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Grammatical Processing in American Sign Language: Effects of Age of Acquisition and Syntactic Complexity

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Abstract

This study investigated the effects of age of acquisition and syntactic complexity on the outcome of American Sign Language (ASL) acquisition. All the participants were born deaf, had used ASL as a primary language for a minimum of 12 years, and began to acquire it at three different ages. The experimental task was grammatical judgement. In this task, the signer saw dynamic ASL sentences on a computer screen and decided whether they were grammatical or not. Response accuracy and latency were measured. The stimuli were 168 examples of six ASL syntactic structures ranging from simple to complex. Results showed that as age of acquisition increased, response accuracy decreased and response latency increased. Also, as ASL syntactic complexity increased, accuracy decreased and latency generally increased, independent of age of acquisition. The results provide additional evidence for the critical period for language acquisition and psycholinguistic evidence for previous linguistic descriptions of ASL syntax.

Résumé

La présente étude vise à vérifier, par le biais de l'acquisition de la Langue des Signes Américaine (ASL), les effets de l'âge auquel l'apprentissage est effectué et la complexité syntaxique qui en résulte. Tous les participants sont sourds de naissance, ont utilisé l'ASL comme langue primaire pour un minimum de 12 ans, et ont commencé à l'acquérir à trois niveaux d'âge différents. La tâche expérimentale consiste à vérifier le jugement grammatical des signeurs. Cette tâche consiste à présenter des phrases sur un écran d'ordinateur aux signeurs, ces derniers doivent ensuite décider si les phrases sont grammaticales ou non. L'exactitude et le temps de latence des réponses sont mesurés. Les stimuli consistent en 168 exemples de six structures syntaxiques différentes d'ASL, allant du simple au complexe. Les résultats indiquent que lorsque l'âge d'acquisition d'ASL augmente, l'exactitude des réponses décroît, tandis que leur temps de latence augmente. Également, lorsque la complexité syntaxique d'ASL augmente, l'exactitude des réponses diminue et le temps de latence est généralement supérieure et ce, indépendamment de l'âge d'acquisition. Les résultats fournissent des argumentations additionnelles en ce qui à trait à la période critique de l'acquisition du langage, et certaines évidences psycholinguistiques des recherches précédentes sur la description syntaxique d'ASL sont confirmées.

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I dedicate this thesis to the Deaf community around the world and to my Deaf family who have taught me the value of the Deaf culture and sign language. And my life partner who contstanly supports and loves me in my attempt to succeed in this research.

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Grammatical Processing in American Sign Language: Effects of Age of Acquisition and Syntactic Complexity

This thesis investigates whether syntax acquisition in sign language is constrained by age of acquisition. In other words, is there a critical period for learning a language, especially for learning syntactic structure, that is due to age of acquisition? This is a crucial research question regarding the outcome of language acquisition. The deaf population in general has delayed language acquisition due to various factors such as the inability of hearing parents to communicate with their deaf children, an absence of language input from the environment, and so forth. Understanding and documenting the effects of delayed language acquisition may help prevent the disastrous language outcomes many deaf people experience in their ability to communicate and learn.

The general outline of this thesis is as follows. First, the definition of a critical period for language acquisition in general is discussed. Second, one case of social isolation is summarized. Third, research on critical period effects on second language acquisition in general is summarized. Fourth, research on critical period effects on signed language acquisition is summarized. This is followed by a description of American Sign Language (ASL) as it relates to the present study. Following this background, the research questions, methods, results and a general discussion are presented.

Critical Period Concept

Many researchers have suggested that language acquisition is most successful if it is learned at the "right" time, or inside a maturational schedule. Many theorists would agree that the optimal time for language acquisition is early in life (childhood); if language is acquired after childhood, then language performance is more likely to be unsuccessful.

The critical period concept for language emerged in the late 1960's and was first proposed by Lenneberg (1967). Lenneberg was the first researcher to investigate the biological basis of language by investigating brain maturation and language function. Lenneberg (1967) proposed that childhood (before puberty) is the time period during which language acquisition must occur if it is to be acquired successfully. In particular, he

compared aphasia in children and adults and observed that language recovery was better for children than adults. He suggested that was because the brain was malleable before puberty with regard to hemispheric brain specialization and thus was better able to recover language. The main hypothesis made by Lenneberg (1967) was that language acquisition is constrained by a developmental schedule, later to be termed the 'critical period' or 'sensitive period' for language acquisition. His was one of the first scientific investigations of how important age of acquisition is for language throughout life. Following this work, research on the critical period for language acquisition emerged rapidly. There were investigations which observed this phenomenon in animals and perceptual systems, as studied by ethnologists, biologists, and psychologists (Columbo, 1982). For example, research on development of the visual-cortex has found that there is a critical period for neurological development of certain visual functions as demonstrated by visually deprived animals (van Hof-van Duin, 1976a, 1976b). These neurological systems organize over time, guided by visual stimuli from the environment, which interacts with brain development (Bornstein, 1987).

