any language. Scholars have suggested that Victor may have been autistic (Lane, 1976). Socially isolated children, including feral children, often develop autistic-like tendencies, but young autistic children can and do acquire sign and spoken language (Frith, 2003).

If the critical period phenomenon for language described here is robust and a key factor in adult sign language proficiency, why are incomplete language acquisition and low sign language proficiency among deaf signers not more often identified and urgently treated by clinical and educational professionals? One reason is a lack of educational or clinical models of normal versus delayed sign language acquisition, such as are in place for spoken language acquisition, including assessment tools and specialists. Educators and clinicians need to be trained to assess language development in sign.

A clinical anecdote illustrates the serious nature of the problem. An adolescent boy who had been educated in total communication in a public school for deaf students was brought to a university clinic for an educational assessment. His ability to read English was limited, as was his ability to comprehend simple sentence structure in ASL or signed English. When asked about his sign language skills, his teachers uniformly replied that they could not understand him and attributed this to his quick signing rate. His parents, who did not sign, were aware of his limited reading ability but assumed him to be a proficient signer, again due to his fast signing rate. In short, neither his teachers nor his family were aware of his aphasic-like symptoms in sign language. MRI scans revealed numerous and widespread brain lesions due to birth complications. The lesions explained the aphasic-like symptoms in his signing, but they were invisible to professionals unprepared to ascertain the difference between normal and aphasic development in sign language.

In conclusion, research investigating whether there is a critical period for language acquisition has used several kinds of variation in the temporal onset of language acquisition over human development: spoken language, sign language, case studies of childhood social/linguistic isolation, and two types of acquisition, L1 and L2. L2 research with sign and spoken language has found a negative correlation between age of acquisition and L2 attainment. Nonetheless, near-native skills are often achieved by older L2 learners depending upon amount of education undertaken in the L2 and the linguistic similarities between the L1 and L2. However, unlike the findings for L2 acquisition, delayed L1 acquisition impedes the ultimate proficiency attained in any language, signed or spoken.

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Figure Legends

Figure 1. Adjusted mean proportion of recall responses that were grammatical as a function of age of acquisition and sign presentation rate (normal and speeded). (Figure 2 from Mayberry, R. & Eichen, E., 1991, *J of Memory and Language, 30*, 486-512, with permission.)

Figure 2. The mean proportion of the subjects' total responses that were grammatically acceptable and semantically parallel to the stimuli for subjects grouped by age of ASL acquisition and first versus second language acquisition (Figure 4 from Mayberry, R., 1993, *J of Speech and Hearing Research, 36*, 1258-1270, with permission.)

Figure 3. Effecs of early experience on later language learning. **a**. American Sign Language (ASL) performance of deaf adults who had experienced no language in early life. Subjects were tested using a task requiring recall of complex ASL sentences. **b**. English performance of deaf adults who had had experienced ASL in infancy, and of hearing adults who had experienced a spoken language other than English in infancy. Subjects were tested using a task requiring judgments of whether complex English sentences given in print were grammatically correct; chance performance is 50%. (Figure 1 from Mayberry, R. I., Lock, E., & Kazmi, H., 2002, *Nature 417*, 38, with permission.)

Figure 4. Mean performance of deaf adults grouped by ASL proficiency level, skilled and less skilled, on the reading comprehension subtest of the Stanford Achievement Test and the Gates-MacGinitie passage and vocabulary

comprehension subtests of the Gates-MacGinitie. (Data from Chamberlain, C., & Mayberry, R. I. 2008, *J of Applied Psycholinguistics, 29*, 367-388.)

