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First-Language Acquisition After Childhood Differs From Second-Language Acquisition: The Case of American Sign Language

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This study determined whether the long-range outcome of first-language acquisition, when the learning begins after early childhood, is similar to that of second-language acquisition. Subjects were 36 deaf adults who had contrasting histories of spoken and sign language acquisition. Twenty-seven subjects were born deaf and began to acquire American Sign Language (ASL) as a first language at ages ranging from infancy to late childhood. Nine other subjects were born with normal hearing, which they lost in late childhood; they subsequently acquired ASL as a second language (because they had acquired spoken English as a first language in early childhood). ASL sentence processing was measured by recall of long and complex sentences and short-term memory for signed digits. Subjects who acquired ASL as a second language after childhood outperformed those who acquired it as a first language at exactly the same age. In addition, the performance of the subjects who acquired ASL as a first language declined in association with increasing age of acquisition. Effects were most apparent for sentence processing skills related to lexical identification, grammatical acceptability, and memory for sentence meaning. No effects were found for skills related to fine-motor production and pattern segmentation.

KEY WORDS: acquisition, critical period, deafness, American Sign Language (ASL), second-language acquisition

Early in life children spontaneously acquire language, barring exceptional circumstances. For most people, then, any languages they learn after early childhood are second languages—languages acquired over and above the prior acquisition of a first language. For children who are born severely or profoundly deaf, the timing of first-language acquisition can be radically off-schedule. Unlike normally hearing children, many deaf children have only limited access to language during early childhood in either spoken or signed forms (Mayberry, 1992). This means that the acquisition of sign language by some (but not all) deaf individuals is an example of first-language acquisition begun atypically late.

The unusual circumstances of sign language acquisition compels us to ask whether the long-range outcome of language acquisition begun after childhood is the same regardless of whether it is a case of first- as compared to second-language acquisition. The present study was designed to answer this question. The context and motivation for this study are rooted in previous research in spoken and sign language acquisition and processing, as will shortly become clear.

The notion that children are better at language acquisition than adults is an old idea that underlies much early childhood language education and intervention (e.g., see Penfield, 1959). The "critical period hypothesis for language acquisition" specifically proposes that the outcome of language acquisition is not uniform over the lifespan but

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rather is optimal when it occurs during childhood (Lenneberg, 1967). Although the critical period hypothesis for language acquisition is widely held to be true (Snow, 1987), it has been very difficult to test (Columbo, 1982). One main problem is that the circumstances that prevent language acquisition in early life are often so devastating to the child's development that the data are confounded (Curtiss, 1977; Skuse, 1988). Two normally occurring circumstances of post-childhood language acquisition have been available for study, however. One is second-language acquisition, which has been studied extensively. The other is sign language acquisition, the study of which is more recent.

The long-range outcome of second-language acquisition is predicted in large part by the age at which the learning occurs (Scovel, 1989). Given equal practice and training, individuals who begin to learn a second language during childhood outperform their peers who begin to learn it after childhood on a variety of language measures (Krashen, Long, & Scarcella, 1979). The most salient effects of age of acquisition are on speech production. The ability to pronounce a second language without an accent, or like a native speaker, declines gradually throughout childhood and precipitously afterwards (Flege, 1987; Flege & Fletcher, 1992; Oyama, 1976). Age of acquisition has also been found to affect performance on tasks such as recall of sentence meaning (Oyama, 1978), paraphrase and syntax skills (Coppieters, 1987), and grammatical judgments (Johnson & Newport, 1989, 1991).

The effects of age of acquisition on the long-range outcome of language acquisition are not limited to spoken languages but also appear in sign languages. Newport (1988, 1990) found age of acquisition to predict the accuracy with which highly practiced deaf signers could comprehend and produce the complex morphology of American Sign Language (ASL). Emmorey and Corina (1990) found age of acquisition to predict the speed with which deaf signers could recognize ASL signs (i.e., words). In a series of studies, Mayberry and her colleagues (Mayberry, 1993; Mayberry & Eichen, 1991; Mayberry & Fischer, 1989) have found numerous effects of age of acquisition on sign language processing. The present study is an extension of these findings, so they are summarized here in detail.

In the first study, Mayberry and Fischer (1989) found prior experience with ASL (measured in years of usage) to predict the performance of 55 deaf college students on two kinds of sentence-processing tasks, immediate recall and shadowing (simultaneous reception and production of sentence stimuli). Length of sign language experience affected performance on both processing tasks in a linear fashion: the longer the signer had used sign language (from 2 to 20 years), the more accurately he or she could recall and shadow ASL sentences.

In a second study, Mayberry and Fischer (1989) measured the comprehension performance of 16 deaf college students for narratives given in both ASL and Pidgin Sign English (PSE).[1] Half the subjects were native learners of ASL (that is, deaf adults who were raised in families headed by deaf parents whose primary language was sign, either ASL or PSE). The other half of the subjects were non-native learners of ASL (that is, deaf adults who were raised in families headed by normally hearing parents whose primary language was spoken English and who used little or no sign). The subjects shadowed ASL and PSE narratives and answered comprehension questions afterward. The native learners significantly outperformed the non-native learners on the narrative-shadowing tasks and the comprehension-question tasks (in both ASL and PSE). In addition, performance on the two tasks was significantly and positively correlated. Thus, performance accuracy on processing tasks given in sign language reflect the degree to which the subject comprehended the stimuli.

In both studies, performance accuracy was further related to the linguistic nature of the lexical substitutions the subjects made while performing the various tasks (i.e., sentence recall, sentence shadowing, and narrative shadowing). The most common lexical mistake was an omission. Less frequent, but more revealing, were lexical substitutions wherein the subject saw a particular stimulus lexical item but responded with another one. The lexical substitutions were primarily of two linguistic types, semantic and phonological.

Semantic lexical substitutions maintained the intended meaning of the stimulus sentence and were consistent with the semantic domain and syntactic role of the stimulus lexical item. For example, one stimulus ASL sentence (translated into English) was, "As a child I always played with my *older* brother." Some subjects repeated the stimulus with the following lexical substitution: "As a child I always played with my *younger* brother." This semantic lexical substitution (*younger* vs. *older*) shows that the subject basically understood the stimulus sentence, even though his or her response was not a verbatim rendition. Thus, semantic substitutions were positively correlated with both processing accuracy and comprehension-question performance (Mayberry & Fischer, 1989).