Many researchers since Lenneberg (1967) have attempted to investigate the critical period for language (Curtiss, 1977; Krashen, 1973, 1975a, 1975b; Snow & Hoefnagle-Hohle, 1978). Unfortunately, none of these studies has successfully controlled all the important factors necessary to investigate the question as outlined below. Further research is necessary to better understand the effects of the critical period on language development.

As Columbo (1982) has pointed out, a critical period definition is based on several factors, namely that (a) there is an onset and terminus of the period, (b) there is an exact specification of the critical period stimulus to which the organism is most sensitive, and (c) there is an exact specification of the critical system that will be affected later on by exposure to, or deprivation of, the stimulus during the period. Columbo (1982) also pointed out that the plasticity of the organism, which undoubtedly continues throughout ontogeny, should not be confused with the plasticity of one specific biobehavioral system, which may come to

an end early in life. The biobehavioral system under study here is language. The hypothesized onset of the critical period for language is birth and the offset is puberty, according to Lenneberg (1967).

The studies on language acquisition discussed below give us an opportunity to verify the veracity of the critical period for language. In general, these studies show us how significant critical period effects are on the outcome of language acquisition.

Critical Period Effects on Second Language Acquisition.

Much research has been done on critical period effects on second language acquisition. In terms of age of acquisition effects, second language studies are relatively common since most people learn second languages throughout their lives. The studies summarized below on second language, critical period research further our understanding of how important age of acquisition is for second language performance. The main focus here is on studies of critical period effects on syntactic performance. Measuring syntactic performance is complex because this level of linguistic structure impacts on other language levels, such as phonology, semantics, etc. Nonetheless, several researchers have examined oral and written, second language long-term achievement of syntactic abilities (Johnson 1992; Johnson & Newport, 1989; Johnson & Newport, 1991; Johnson, Schenkman, Newport, & Medin, 1996; Oyama, 1978; Patkowski, 1980).

For example, Oyama (1978) tested 60 Italian immigrants for their understanding of English syntax, phonology and intonation through sentences masked with noise. Subjects shadowed the sentences, that is, repeated them while simultaneously listening, and answered questions. All subjects had a minimum of five years of English experience. She divided the subjects into three groups of second language acquisition; the first group acquired English from 6 to 10 years of age, the second group acquired English from 11 to 15 years of age, and the third group acquired it from 16 to 20 years of age. The group who acquired English from 6 to 10 years of age received comprehension scores similar to the native learners, wheras the group who acquired English from 16 to 20 years of age had

significantly poorer comprehension performance. The results showed that age of second language acquisition had an effect on English comprehension performance such that the younger learners had better comprehension scores.

Patkowski (1980) investigated the second language acquisition of English immigrants in a similar manner to Oyama (1978). All subjects were university professors or university students who had more than five years of English exposure and their first languages varied. There were 67 subjects divided into two groups: pre and post puberty learners. Patkowski (1980) used an audiotape-recorded interview based on the Foreign Service Institute Language Proficiency Test. He transcribed the interview and judged the grammatical structures used, judging how native-like they were based on a five-point scale. The results showed a strong effect of age of acquisition. Individuals who acquired English as a second language at younger ages performed better than those who acquired it at later ages.

Johnson and Newport (1989) conducted a study of second language morphology and syntax attainment, investigating the long-term effects of age on second language acquisition. They tested 46 subjects whose first language was either Chinese or Korean; in all cases their second language was English. All subjects had at least five years of English exposure and were either students or faculty at a university. The subjects were separated in half into an early group (who learned English before age 15 years of age) and a late group (who learned English after age 15 years of age). The task was written judgement of sentences with morphological and syntactic errors (grammatical vs. ungrammatical). Judgement accuracy was measured. The results showed that the early learners had a higher overall score (i.e. fewer errors) compared to the late learners. This study also supported the critical period hypothesis for second language acquisition.