Figure 1

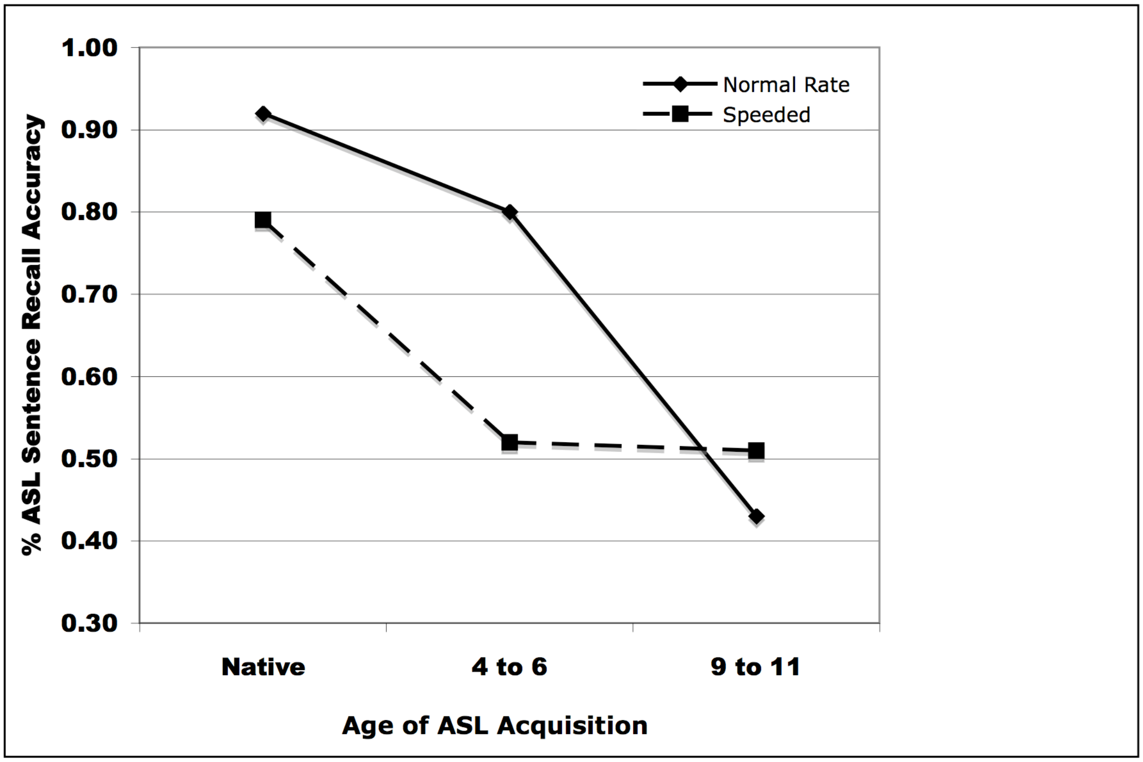

1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
% ASL Sentence Recall Accuracy
Normal Rate
Speeded
Native
4 to 6
9 to 11
Age of ASL Acquisition