Phonological lexical substitutions showed a different linguistic relationship to the stimulus lexical item, one tied to surface pattern structure but divorced from lexical or sentential meaning. For example, one stimulus ASL sentence (translated into English) was, "I ate too much turkey *and* potato at Thanksgiving dinner." One subject changed the sign "and" to the sign "sleep" producing the response translated as, "I ate too much turkey *sleep* potato." The lexical substitution bears no semantic relationship to either the stimulus sentence or the target lexical item (*sleep* vs. *and*). However, there is a striking phonological relationship between the two signs, as Figure 1 shows. The lexical substitution varies from the target in only one articulatory parameter (place of articulation). The two signs rhyme in ASL. The phonological substitution suggests that the subject did not fully understand the sentence, which was borne out by correlation analyses. Phonological lexical substitutions were negatively correlated with both processing accuracy and comprehension-question performance (Mayberry & Fischer, 1989). The finding showed that these mistakes were not simple misarticulations by subjects who otherwise understood the stimuli.

[1]Pidgin Sign English, or PSE, is a sign dialect that is structurally simpler than ASL. Its word order parallels spoken English and has sparse grammatical morphology (Wilbur, 1987; Woodward, 1973).

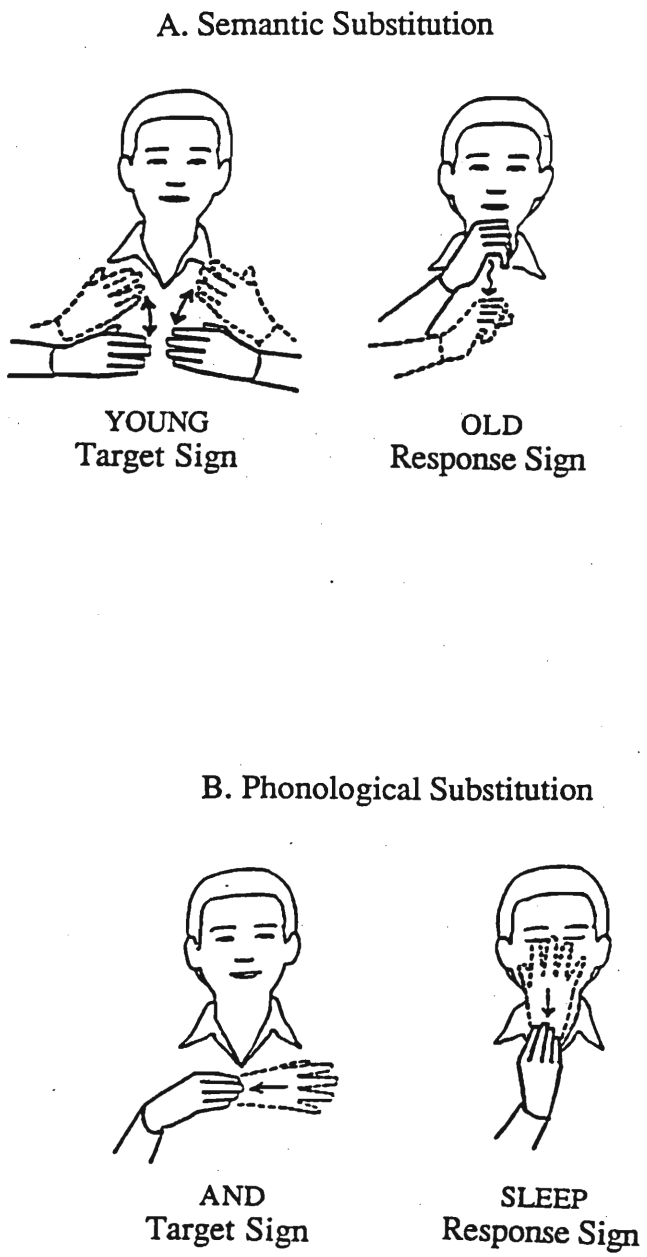

FIGURE 1. Examples of a semantic-lexical substitution (panel A) and a phonological-lexical substitution (panel B). Illustration by Betty Raskin, © R. I. Mayberry.

The results of these two studies demonstrated that as performance on sign language processing tasks improves, comprehension and memory for meaning improves in tandem. We interpreted these results to mean that increases in performance accuracy reflect deeper, or more complete, processing of linguistic structure. Inaccurate performance reflects shallow processing, that is, being intermittently stuck at the surface-phonological level of language structure (Mayberry & Fischer, 1989).

In a third study, Mayberry and Eichen (1991) determined whether the processing effects uncovered in the first two studies were due solely to length of sign language experience or reflected instead age limitations on language acquisition. Subjects were 49 deaf adults who had used ASL for an average of 42 years but began to acquire it at ages ranging from infancy to 13 years. (Most subjects were not college educated.) The processing task was recall of long and complex ASL sentences. A signed digit-span task was also administered to determine whether the subjects' short-term memory spans were comparable.

Age of acquisition had significant effects on several aspects of the subjects' performance. As age of acquisition increased, the grammatical acceptability of the subjects' responses declined. Likewise, as age of acquisition increased, the similarity in meaning between the subjects' responses and the stimulus sentences declined. Age of acquisition was further related to the linguistic nature of the subjects' lexical substitutions. As age of acquisition increased, the proportion of lexical substitutions that were purely phonological increased while the proportion of lexical substitutions that were purely semantic decreased. The results demonstrated that age of acquisition has significant effects on the long-range outcome of sign language acquisition with respect to sentence processing (Mayberry & Eichen, 1991).

Thus, there are clear age limitations on the outcome of sign language acquisition just as there are for spoken language. However, the age of acquisition effects on sign language processing appeared to be greater in magnitude than those reported for spoken language for identical tasks (Mayberry & Eichen, 1991). There is a potentially important difference between the two kinds of data that render the comparison illegitimate. The effects of age on the outcome of spoken language acquisition are for learning a second language. The effects of age on the outcome of sign language acquisition may be for learning a first language (for reasons previously described). This leads us to speculate that the timing of language acquisition may have greater effects on the outcome of first-language acquisition than second-language acquisition, henceforth called the *first-language (L1)-timing hypothesis*.

The L1-timing hypothesis is reasonable given the effects of deafness on language acquisition. Children born with hearing impairment are heterogeneous with respect to the ability to perceive speech. Small amounts of auditory perceptual skill in early childhood can lead to the acquisition of spoken language, ranging from impoverished to complete development (Geers & Moog, 1987). For some adult deaf signers, therefore, ASL may be best characterized as a second language because they acquired a spoken language in early childhood. For other adult deaf signers the scenario may have a more unfortunate outcome. Some adult signers whose hearing losses are of a congenital and profound nature may have acquired only scant spoken language in early childhood prior to acquiring ASL at an older age. For such individuals, ASL may best be characterized as a first language acquired atypically late.