Another study conducted by Johnson and Newport (1991) tested groups of learners whose first language was Chinese and whose second language was English. There were five subject groups. The native control group was composed of 11 subjects. There were

four groups of second language learners, with a total of 23 subjects. The early learners learned English from 4 to 7 years of age; the second group learned English from 8 to 13 years of age; the third group learned English from 14 to 16 years of age and, finally, the last group acquired English in adulthood. The research question was whether there are critical period effects on the universal grammar property of subjacency. The task was auditory grammatical judgements for which accuracy was measured. The results showed that age of second language acquisition affected performance and that the relationship was linear. There was no significant difference between the native control group and the second language learners who learned English from 4 to 6 years of age. However, there was a difference between the native group and the later, second language groups. This study provided additional evidence for the critical period for second language acquisition for this syntactic rule.

In another study, Johnson (1992) replicated and extended the previous study. She reexamined critical period effects on second language acquisition for morphology and syntax with the same subjects one year after they participated in the original study (Johnson and Newport, 1989). This study used the same stimuli as Newport and Johnson (1989) but presented in written form. The rationale was that the oral task requires phonological decoding and on-line auditory decoding to pick out grammatical errors but that the written task does not. The second study yielded results similar to Johnson and Newport (1989) showing that language modality was not a factor. There was a significant effect of age of second language acquisition; the younger learners outperformed the older learners.

Johnson, Schenkman, Newport & Medin (1996) conducted an investigation on age of acquisition effects on second language acquisition for grammaticality judgements (using the same task as Johnson and Newport, 1989). The native control group was 10 subjects and the second language group was also 10 subjects whose first language was Chinese and whose second language was English acquired in adulthood. The results showed a significant effect for age of second language acquisition on grammaticality judgements.

In summary, research on second language acquisition using grammatical judgement accuracy and comprehension supports the critical period hypothesis. The studies described previously show that the ability to master a second language, at least the syntactic and morphological components of a second language, declines with increased age of learning (Johnson 1992; Johnson & Newport, 1989; Johnson & Newport, 1991; Johnson et al., 1996, Oyama, 1979; Patkowski, 1980). Logically, the next question is whether these same critical periods effects are seen for first language acquisition. Sign language acquisition is often delayed in the deaf population. Sign language age of acquisition studies will be described after giving some background on one of the most famous critical period case studies, Genie.

Critical Periods Effects: A Case of Social Isolation.

The investigation of critical period effects on first language acquisition cannot be done with a normal population because language is necessarily acquired in a spontaneous way through interaction with the environmental language by children. Most critical period research has been done with second language acquisition, which is certainly ethical. There are several exceptional cases where a child was abused or isolated from human social interaction, preventing the child from being exposed to language. Throughout history, there have been several cases of social isolation, such as leaving children alone in the wild or locked up in some restricted room for many years during childhood. The most famous case is Genie (Curtiss, 1977). Genie is a prime example of linguistic isolation. She was a little girl who was locked in a small room by her parents throughout her childhood with minimal human contact or exposure to language until she was discovered at the age of eleven (Curtiss, 1977). After discovering Genie in her parent's home, the scientific community took charge to provide her with an education, and especially to provide her with language (English). During seven years of English immersion and tutoring, Genie showed progress in her ability to communicate and to understand English. Despite all efforts to reeducate Genie, however, her language remained abnormal and significantly poorer than the normal

population (Curtiss, 1977). Curtiss (1977) reported that Genie had poorest performance in English morphology and syntax as compared to vocabulary acquisition, which was not as poor. Curtiss hypothesized that a late age of acquisition was the cause of Genie's poor linguistic ability. Genie did acquire some English after puberty, which is obviously beyond the upper age boundary for the critical period proposed by Lenneberg (1967). Beyond her language deprivation, however, other important factors must be accounted for in Genie's developmental deprivation. Those additional factors were nutritional, cognitive and social deprivations, which were very abnormal for any human. Those additional deprivations may have been related to her poor language performance rather than the language deprivation itself. In this case, it is impossible to distinguish between the multiple deprivation factors and the effect of delayed first language acquisition because they all were confounded (Curtiss, 1977).

In sum, language isolation in childhood, which delays language development, appears to affect the outcome of language development although it is uncertain in what precise way. The studies described below investigate the outcome of delayed first language acquisition without the confounds of other (social and physical) deprivations as was the case for Genie.

Critical Period Effects on Sign Language Acquisition.