Figure 2

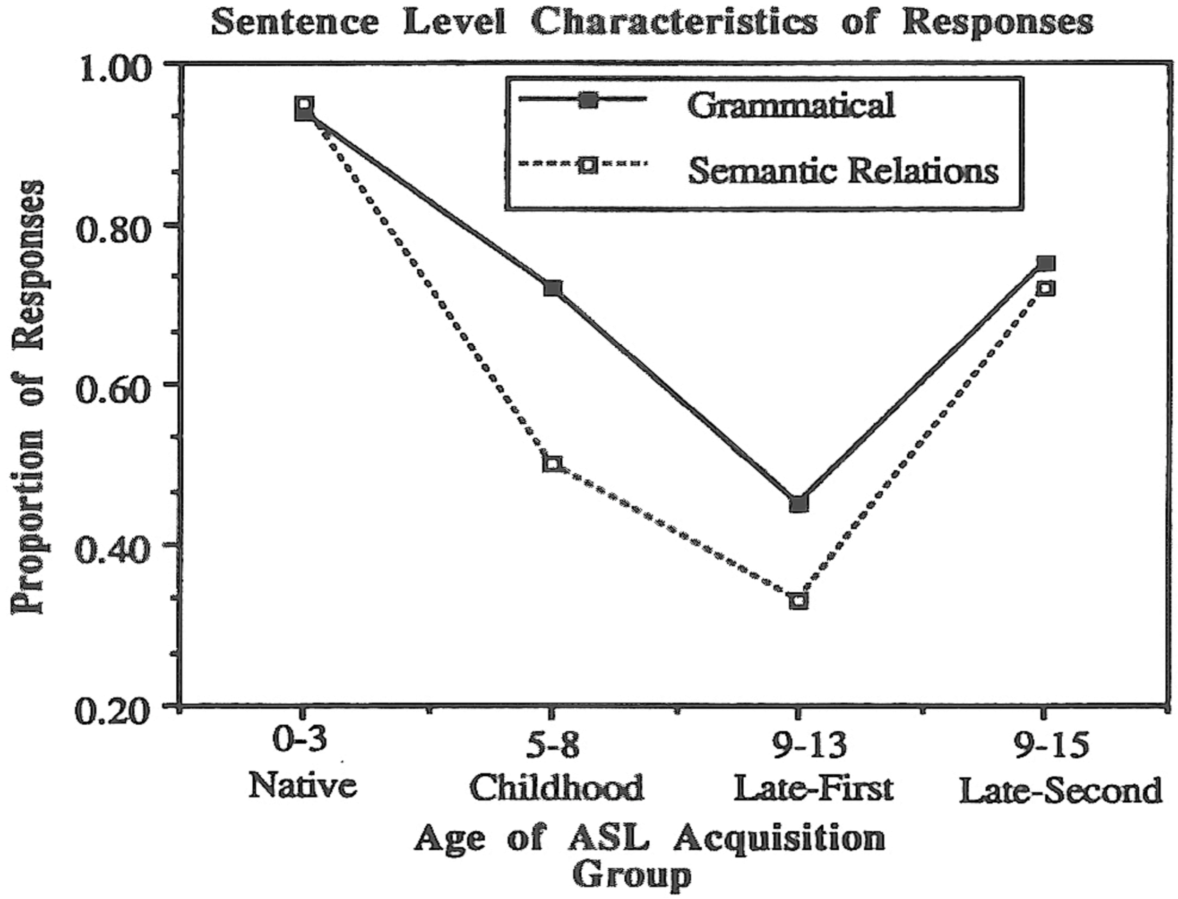

Sentence Level Characteristics of Responses
1.00
0.80
0.60
0.40
0.20
Proportion of Responses
Grammatical
Semantic Relations
0-3
Native
5-8
Childhood
9-13
Late-First
9-15
Late-Second
Age of ASL Acquisition
Group