Thus, the unusual circumstances of ASL acquisition allow us to determine whether the age limitations on the outcome of language acquisition are uniform for both first and second languages. The answer to this question has important implications for theories of language acquisition and critical peri-

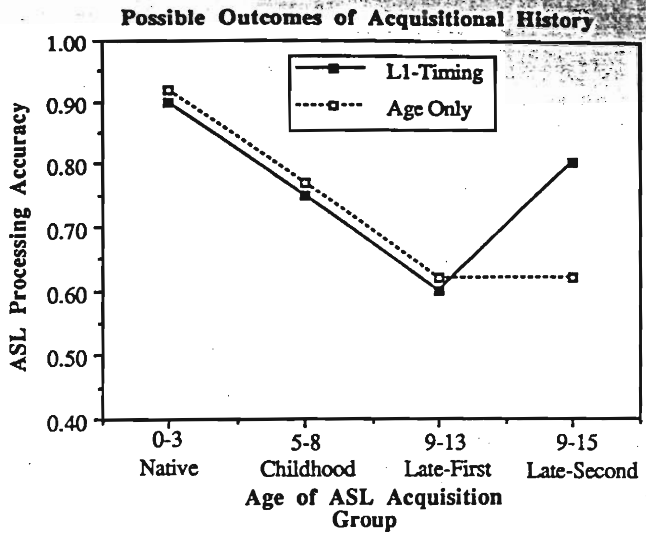

FIGURE 2. The *L1-timing* hypothesis predicts that performance will decline primarily in association with age of first-language acquisition and less so in association with age of second-language acquisition. If age only predicts processing outcome, then performance will decline in association with age of ASL acquisition independent of whether it was a first or second language.

ods. Answering it requires us to examine the processing performance of two distinct kinds of late learners of ASL. (*Late* is defined here as late childhood or older.) One kind of late learner is the deaf signer for whom ASL is a second language learned after childhood—a late-second language—because he or she acquired spoken language in early childhood as a first language, that is, a bilingual. The other kind of late learner is the deaf signer for whom ASL is a first language learned after childhood—a late-first language—because he or she acquired scant spoken language in early childhood prior to acquiring ASL, that is, a monolingual.

The L1-timing hypothesis predicts differential performance on ASL processing tasks for the two types of late learners. Specifically, subjects for whom ASL is a late-first language should perform more poorly than those for whom ASL is a late-second language. (Figure 2 shows the data predicted by the L1-timing hypothesis.) Alternatively, if the age limitations on acquisition are always uniform, independent of whether the acquisition is of a first or second language, the performance of the two groups of late learners should not differ (as also shown in Figure 2). Finally, the most complete picture of the L1-timing hypothesis can be obtained if we also examine the processing performance of deaf signers with more traditional acquisitional histories, that is, acquisition of ASL as a first language begun in infancy or early childhood. Doing so allows us to compare the processing performance of two kinds of late learners of ASL (first- and second-language learners) and two kinds of early learners (those who acquired ASL as a first language beginning in either infancy or early childhood).

Method

The L1-timing hypothesis was tested with a matching design. Late-second language learners of ASL were matched by age (and sex where possible) to three groups of first-language learners of ASL: late-first language learners, native learners, and childhood learners. Because the subjects' acquisitional histories are crucial to the experimental design, they are described here in detail. (Table 1 shows the way in which the four groups were matched.)

Subjects

Thirty-six subjects with contrasting histories of sign language and spoken language acquisition were recruited and tested. To control for practice effects, only subjects who had used ASL continuously for at least 20 years were included. (Most subjects had considerably more experience than this, as Table 1 shows.) Subjects were placed into four experimental groups according to acquisitional history with ASL and spoken English. Three groups of subjects were prelingually (congenitally) deaf and used ASL as their primary means of communication. They acquired ASL as a first language at three different age ranges: 0–3, 5–8, and 9–13. One group of subjects was postlingually deafened and used both ASL and spoken English, ASL when in the Deaf Community and spoken English when in the hearing community.[2]

For the present study, age of acquisition was defined as the initial age at which the subject had regular contact with other deaf individuals who used sign language as a primary means of communication. This information was obtained through in-depth interviews conducted in ASL. Because this event is so salient to deaf individuals (and their families), they

[2]The implication here is not that all postlingually deafened individuals acquire ASL and assimilate into the Deaf Community. Many, possibly a majority, do not. However, testing the L1-timing hypothesis requires postlingually deafened subjects who did so.

TABLE 1. Sample characteristics.

Group	Age of hearing loss *M*	Age of hearing loss Range	Age of ASL acquisition *M*	Age of ASL acquisition Range	Years of ASL experience *M*	Years of ASL experience Range	Chronological age *M*	Chronological age Range	Sex M	Sex F	*n*
Late-second	9	(8–12)	11	(8–15)	50	(29–61)	60	(38–72)	6	3	9
Late-first	Birth	(0)	11	(9–13)	54	(28–61)	60	(40–72)	6	3	9
Childhood	Birth	(0)	7	(5–8)	51	(31–65)	61	(37–71)	5	4	9
Native	Birth	(0)	Birth	(0–3)	51	(43–67)	51	(43–67)	2	7	9

have clear and detailed memories of it, which they readily describe. The validity of subjects' self-reports of when this event happened is demonstrated by recent studies, each showing age of acquisition (defined in this manner) to predict sign performance on a variety of tasks (Emmorey & Corina, 1990; Mayberry, 1993; Mayberry & Eichen, 1991; Mayberry & Fischer, 1989; Newport, 1988, 1990). (The situation is identical to asking English speakers in Canada if and when they associated daily with French speakers, a memorable event.) The four experimental groups had the following characteristics.[3]

Late-second language learners. Nine subjects had normal hearing throughout early childhood and spontaneously acquired spoken English as a first language beginning in infancy. Each subject was thus an unquestionable case of second-language acquisition of ASL. The cause of deafness for all subjects was viral infection (according to self-report), meningitis in seven cases, measles in one case, and encephalitis in another. After becoming deaf, these subjects were subsequently educated in the company of congenitally deaf children whose primary language was sign (ASL or PSE in the majority of cases, but some version of MCE—Manually Coded English—in one case as described below). For the most part, the late-second language subjects acquired sign in an immersion setting. Only 1 subject received didactic instruction in how to sign. Six subjects were educated in residential schools for deaf children after becoming deaf. Three subjects were educated in day schools and classes for deaf children. The length of time the subjects had used ASL ranged from 28 to 67 years with a mean of 50 years. The subjects ranged in age from 37 to 72 years with a mean of 60 years.

Subject matching. Each subject in the late-second language group was matched by chronological age (± 5 years) to 1 subject in each of the following three groups of prelingually deaf signers, late-first language learners, native learners, and childhood learners. Subjects were additionally matched for sex where possible, as shown in Table 1.

Late-first language learners. Nine congenitally deaf subjects began to acquire sign language after early childhood between the ages of 9 and 13. Each subject had normally hearing parents who neither knew nor used any sign language with him or her in childhood or adolescence. Like the late-second language learners, the late-first language learners acquired sign in an immersion setting. They acquired sign when they enrolled in residential schools for deaf children (between the ages of 9 and 13). Prior to attending residential schools, they had attended a variety of schools where sign language was neither used nor known. Each subject reported that he or she was transferred to a residential school because his or her spoken language was deemed insufficient for educational purposes. Although no formal assessment of spoken language skills was given, only 1 subject reported being able to use speech for communication purposes. The length of time these subjects had used ASL ranged from 28 to 61 years with a mean of 54 years. They ranged in age from 40 to 72 years with a mean of 60 years.