Research on critical period effects on sign language acquisition requires a different point of view compared to research on second language critical period effects. In second language research, a first language was acquired from birth. This is very rare in the deaf population. The deaf population allows researchers to ask if there is a critical period for a first language and for sign language. The majority of the deaf population has hearing parents, approximately 90% (Schein & Delk, 1974). Deaf individuals do not have access to spoken language since they do not have the ability to hear or learn naturally in this speech environment. Language acquisition is thus mostly delayed in the deaf population because the majority of hearing parents do not use sign language with their deaf children. The

advantage of investigating the deaf population is that other dysfunctional factors that confound isolation cases, such as psychological and sociological deprivation, are excluded. This allows us to understand the effects of delayed language acquisition on the language system itself without these confounding factors. This is because the majority of deaf children receive normal social, cognitive, and environmental stimulation from birth.

Deaf children of deaf parents, however, have full access to mature, fluent and interactive communication with the adult language models. These deaf individuals can be compared to hearing children who have normal language stimulation. Native signing deaf children can be used as a control group in most signed language acquisition research. For critical period research in sign language acquisition, both groups are used: deaf children with hearing parents vs. deaf parents. The comparison is that for one group sign language acquisition was delayed but for the other group sign language was acquired on a normal schedule. Comparison of these two groups allows researchers to investigate whether the delay of sign language acquisition affects later sign language performance on various grammatical components of ASL. Several studies have investigated the importance of the critical period for signed language acquisition. These studies examined the long-term outcome of signed language production and comprehension on various grammatical structures in ASL (Emmorey, 1991; Emmorey, Bellugi, Friederici, & Horn, 1995; Lock, 1996; Mayberry, 1993; Mayberry & Eichen, 1991; Mayberry & Fischer, 1989; Newport, 1990).

For example, Mayberry and Fischer (1989) investigated critical period effects on sign language processing. The research question was whether native signers would outperform late learners on signed language processing tasks, such as narrative shadowing where subjects simultaneously watched and copied the signing of a signed narration given on video, comprehension questions, and memory for sentences.

In the first study, Mayberry and Fischer (1989), focused primarily on narrative shadowing, which was an on-line measure of signed language processing. The independent

measures were (1) age of sign language acquisition, (2) viewing condition, with and without visual noise, and (3) sign language dialect, ASL vs. PSE. There were 16 subjects in this study in two groups. Native signers (N=8) ranged in age from 18-22 years and their mean years of ASL experience was 20. The second group were the late learners (N=8) who acquired ASL between the ages of 9 to 16 years. They ranged in age from 18 to 22 years and their range of ASL experience was 2 to 11 years. The results showed that the native learners significantly outperformed the late learner group on shadowing accuracy, comprehension accuracy, and linguistic error types, independent of viewing condidtion and dialect.

In the second study, Mayberry and Fischer (1989) investigated sentence shadowing, recall accuracy, and linguistic error type. The study compared on- and off line tasks, shadowing vs. recall of signed sentences. The independent measures were (1) age of sign language acquisition and (2) sign order in sentences. The five age of acquisition groups were people who learned to sign at birth, 5, 8-10, 13-15, 18 years of age. Years of ASL experience was confounded with age of acquisition and were 20, 15, 8-10, 6, and 2 respectively. The dependent measure was accuracy and lexical error type (semantic vs. phonological) in sentence shadowing and sentence memory. The results showed that there was a linear relation between shadowing and recall accuracy and age of acquisition. In addition, native signers made more semantic errors and fewer phonological errors. As age of acquisition increased, errors became increasingly phonological and different from those of the native signers.

These findings showed that age of sign language acquisition affects performance on signed language processing tasks as well as the linguistic nature of the errors made, phonological vs. semantic. However, there was a weakness in these studies; years of ASL experience was confounded with age of acquisition. Thus, there may have been some practice effects. Some late learners had fewer years of ASL experience than the native signers so that the effects of age of acquisition may have been due to practice effects.

Mayberry and Eichen (1991) controlled practice effects in their next study. The research question was whether age of signed language acquisition affects linguistic processing in sentence memory. The hypothesis was that the younger the age at which signed language was learned, the more accurate performance and comprehension would be, despite lengthy ASL experience. Here were two factors examined in this experiment; first, age of language acquisition and, second, speed of the signed stimuli which was normal and 68% faster than normal speed. The experiment included three groups of learners with a total of 49. The native signers acquired sign language at birth (N=16). The early learner acquired sign language at a mean of 6 years old (N=20). The late learners acquired sign language at a mean of 13 years old (N=13). The years of ASL experience across the groups were, 40, 44, 42 years respectively. This means that the groups' years of ASL experiences was well beyond 20 years. The groups' mean ages were 40, 51 and 53 years respectively. The dependent measures were sentence recall accuracy and several measures of linguistic processing: (1) lexical preservation, (2) preservation and change of bound morphology, (3) preservation and sequencing of syntactic constituents, (4) response grammaticality, and (5) response meaning or paraphrase. The results showed that there were significant effects of age of acquisition and significant differences among all learning groups for all grammatical structures analyzed, indpendent of presentation speed. The results of the Mayberry & Eichen (1991) study provided conclusive evidence in support of the critical period hypothesis for signed language acquisition at various levels of linguistic structure.