Figure 3

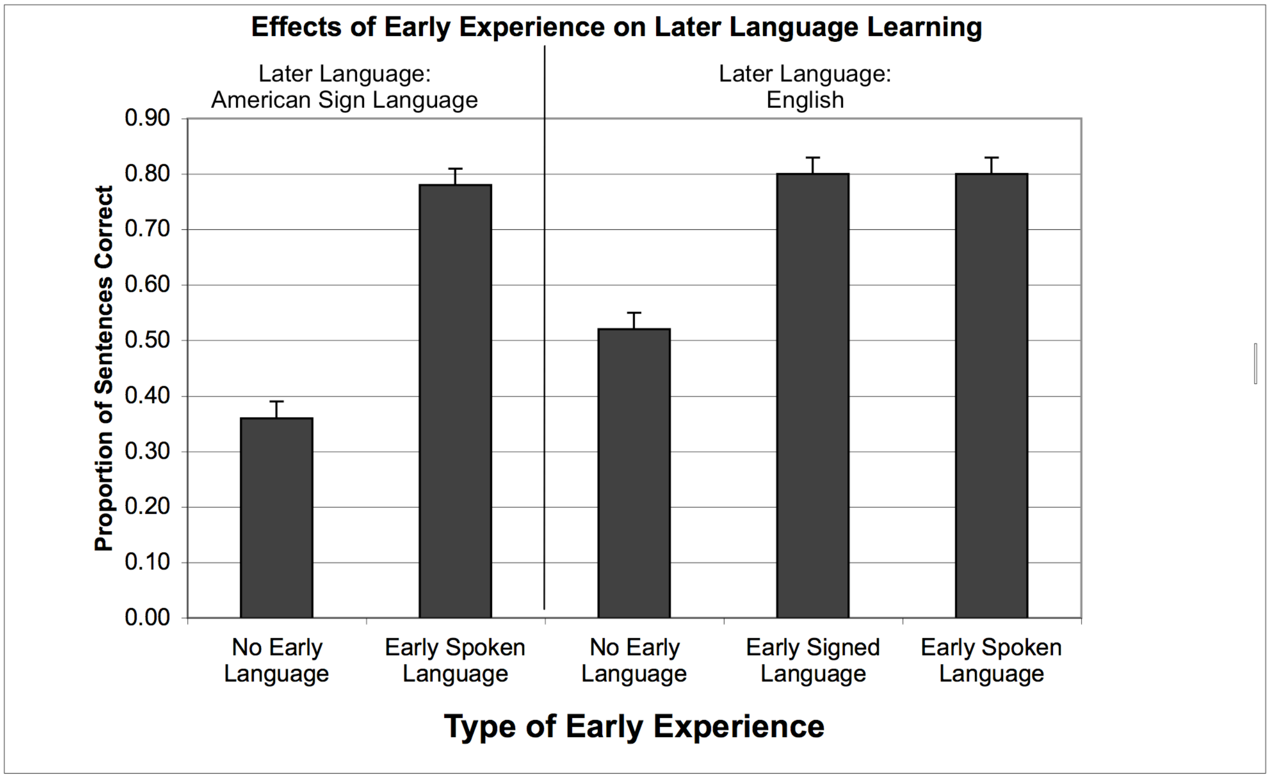
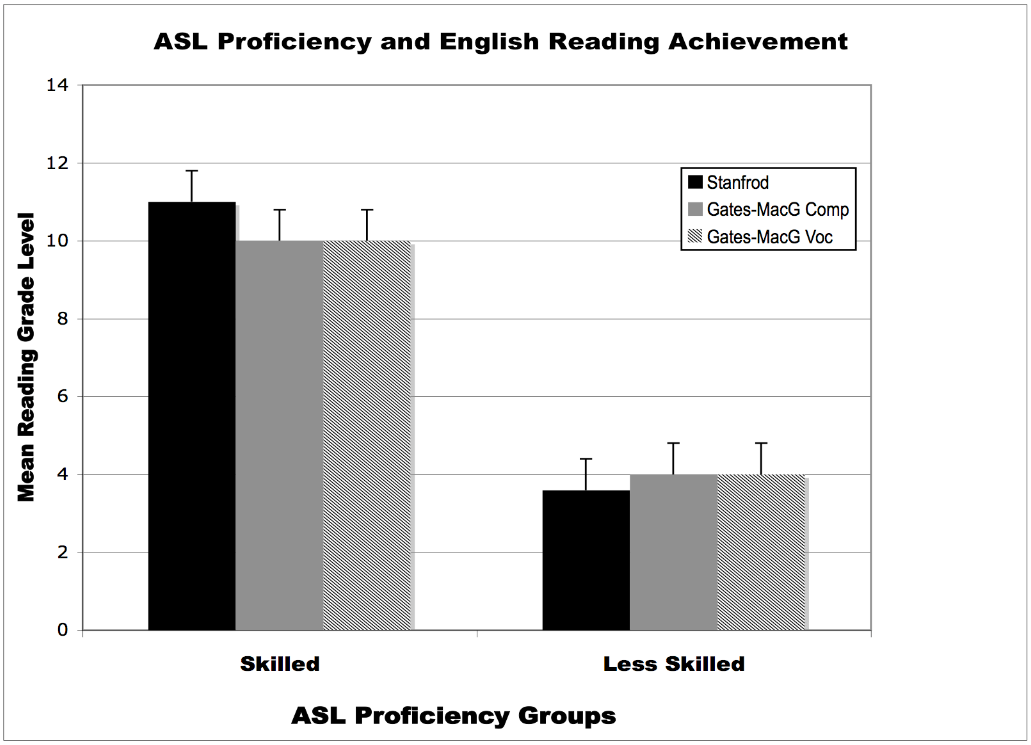

Effects of Early Experience on Later Language Learning
Later Language:
American Sign Language
Later Language:
English
Proportion of Sentences Correct
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
No Early Language
Early Spoken Language
No Early Language
Early Signed Language
Early Spoken Language
Type of Early Experience

Figure 4


ASL Proficiency and English Reading Achievement
Mean Reading Grade Level
0
2
4
6
8
10
12
14
Stanfrod
Gates-MacG Comp
Gates-MacG Voc
Skilled
Less Skilled
ASL Proficiency Groups