Childhood learners. Nine congenitally deaf subjects began to acquire sign between the ages of 5 and 8 years when they enrolled in a school with other deaf children who used sign language. Each subject had normally hearing parents who neither knew nor used any sign with them during childhood or adolescence. These subjects learned to sign in an immersion setting in residential schools for deaf children. The residential school was the first educational experience for 7 subjects; 2 other subjects began their education in day classes for deaf children where sign language was not used; they later were transferred to a residential school (at age 8). Of these 2 subjects, 1 reported having no speech and the other reported having limited speech. The length of time the subjects had used ASL ranged from 31 to 64 years with a mean of 51 years. They ranged in age from 37 to 71 years with a mean of 61 years.

Native learners. Nine congenitally deaf subjects began to acquire ASL in infancy (or very early childhood in two cases). Seven subjects had deaf parents who used sign language with them beginning at birth. Two subjects had normally hearing parents but began to learn sign at 2 and 3 years of age respectively in preschools for deaf children where the language of instruction was MCE (Manually Coded English). One subject had a deaf aunt and uncle who lived nearby and with whom he/she had frequent contact. (The performance of these 2 subjects was indistinguishable from that of the native learners so they were included in the native group.) For ease of terminology, this group is called the *native* learners by which is meant that they acquired ASL from their parents. The native learners ranged in age from 43 to 67 years and had used sign for nearly as long, as Table 1 shows.

Sample characteristics. As previously described and shown in Table 1, the groups' mean length of ASL experience was 51, 51, 54, and 50 years respectively. A one-way analysis of variance showed no significant effects for length of sign language experience [$F(3,32) = 0.24$, n.s.]. This indicates that the groups differed primarily in the age at which they first began to acquire ASL and not in the length of time they had used it.

Mean chronological age of the groups was 51, 61, 60, and 60 years respectively, as previously described. A one-way analysis of variance showed no significant effects for chronological age [$F(3,32) = 1.51$, n.s.]. This indicates that the age-matching across groups was successful. Although the mean age of the groups was older, 50 to 60 years, both younger and older subjects were represented in each group with a range of 37 to 72 years, as Table 1 shows.

Inspection of Table 1 shows the sex distribution of the second-language group to favor males over females with a ratio of .67. In fact, Wolff and Brown (1987) found the prevalence of meningitis-induced hearing loss in the general

[3]Individuals who assimilate into the Deaf Community do not necessarily all have the same degree of ASL proficiency even though they use the language for interpersonal communication. The situation is identical, for example, to an English-speaking community in which many members are highly proficient in English (such as adult native speakers) but others are less proficient (such as children or second-language speakers); despite this variation, communication in English can occur with more proficient speakers adapting to those with less proficiency. Thus, identification with and assimilation into the Deaf Community does not imply uniform proficiency in ASL. The research studies cited here show that ASL users have a wide range of proficiency related to the same factors that produce variability in spoken language. (For descriptions of ASL in the Deaf Community, see Jacobs, 1989, Padden & Humphries, 1988, and Schien, 1989.)

population to be greater for males than females with a ratio of .68. Thus, the male bias of the second-language group reflects population trends. By contrast, the native-learner group favors females, which does not reflect the population to the best of our knowledge. However, it is important to note that the recruitment pool for native learners is limited because they constitute less than 10% of the deaf population (Rawlings & Jensema, 1977).

The hearing levels of all the subjects were not assessed but each subject described him or herself as being profoundly deaf. In pilot research (Mayberry, 1993), the accuracy of the subjects' self-report was ascertained by testing the hearing of 16 subjects. Mean and median hearing threshold was 110 dB (averaged across 500, 1k, 2k Hz, ISO) for the better ear.

Experimental Procedures

ASL processing task. The sign language processing task was immediate recall of long and complex ASL sentences. Sentence recall was used as the dependent measure because previous research had shown it to be highly sensitive to age of acquisition in several ways (as previously described) and because the present study was an extension of these previous results (Mayberry & Eichen, 1991; Mayberry & Fischer, 1989). The psycholinguistic rationale for using immediate recall (or elicited imitation) as a measure of language processing is that recall of complex sentences requires a high degree of language proficiency. The ability to recall language stimuli without comprehension, or echolalia, is not characteristic of normal language processing. Moreover, when the language stimuli are long and complex sentences, as in the present study, subjects make highly consistent mistakes (both within and between subjects) that yield insights into how they may be processing the stimuli, as previous research has demonstrated (Mayberry & Eichen, 1991; Mayberry & Fischer, 1989).

Sentence stimuli. The stimulus sentences were eight ASL sentences used in previous research (Mayberry & Eichen, 1991). The sentences were long (ranging from 12 to 15 base signs with a median of 14 signs) and complex (with conjoined or relativized clauses). These kinds of stimuli were used for two reasons. Long sentences circumvent ceiling effects for native and childhood learners of ASL who can recall sentences of shorter lengths easily and without error. Complex sentences require a good grasp of ASL syntax to understand and recall. Finally, because long sentences exceed short-term memory (STM) span, they must be linguistically processed and cannot simply be recalled in a list fashion. The stimulus sentences are given in the appendix.

The eight target sentences were created and signed by a deaf native signer and videotaped. Because the sentences were given in ASL, which is a separate language from English, the signer used no speech or mouth movements. The target sentences were nested randomly within an experimental list of 30 total sentences presented consecutively.[4] Each stimulus sentence was followed by a 30-sec interval during which the subject responded.

Short-term memory span for signed digits. To compare performance on the sentence recall task with a word recall task (where the words are highly practiced), STM recall for signed digits was also tested. The purpose of this comparison was to determine whether differences in ASL sentence recall among the groups could be attributed to pre-existing differences among them in STM span. Digit span was assessed by administering the digit span subtest of the WAIS (Weschler, 1981). Both forward and backward span were assessed. Stimuli were 14 lists of single digits that were random sequences of the numbers 1 to 9. Lists increased in length from two to nine digits with two trials at each length. The lists were signed by a deaf native signer and videotaped. The signed digits were produced at the rate of one per second with a normal list "intonation" in ASL, that is, with a slight pause between each digit and a return of the hand to resting position after the last digit of each list. Digits were presented in sign with no speech or oral movement.

Testing procedure. Each subject was tested individually by two fluent signers (one native and one non-native). Subjects were told that they would see videotaped sentences given in ASL and instructed to repeat in sign language each stimulus sentence as accurately as possible immediately after watching it. Subjects were warned that the stimulus sentences were long and complex by design in an effort to elicit mistakes. The experimental list was preceded by four practice sentences. The stimuli were presented on a 26-inch color video monitor. A color video camera placed beside the monitor recorded the subjects' sign performance.