Newport (1990, 1991) conducted other studies on the critical period for signed language acquisition. Although Newport (1990) discussed studies on both spoken and sign language, the focus here is on the sign language portion only. Newport (1990, 1991) reported that performance on sign language comprehension and production tasks declined in relation to increasing age of signed language acquisition. Her experiment measured the correctness of grammatical production and comprehension of ASL verb morphology.

There were 30 deaf subjects who participated, but it is not possible to know exactly how many were in each of three groups because this information was not given. All subjects had more than 30 years of ASL experience. The native learners acquired sign language from birth; the early learners acquired sign language from 4 to 6 years of age, and the late learners acquired sign language from 12 years of age and beyond. The independent factor was age of sign language acquisition. The dependent measures were ASL syntactic and morphological production and comprehension (8 tests in total). The accuracy data were converted to Z-scores and correlations were conducted between test performance and age of acquisition. The resulting correlations were between r= -.6 and -.7. The negative correlation shows that the late learners performed more poorly than the native learners. The findings support the critical period hypothesis by showing that performance declined in association with increasing age of acquisition. One problem with the study is that it is lacking in details in the design, data and statistical analyses so that it is impossible to judge the magnitude of the effects or assess the validity of the results.

Emmorey (1991) conducted a study on critical period effects on morphology in ASL. Emmorey (1991) hypothesized that the native group would show a different pattern of morphological priming compared to the late learner group. The research questions were (1) is morphological priming a modality independent process; (2) do the different properties of agreement and aspect morphology in ASL affect morphological priming; and (3) does early language experience influence the pattern of morphological priming? To answer these questions, Emmorey (1991) conducted two studies.

In the first study, Emmorey (1991) investigated the factors of (1) age of sign language acquisition, (2) morphology type -- agreement and aspectual, and (3) prime type base, inflected and no prime. There were 26 subjects in two groups. The first group were native signers who acquired sign language at birth (N=14); their mean age was 28 years. The second group were late learners who acquired signed language at a mean of 6.8 years of age (N=14); their mean age was 30. The data were decision accuracy (yes or no) and

reaction time. The results showed no effects for age of acquisition on decision accuracy, but the late learners had significantly slower reaction times than the native learners.

In the second study, Emmorey (1991) extended the previous study by investigating verb agreement and aspect inflection. The independent measures were (1) age of sign language acquisition and (2) prime type, base, dual agreement, habitual aspect and no prime. There were 28 new subjects. There were two groups. The first group were native signers who acquired sign language at birth (N=16); their mean age was 27 years. The second group were late learners who acquired sign language at mean of 7.8 years (N=12); their mean was 28 years. The results again showed no age of acquisition effects for ASL morphological priming. However, the reaction time was slower for the late learner group compared to the native group. The results showed age of acquisition effects on the speed of morphological processing in ASL but not on accuracy.

In another study, Mayberry (1993) investigated whether age of acquisition affects ASL sentence processing similary for delayed first vs. second language acquisition. The question was, do second-language learners show the same effects as the first-language learners when both kinds of signers have the same age of signed language acquisition? Mayberry (1993) used recall of long and complex sentences as the processing measure. There were 36 total subjects; all subjects were deaf and had used ASL for more than 20 years. The experiment included three groups of first language learners of ASL with three different ages of learning; these groups were deaf from birth. The fourth group were the second language learners and they lost their hearing at age 9 and subsequently acquired ASL as a second language after having acquired English as a native language. The native ASL signers acquired sign language at birth (N=9); the early learners acquired sign language at a mean age of 7 years (N=9). The late learners acquired sign language at a mean of 11 years (N=9). The second language learners also acquired sign language at a mean of 11 years (N=9). Years of ASL experience across the groups were 51, 51, 54 and 50 respectively. This means that ASL experience was well beyond 20 years. The dependent