For the digit-span task, subjects were instructed to watch the videotaped signer and repeat the signed digits in the separate two conditions, forward and reversed sequence. Testing followed the standard procedure of the WAIS (Weschler, 1981) and was stopped when the subject failed to recall correctly two trials of the same length. Span was determined to be the longest digit list length recalled in sequence without error.

Performance Analyses

Sentence recall. The transcription, coding, and analysis of the subjects' sentence recall consisted of several steps identical to those used in previous research (Mayberry & Eichen, 1991; Mayberry & Fischer, 1989). In the first step, sign performance was first transcribed independently by two coders who were unaware of the subject's acquisitional history. Both were highly practiced with this kind of sign language transcription. Each coder used a transcription code previously developed for this purpose. The code is an elaborated transcription wherein a separate and unique English word represents each ASL lexical stem and bound morpheme of the subject's response.

[4]The data analysis presented here is limited to eight sentences because of the time-consuming nature of sign language transcription. For the present study, 576 videotaped sentences were transcribed into a written code prior to a detailed analysis (i.e., 8 stimulus sentences × 36 subjects × 2 transcribers). Subjects' performance was examined several times to measure and analyze sign rate, accuracy of bound morphology production, and so forth. Thus, the data reported here are based on thousands of examinations of sign language performance.

In the second step, the transcriptions of the two coders were compared stem by stem and bound morpheme by bound morpheme in the presence of, and in reference to, the original videotaped performance. Transcription differences were resolved through discussion and repeated viewing of the performance in question by the two coders. Transcription reliability was quite high, ranging from 94 to 100% agreement across all stems and inflections. High reliability was readily achieved because both coders were highly practiced at the task and the signed utterances were highly predictable (being variations of the same stimuli).

In the third step, mismatches between the stimulus sentence and the subject's response were noted and described linguistically at the lexical, inflectional, phrasal, and sentence levels. A code that categorized the various types of mismatches was then appended to each transcribed response. The code was previously developed for this purpose (Mayberry & Eichen, 1991). In the fourth step, the transcription of each response and its appended error code were entered into a computer program, SALT (Miller & Chapman, 1984). The program was designed to compare utterances from two speakers, and we used this capability to compile the linguistic similarities and differences between the stimulus sentence and the subject's coded response.

As in previous research (Mayberry & Eichen, 1991), the subjects' responses were analyzed from four different perspectives with respect to the stimulus sentences: (a) response length and sign production rate, (b) lexical and inflectional preservation and change, (c) preservation and sequencing of syntactic constituents, (d) grammatical acceptability, and (e) preservation of sentence meaning. STM for signed digits was also analyzed. For purposes of clarity, computational details for each type of analysis are given below in tandem with each set of associated results.

Results

For the statistical analyses, each category of performance analysis was computed and analyzed separately. Sentence recall data were analyzed with one-way analyses of variance (unless otherwise noted). The between-subjects factor was age of ASL acquisition with four levels: native, childhood, late-first, and late-second language learner groups, as described above and shown in Table 1. Digit span data were analyzed with a two-way, repeated-measures analysis of variance. The between-subjects factor was age of acquisition with four levels of group. The within-groups factor was recall sequence with two levels, forward and reverse order.

Response Length and Rate

Response length. If age of acquisition effects are associated with problems in the fine-motor control and coordination required to sequence long sentences (13 to 15 signs in length), or, alternatively, if the effects are due to an inability to parse the lexical items of the stimulus sentences, then the responses of late-first and late-second language learners should be abbreviated in comparison to those of native and childhood learners. To determine whether this was so, the number of root lexical items (base signs) each subject gave in each response was summed and analyzed.

TABLE 2. Response length and sign production rate.

Group	Signs/Response		Seconds/Sign	
	M	SD	*M*	SD
Native	12.19	1.4	0.74	0.10
Childhood	12.36	2.4	0.83	0.11
Late-first	11.67	2.4	0.65	0.24
Late-second	10.22	1.8	0.83	0.30

The groups could not be distinguished on the basis of their response length [$F(3,32) = 2.11$, n.s.]. As Table 2 shows, mean response length was similar across the groups. This result extends previous research by showing that early and late learners of ASL, including late-second language learners, cannot be distinguished solely on the basis of response length. The result further shows that any processing differences among early and late learners are not due to basic problems in the parsing of lexical items in given ASL sentences.

Sign production rate. The subjects' sign production rate was measured by timing the duration of each response in hundredths of a second, beginning with the initiation of lexical movement in the first sign of the response and ending with the release of lexical movement of the final sign (Liddell & Johnson, 1989; Padden & Perlmutter, 1987). Response duration was then divided by the number of signs (base lexical items) in the particular response. This yielded a sign production rate in hundredths of a second per sign for each response, which was then averaged and analyzed.

The groups could not be distinguished on the basis of their sign articulation rate [$F(3,32) = 1.128$, n.s.], as Table 2 shows. This result extends previous research by showing that early and late learners, including late-second language learners, cannot be distinguished from one another with respect to their rate of sign articulation. The result further shows that any processing differences among the groups are not due to the later learners producing signs at a significantly slower rate than the early learners.

Lexical and Inflectional Preservation and Change

Recall of lexical stems (base signs) and bound morphology (sign inflections) was examined with respect to (a) preserved nature of lexical recall, (b) preserved nature of bound-morpheme recall, and (c) linguistic type of lexical substitutions.

Preserved lexical stems. Overall accuracy of lexical recall was measured by scrutinizing the lexical stems given in each response. For this measure the proportion of signs in each response that were identical in phonological form and meaning to that of the stimulus sentence was computed. The proportion for each response was then averaged and analyzed.

Age of acquisition significantly affected the extent to which the lexical stems were recalled in a preserved fashion [$F(3,32) = 3.82$, $p < .05$]. As Table 3 shows, the effect was due to the native learners who recalled significantly more

TABLE 3. Proportion of stimulus lexical stems preserved in each response.

Group	*M*	SD
Native	0.72	0.05
Childhood	0.56	0.13
Late-first	0.56	0.09
Late-second	0.56	0.18

lexical stems in a preserved fashion than the other three groups, childhood, late-first, and late-second language learners (p <.05 for each comparison, Student-Newman-Keuls). The finding extends previous research by showing that native learners display greater skill at preserved lexical recall than signers who acquired ASL at later ages, regardless of whether they are first- or second-language learners.

Preserved bound morphemes. To measure the preserved nature of bound morphemes (both inflectional and derivational) in sentence recall, the number of bound morphemes the subject recalled in a preserved fashion (i.e., identical phonological form and morphosyntactic function to that of the stimulus) was computed, independent of whether the base stem was recalled in a preserved fashion. Bound morpheme recall was treated as a single response category and summed over all responses. This computation was necessary because there was an unequal number of several different kinds of ASL bound morphemes represented in the ASL stimulus sentences (i.e., classifier, adverbial, and aspectual inflections).

Mean recall of bound morphemes was unaffected by age of acquisition, as Table 4 shows. This result parallels that of previous research in which native learners tended to recall more preserved bound morphemes than signers who acquired ASL at older ages, but the trend did not reach significance because not all subjects showed the effect.

Linguistic level of lexical substitutions. The lexical stems the subjects mistakenly substituted for stimulus lexical items were examined in detail by scrutinizing the linguistic relationships between these substitutions and the stimulus lexical items they replaced. Most lexical misrecalls were of two constrastive types, phonological and semantic, as described in detail above and shown in Figure 1.

For the present study, the proportion of total lexical substitutions (across all responses) the subject made that were of the two types, semantic or phonological, was computed and analyzed. First, every lexical substitution produced by the subject was summed across all eight responses. There were five total categories of lexical substitution: (a) semantic, (b) phonological, (c) unexplainable/ambiguous, (d) unintelligible, and (e) both phonological and semantic. To derive proportion scores, the sum of lexical substitutions that were

TABLE 4. Proportion of stimulus-bound morphemes preserved across all responses.

Group	*M*	SD
Native	0.42	0.13
Childhood	0.26	0.15
Late-first	0.26	0.15
Late-second	0.34	0.22

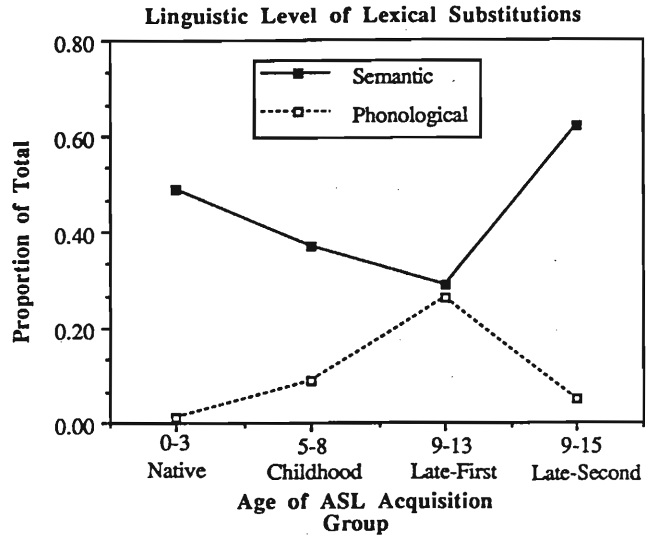

FIGURE 3. The mean proportion of phonological and semantic-lexical substitutions produced by the subjects during sentence recall as a function of age of ASL acquisition and first versus second language acquisition (for total substitutions produced by each subject summed across all responses).

solely phonological in nature was divided by the total number of substitutions. Likewise, the sum of lexical substitutions that were solely semantic in nature was divided by the total number of substitutions. Using proportion scores ensured the comparability of the comparison across subjects because early learners made fewer substitutions overall than did late learners as indicated by the results shown in Table 3. Phonological and semantic lexical substitutions were analyzed with one-way analyses of variance by ranks.

As previous research predicted and Figure 3 shows, the tendency to produce lexical substitutions of either a semantic or phonological nature was associated with age of acquisition. Across the three groups of first-language groups (native, childhood, and late-first language learners), the proportion of total lexical substitutions that were semantic in nature declined as age of acquisition increased (χ^2 = 13.26, df = 3, p <.01, Kruskal-Wallis). At the same time, the proportion that were phonological in nature increased across the three groups (χ^2 8.84, df = 3, p <.05). However, the relationship between age of acquisition and linguistic-error pattern did not encompass the late-second language learners in the following manner.

Even though the late-second and late-first language learners acquired ASL at the same late ages, the linguistic pattern of their lexical substitutions differed, as Figure 3 shows. The late-second language learners showed a pattern of lexical substitution that was more akin to that of the native learners in terms of predominant linguistic-error type. They made mostly semantic lexical substitutions and few phonological ones (late-second language learners: χ^2 = 135.53, p <.01; native learners: χ^2 = 135.53, p <.001, median-sign test with Yates correction). The childhood learners also tended to make more semantic than phonological lexical substitutions but to a lesser degree than native and late-second language learners (χ^2 = 6.06, p <.05, median-sign test with Yates correction). By contrast, the pattern of lexical substitutions

TABLE 5. Proportion of stimulus grammatical constituents preserved in each response.

Group	*M*	SD
Native	0.71	0.04
Childhood	0.53	0.16
Late-first	0.47	0.09
Late-second	0.69	0.14

produced by the late-first language learners was unique: They produced nearly equal proportions of phonological substitutions and semantic ones ($\chi^2 = 0.669$, $p = 0.41$, median-sign test with Yates correction). These findings support the L1-timing hypothesis. The age at which a first language is acquired has lasting effects on the way in which language is processed in later adulthood.

Recall of Syntactic Constituents

The degree to which the constituent structure of the subjects' responses mirrored that of the stimulus sentences (i.e., subject or object-noun phrases, verb phrase, adjective and adverbial phrases, and so forth) was analyzed. The syntactic constituents of each response were first categorized according to type, then matched by sequence to that of the stimulus. This procedure yielded the proportion of syntactic constituents each subject gave in each response that were of both the same type and the same order as that of the stimulus.

Age of acquisition significantly affected constituent recall [$F(3,32) = 13.77$, $p < .001$], as Table 5 shows. The effect was primarily due to the native and late-second language learners whose responses mirrored the constituent structure and sequencing of the stimulus sentences to a greater extent than those of both the childhood and late-first language learner group [$p < .05$ for each comparison, Student Newman-Keuls]. This result is predicted by the L1-timing hypothesis.

Sentence-Level Performance

Grammatical responses. The grammatical acceptability of the subjects' responses was assessed without regard to particular semantic or syntactic content. Subjects' responses were judged by two native ASL learners (unaware of the subject's acquisitional history) to be either grammatical or ungrammatical in either ASL or PSE. The proportion of the subject's total responses that was deemed grammatical by both judges was then analyzed.

Age of acquisition significantly affected the extent to which the subjects gave grammatically acceptable responses [$F(3,32) = 4.87$, $p < .01$], as Figure 4 shows. The effect was primarily due to the late-first language learners who gave significantly fewer grammatically acceptable responses than the native, childhood, and late-second language learners ($p < .05$ for each comparison, Student Newman-Keuls). Although there was a clear trend for the native learners to give more grammatical responses than the other groups, it did not reach significance.