measure used was almost identical to that used in the Mayberry & Eichen (1991) study, and was an extension of that study. The dependent measures were linguistic analyses of sentence recall errors and included: (1) lexical preservation and change, (2) preservation and change of bound morphology, (3) preservation and sequencing of syntactic constituents, (4) response grammaticality, (5) response meaning or paraphrase, and (6) signed digit span, forward and backwards. This last measure was added to the measures of the previous study (Mayberry & Eichen, 1991). The results showed significant effects for age of acquisition on all measures except signed digit span. In addition, the second-language learners of ASL performed significantly better than the late first-language ASL learners. The results showed, again, that age of acquisition has significant effects on the outcome of signed language acquisition, especially as a first language. In other words, critical period effects for first and second language acquisition are not uniform. The second language learners outperformed the first language learners and performed similarly to the early language learners. This research showed that a first language foundation is critically important for additional language acquisition and is more affected by age of acquisition than is second-language acquisition. These results suggest that the first language delay of the deaf population can have significant repercussions on language mastery.

Another study on the critical period for sign language acquisition was conducted by Emmorey, Bellugi, Friederici, & Horn (1995). The question was whether native and late learners would demonstrate differential sensitivity to ASL verb morphology within a syntactic context. In the first study, Emmorey et al. (1995) hypothesized that there would be slower response times for targets that followed an error in verb agreement compared to targets that followed no error and that this would depend upon age of acquisition. There were two independent factors (1) age of sign language acquisition and (2) sentence context (error versus correct). There were 21 subjects in this study in two groups. The first group was native signers who acquired sign language at birth (N=11); their mean age was 32 years and their mean years of ASL experience was 32 years. The second group were late learners

who acquired sign language at a mean of 14 years (N=10). Their mean age was 35 years and their mean of years of ASL experiences was 23. The data were judgement accuracy (of correct vs. incorrect verb agreement) and reaction time. The results showed no effects for age of acquisition on decision accuracy. However, there were significant effect on reaction time; the native learners were slower following an error whereas the late learners showed no effects. Emmorey et al. (1995) interpreted the results as showing that the late learner groups did not recognize the verb agreement errors and therefore that they had less sensitivity to verb morphology than the native learners.

In the second study, Emmorey et al. (1995) followed up on the previous study by controlling for practice effects by selecting subjects such that each group had the same mean years of signing experience. The dependent measures were (1) age of language acquisition (2) sentence error type (verb agreement and temporal aspect), and (3) sentence context (error vs. correct). There were 30 subjects in this study in three groups. The first group were native signers who acquired sign language at birth (N=10). The second group were early learners who acquired sign language at a mean of 4 years (N=10). The third group were late learners who acquired sign language at a mean of 14 years (N=10). The mean age for the groups was 21, 27 and 32 years respectively. The mean years of ASL experience was 21, 23 and 18 years respectively. The data were decision accuracy and reaction time. The results were similar to the previous studies conducted by Emmorey (1991, 1995); there were no effects for age of sign language acquisition on decision accuracy but there were effects on reaction time.

Emmorey's (1995) findings suggest that it is worthwhile to investigate effects of age of acquisition by measuring response latency. Perhaps response latency is highly sensitive to grammatical processing in ASL. The natives were more sensitive to grammatical errors so that they responded slower. By contrast, the late learners of ASL appeared to be insensitive to grammatical errors in ASL and had faster response times.

The final study on critical period effects for language acquisition by the deaf population was conducted by Lock (1996). Her study focused primarily on whether delayed first-language acquisition affects the outcome of second language acquisition. In this study the second language was written English acquired by deaf individuals whose first language was ASL. Lock (1996)'s hypothesis was that syntactic judgement performance in a second-language (English) would be affected by the age of acquisition of the first language (ASL). Her second hypothesis was that syntactic complexity would be an important factor as well. There were two factors, (1) syntactic structure (with six increasingly complex English sentence structures) and (2) age of signed language acquisition. The control group was normally hearing, native learners of English with a mean of age of 29 years (N=7). Two other groups were deaf individuals who acquired ASL as their first language and English as their second language upon enrolling in a school for the deaf. The first deaf group was early learners who acquired ASL before age 3; their mean age was 26 years (N=7). The second deaf group was late learners who acquired ASL between 6 to 13 years; their mean age was 32 years. The data were grammatical judgement accuracy and reaction time. The results showed that the native English control group outperformed the deaf groups. In addition, the early ASL learner group significantly outperformed the late ASL learner group on their second-language grammatical processing of English structures. Syntactic complexity interacted with age of first-language acquisition. The late ASL learners performed significantly worse than the early ASL learners as syntactic complexity increased. These effects occurred for both grammatical decision accuracy and latency. The results provide further support for the hypothesis that there is a critical period effect for age of first language acquisition that is greater than and different from the effects for second language acquisition.