Preserved meaning of responses. The extent to which the subjects' responses preserved the meaning of the stimulus sentences in their response was examined, independent of the syntactic structure or grammatical acceptability of the response. The rationale for this analysis is that successful language processing typically entails memory for sentence meaning independent of its original structural form for both speech and sign (Hanson & Bellugi, 1982; Sachs, 1967). A response was judged to have preserved the intended meaning of the stimulus sentence if it conveyed the semantic gist of the stimulus in terms of semantic relations, that is, same actors, relations among actors, actions, and relations among actors and actions. Two judges (unaware of the acquisitional history of the subject) independently compared each response to each stimulus sentence and decided whether the semantic relations of the stimulus were the same as those given in the response. The responses that both judges agreed upon were then summed and analyzed.

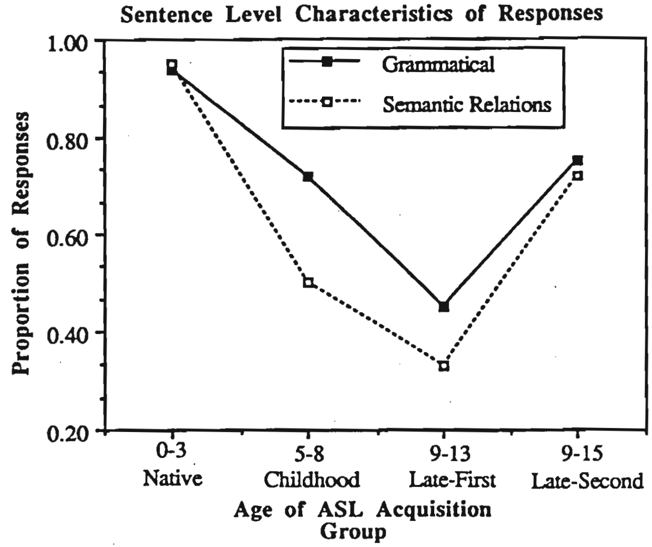

FIGURE 4. The mean proportion of the subjects' total responses that were grammatically acceptable and semantically parallel to the stimuli for subjects grouped by age of ASL acquisition and first versus second language acquisition.

Age of acquisition significantly affected the subjects' ability to maintain the general meaning of the stimulus sentences [$F(3,32) = 14.52$, $p < .001$]. As Figure 4 shows, preservation of stimulus sentence meaning in the subjects' responses declined with increasing age of acquisition across the three groups of first-language learners. The native learners significantly outperformed the childhood and late-first language learner groups; the childhood learners, in turn, significantly outperformed the late-first language learners [$p < .05$ for each comparison, Student Newman-Keuls]. The late-second language learners performed less well than the native learners but also outperformed the childhood and late-first language learner groups [$p < .05$ for each comparison, Student Newman-Keuls]. This result is predicted by the L1-timing hypothesis.

Digit Span

STM span for signed digits in both forward and reverse order was computed and analyzed. Subjects recalled on average one more digit in the forward than reverse sequence [$F(3,32) = 28.13$, $p < .001$]. Age of acquisition also affected digit span [$F(3,32) = 4.42$, $p < .05$]. The mean span of the groups was 4.7, 4.2, 4.3, and 5.2 digits respectively. The digit span of the late-second language learners was significantly larger than that of the childhood and late-first language learners. However, the digit spans of the late-second language learners did not differ from those of the native learners ($p < .05$ for each comparison, Student Newman-Keuls).

In summary, the results of this study show that ASL proficiency as measured by recall of long and complex sentences is predicted by the timing of first-language acquisition. Multiple aspects of ASL sentence processing performance were related to the timing of first-language acquisition as evidenced by the fact that the late-second language learners significantly outperformed the late-first language learners even though both groups began to acquire ASL at the same late ages. These effects were (a) preservation of semantic roles and relations at the sentence level, (b) grammatical acceptability of responses, (c) preservation of constituent structure and sequencing, (d) preservation of the domain of lexical meaning independent of surface phonological form, and (e) STM span for highly practiced signs (digits). One aspect of sentence recall was related solely to native acquisition of ASL, namely recall of lexical items in a fully preserved fashion (i.e., both surface phonological form and meaning). Finally, measures of response length and sign production rate showed no effects.

Discussion

The L1-timing hypothesis predicts that the age at which a first language is acquired has greater effects on language processing skills in adulthood than does the age at which a second language is acquired. In terms of the present study, the hypothesis predicted that adult deaf signers who acquired ASL at the same late ages would show unequal skill at ASL processing as a function of whether they acquired a language on schedule in early childhood. The results of the present study support the hypothesis. Adult deaf signers who unquestionably acquired ASL as a second language after early childhood outperformed their matched peers (for chronological age, length of ASL experience, and sex) who acquired ASL as a first language at the same late ages on several measures of language processing. The acquisition of language early in life is apparently necessary for language processing to be carried out efficiently in later adulthood.

The unique feature of the present results is that they show the effects to be robust and impervious to the linguistic details of the language acquired early. In other words, the timing of first language acquisition in development affects language processing skills in later adulthood independent of the specific type of language acquired early. Thus, adult deaf signers who acquired a first language on schedule in early childhood outperformed those who did not, even though they were processing sentences in a language other than the one they originally acquired at an early age, namely, a second language they learned at an older age.

What is the nature of the advantage conferred on adult language processing by acquiring language early in life? The present results in conjunction with previous research provide some hints. The easiest way to organize these clues is to eliminate those processing skills that showed no effects and then focus on those that did.

Two measures were unaffected by age of acquisition—the rate at which the subjects signed and the total number of signs/words they gave in each response. This means that the effects associated with the timing of first-language acquisition are not due to problems in fine-motor movement and coordination or in parsing surface pattern structure. The finding extends previous research by showing that this is true regardless of whether the language being processed is a first or second one (Mayberry & Eichen, 1991; Mayberry & Fischer, 1989).

Several measures were significantly affected by age of acquisition. For example, the late-first language learners were particularly disadvantaged on the measure of grammatical acceptability in comparison to the other groups, including the late-second language learners. This finding is in keeping with previous research showing that the ability to make grammatical acceptability judgments is associated with age of second-language acquisition in speech (Coppieters, 1987; Johnson & Newport, 1989, 1991). In the present study, the performance of the late-second language learners on the grammatical acceptability measure was not significantly different from that of the native and childhood learners. One reason for this may be that the grammaticality measure of the present study was quite broad. Responses were judged grammatical without reference to the stimulus or sign dialect. Nevertheless, the finding suggests that syntactic skill, by itself, may not be the primary source of the advantage conferred on language processing by acquiring language early in life.

The timing of first-language acquisition showed significant effects on several measures of language processing skill that are related to memory skill: sequencing of constituent structure in the same order as that of the stimulus, preservation of the general semantic gist of words and sentences in relation to the stimulus, and STM span for signed digits. The late-second language learners significantly outperformed the late-first language learners on all these measures. This suggests that the advantages conferred by acquiring a language in early life may turn on memory skill, but how?

Of all the groups, the native learners showed the best performance for preserved lexical recall. Native learners were better able than the other groups to recall the precise phonological structure and meaning of the lexical stimuli. The three groups who acquired ASL at later ages, the childhood, late-first, and late-second language learners, all showed diminished skill at preserved lexical recall in comparison to the natives. This suggests that individuals who acquire a given language after early childhood have processing skills for that language that are limited in some way. Thus, one important difference between the late-first and late-second language learners may lie in whether and how they circumvent limitations in language processing.

The late-first language learners made unique lexical substitutions that were related solely to the surface phonological structure of the signs they were processing. This kind of lexical substitution was unrelated to stimulus meaning at the lexical or sentence levels. Production of such errors suggests that the late-first language learner is intermittently stuck at the surface level of language structure. Other research suggests that this may indeed be the case (Emmorey & Corina, 1990; Mayberry & Fischer, 1989). By contrast, the late-second language learners made few phonologically based lexical substitutions but mostly semantic ones. This suggests that the late-second language learner, but not the late-first language learner, can rectify intermittent failures in lexical identification and sentence comprehension.

Why would the late-second language learner be able to circumvent processing failures and the late-first language learner not? The simplest explanation is that the late-second language learner may use his or her first language (acquired on schedule in early life) to circumvent the processing limitations posed by acquiring a language at a late age in at least two ways. First, the late-second language learner has acquired general knowledge about how language is structured in addition to a detailed and extensive lexicon. Together these knowledge sources may help predict sentence meaning in the face of uncertainty (in the second language). That is, the late-second language learner may be aware that he or she has "missed" something in the second language and thus actively seek to fill the "gap" by guessing. This guessing, in turn, may be guided by linguistic knowledge of both a grammatical and semantic nature derived from the first language.

In addition, the late-second language learner may use a phonological "recoding" strategy as a memory aid. Recoding signs/words from a second language into the first language (acquired early in life) would capitalize on a well-developed (native) phonological system as a means of holding meaning (already processed from the second language) in working memory. This strategy may be especially important to language processing when the language was learned at a late age because late learners are slower at recognizing lexical items than are native learners (Emmorey & Corina, 1990). Increased time to identify signs/words means that late learners must hold information in working memory longer than native learners in order to compute sentence structure and derive sentence meaning.

The late-first language learner, unlike the late-second language learner, has no auxiliary linguistic system (acquired in early childhood) with which to circumvent delays and lapses in lexical and clausal identification. If this explanation is correct, the late-first language learner has at least four major difficulties in language processing but the late-second language learner has only one. The late-first language learner has difficulty with lexical identification, uncertain grammatical expectations, an under-developed lexicon, and an overburdened working memory. The late-second language learner has difficulty with lexical identification too. But unlike the late-first language learner, the late-second language learner can partially remedy difficulty with lexical identification via grammatical expectations (from the native language). The late-second language learner expects, as a general principal, sentences to decompose into clauses and phrases, subjects to take verbs, some verbs to take objects, and so forth. Moreover, the late-second language learner can alleviate the increased load on working memory by recoding into the first language (via the phonological system of the native language). Thus, the late-second language learner can translate the second language into the first one, if necessary, and thereby access a rich and detailed semantic system.

The present results are in concert with previous research showing that the effects of age of acquisition on language processing increase as memory demands increase (Mayberry & Fischer, 1989). The present results extend our understanding of the phenomenon by showing that it is compounded by failure to acquire a language early in life. Clearly, more research is needed to uncover the precise nature and locus of L1-timing effects reported here.

Finally, the question arises as to whether the L1-timing effects are experimental artifacts. That is, do the findings reported here characterize the subjects' sign communication outside the laboratory? Two sources of evidence suggest that the effects reported here are valid. First, in a previous study, Mayberry and Eichen (1991) asked subjects (adult deaf signers who varied in age of ASL acquisition) to rate their everyday sign comprehension skill on a 5-point scale ranging from "always understand" to "never understand." The subjects' self-assessment of their sign skills was positively correlated to performance on the ASL processing task (identical to the task of the present study). Of all the processing measures, preservation of stimulus sentence meaning was most closely associated with the subjects' self-assessment of sign skill. The probability is high that the same relation would hold for the present study if the measure had been taken.

The second line of evidence comes from within the Deaf Community. In describing the Deaf Community, Jacobs (1989) constructs a typology of adult deaf signers. He categorizes signers in terms of language skill, which he believes to be the product of hearing loss, educational experience, and family environment. Jacobs' categories parallel the experimental groups of the present study. For example, his *adventitiously deaf adults* and *prelingually deaf adults from deaf families* correspond exactly to the late-second language and native learner groups of the present study. He describes these two types of signers as having excellent language skill because ". . . they had early communication," (Jacobs, 1989, p. 73). His third category is *prelingually deaf adults from hearing families* which corresponds to the childhood learners of the present study. He describes these signers as having less proficiency than the first two types of signers because "They come from hearing families who have had trouble communicating with them when they were little" (Jacobs, 1989, p. 74). His fourth category, *low-verbal deaf adults,* is not fully comparable with the late-first language learners of the present study. The language he ascribes to the fourth type of signer is worse than that of the fourth group of the present study, namely the late-first language learners. He describes production of signs mixed with gesture and pantomime for *low-verbal deaf adults.* However, he also observes that this type of signer has difficulty with ". . . long or involved sentences" (Jacobs, 1989, p. 74), which was true for the late-first language learners of the present study.

The correspondence between Jacobs' typology of signers and the experimental groups of the present study is striking because each grouping was derived independently by different means. Jacobs' typology was based on sociological observation from within the Deaf Community. The grouping of the present study was based on a series of psycholinguistic studies designed to determine whether the age at which sign language is first acquired has long-lasting effects on sign language processing in later adulthood.

In conclusion, the L1-timing hypothesis accounts for significant variation in ASL proficiency among adult deaf signers. The hypothesis may not have been previously proposed because first languages are rarely acquired after childhood in the normally hearing population. The results of the present study suggest that the phenomenon may be a common one that has long-lasting repercussions on the language comprehension skills of individuals who are born profoundly deaf.

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Appendix

ASL Stimulus Sentences (Given in English Translation)

1. The approaching man who is deaf doesn't know American sign because he lives in England.
2. On Sundays, men are much more likely than women to just sit and watch televised sports all day long.
3. My boyfriend's best friend, who is standing over there, really wants to date my sister, but she won't have anything to do with him.
4. That man's oldest daughter just had a baby boy, so he's a very proud grandfather right now.
5. When I was younger, I was very active in various Deaf Clubs that are located all over the city, but I haven't any time any more.
6. Yesterday, I was surprised to bump into my two best childhood friends with whom I grew up and whom I hadn't seen for 10 years.
7. Once when I had a terrible cold that wouldn't go away, the doctor gave me a new medicine that cured my nasal drip instantaneously.
8. In the past, very few people rode bikes to work, but since gas has gotten so expensive, scads of people ride bikes to work now.