In summary, research on age of sign language acquisition has found significant effects on several types of grammatical structure using different processing tasks and measures. The present study further investigates age of acquisition effects on the

grammatical processing of increasingly complex ASL syntactic structures using both decision accuracy and reaction time as dependent measures. Before describing the research, it is necessary to first briefly describe the linguistic structure of ASL and its acquisition by children who learn it natively.

American Sign Language: A Brief Description

ASL is a natural language that arose within the Deaf community in North America almost two hundred years ago and has origins in French Sign Language (LSF). For a long time, ASL was considered as a pantomime or a language that had no linguistic rules until the first research study showed that ASL was a language. Stokoe (1960) and Stokoe, Casterline & Croneberg (1965) analyzed sign features. He and other linguists discovered that ASL is a fully grammaticized language that displays various grammatical characteristics found in spoken languages. ASL is based on the visual-gestural modality, unlike spoken language. Thus, ASL has a different linguistic typology from languages such as English, for example. ASL is a highly morphemic language and often ASL phonological and morphological units are combined with one another simultaneously rather than sequentially as in the case for English (Newport & Meir, 1985). The study of ASL has only recently emerged, but already we better understand the complexity of ASL grammatical structures. The following summary of ASL structure is necessary to understand the motivation of the present study.

Phonology was one the first grammatical features that sign language researchers investigated (Stokoe, 1965). This was a breakthrough in sign language research because it showed that there are minimal contrasts in sign language phonology with a restricted set of values. These values are called phonological 'parameters' and include handshape, movement, localization, and orientation.

The morphology of ASL is complex and is considered as polysynthetic (Padden, 1982; Padden, 1990; Supalla, 1978; Wallin, 1998). ASL is a highly inflected language and often several morphemes are assembled simultaneously. ASL has verb agreement in which

the verb is inflected to agree with noun arguments. Agreement inflections modify the verb's location, orientation and movement from a morphophonological standpoint. ASL verb agreement has been discussed in several studies (Fischer, 1973; Fischer & Gough, 1978; Klima & Belligi, 1979; Klima, Bellugi, Newkirk & Battison,1979; Newport, 1981; Newport & Bellugi, 1979; Newport & Meir, 1985; Padden, 1981; Padden 1983; Supalla, 1982; Supalla & Newport, 1978).

ASL syntax uses a basic SVO sign order like many spoken languages. However, because ASL is highly inflected, sign order in ASL sentences is less rigid than in English. ASL uses grammaticized facial expression for the syntactic structures of topicalization, question, negation, and subordination (Coulter, 1979; Liddel, 1980; Padden, 1981).

Children who acquire ASL natively, of course, master its grammatical structure. Newport & Meir (1985) summarized ASL development. To a certain degree, ASL development follows stages that reflect ASL grammatical complexity.

Like all spoken languages, the first stage of ASL acquisition is the one-word stage and it is the most recognizable; it is the initial step toward full language function. The mean age of the one-sign stage across several studies summarized by Newport & Meir (1985) is from eight to twelve months. Before the one word stage, there is certainly babbling and gesture, but they are not linguistically recognizable or meaningful (Maestas & Moores, 1980; Petitto, & Marentette, 1991; Prinz & Prinz, 1979). The next stage of ASL development is two-sign combinations, which is also early syntax. ASL two-sign combinations are typically not inflected and often there are semantic relationships between the two signs. Deitic pronouns begin to appear at this stage. Based on Petitto's (1983) data, this stage is around 12 months to 23 months.

The next stage is the acquisition of ASL morphology. This stage occurs at approximately 2 1/2 to 3 years of age. Morphological acquisition includes such markers as subject-verb agreement as well as complex classifier constructions. Verb agreement acquisition occurs generally at ages 3;0 to 3;6 (Meier, 1982). The acquisition of classifier

constructions begins at 3 and continues until age 8 or later (Kantor, 1980; Supalla, 1982). At ages 7 or 8, children still make many errors on classifiers, sometimes referred to as complex verbs of motion. This has led some researchers to suggest that these structures are the most morphologically complex in ASL (Newport & Meier, 1985).

In summary, ASL has its own grammatical structure, which is different from spoken languages because it is based in space. ASL grammatical structures are made with the hands, arms, body, movement, and facial expressions. Studies of ASL development indicate that, like other natural languages, ASL has its own timeline and that grammatical structures are acquired step by step from less to more complex.

Research Questions

The present study uses a design similar to that used by Lock (1996) who used grammatical structures of increasing complexity that are acquired at increasingly older ages by native English learning children. The present study applies this design to grammatical structures in ASL. Increasingly complex, ASL grammatical structures are used as stimuli. As just discussed, this is based, in part, on ASL acquisitional research. Although many studies have found various effects of age of acquisition on various ASL structures, no study has systematically compared these effects across a range of ASL syntactic structures.

The present study tests three main hypothesis. The first hypothesis is that age of acquisition will affect ASL grammatical processing. The second hypothesis is that syntactic complexity will affect ASL grammatical processing. The third hypothesis is that age of acquisition and syntactic complexity will interact to affect ASL grammatical processing; age of acquisition effects on ASL grammatical processing will increase with increasing grammatical complexity.

These three hypotheses are tested with one experiment of ASL grammatical processing. The task is grammatical judgement. The dependent measures are (1) response accuracy and (2) response latency. The subjects are deaf users of ASL who first acquired it at various ages ranging from birth to 13 years.

The three hypotheses make the following predictions:

(1) Response accuracy will decline and latency will increase with increasing age of ASL acquisition.

(2) Response accuracy will decline and latency will increase with increasing ASL syntactic complexity.

(3) Response accuracy will decline and latency will increase more significantly the later the age of ASL acquisition in association with increasing ASL syntactic complexity.

Method

The hypotheses for this study were tested experimentally. Three groups of Deaf subjects who had acquired their first language, ASL, at varying ages participated by performing one experimental task, grammatical judgement of ASL sentences across increasingly complex ASL grammatical structures.

Subjects

Thirty Deaf subjects (seventeen men and thirteen women) participated in this study. ASL was the primary language of communication for all subjects. They had used ASL in their everyday life since their first contact with sign language and had at least 12 years of experience using ASL. None of the subjects had a successful oral background (lipreading, speech, etc.). Several subjects did have oral backgrounds, but because they did not fully master spoken language, they did not feel that it was their first or primary language.

Subjects were recruited by Internet advertisement, flyers, phones calls from various Deaf community phone book listings, and by "sign-of-hand". Deaf subjects from Montreal, Toronto and surrounding cities, Ottawa, Winnipeg and Halifax participated. Any subject with a masters degree, or who had formal training in sign language teaching or in linguistics was excluded in an attempt to control for educational background.

The Deaf subjects were divided into three groups depending on their age of first contact with ASL. The first group is designated as "Native" (henceforth N). They acquired ASL as their native language from one or both parents who communicated in ASL at home. The second group, designated "School Aged" (henceforth SA) group, were

individuals who acquired ASL between the ages of 4 and 7. The third group, designated "Late Learners" (henceforth L) group, were individuals who acquired ASL between the ages of 8 and 13 years. All subjects learned ASL through social interaction with members of the Deaf community, and not from schools for the deaf where the signed language used was mostly Total Communication or SEE. All subjects reported that they did not use Total Communication or SEE outside of the classroom. The subject characteristics and language background of the three groups are presented below and discussed by group.

Native group. The Native group consisted of ten Deaf subjects who acquired ASL from their Deaf parents. The characteristics of these subjects are shown in Table 1. Their language and education backgrounds are as follows. All subjects were right handed except N1 who was left-handed and N10 who was ambidextrous, according to self-report, (who used the right hand during the experiment). Most of the subjects were enrolled in college or university (BA level) studies. Subject N2 had only a high school diploma, and subject N5 had vocational training. Only one subject (N10) used a hearing aid.

School aged group. The School Aged group consisted of ten Deaf subjects who acquired ASL when they began attending a school for the deaf, between the ages of 4 and 7 years old. They did not have a prior first language. The characteristics of these subjects are shown in Table 2. Their language and education backgrounds were as follows. All subjects were right-handed except SA1 who was ambidextrous, according to self-report, (who used the left hand during the experiment). These subjects had various academic backgrounds similar to the N group. Only one subject (SA7) used a hearing aid.

Late learner group. The Late Learner group consisted of ten Deaf subjects who acquired ASL when they began attending a school for the deaf, between the ages of 8 and 13 years. They had spent the previous school years in oral schools for the deaf, which did not allow the use of signed language. They had not successfully acquired a prior first language. The characteristics of these subjects are shown in Table 3. Their language and education backgrounds were as follows. All subjects were right-handed according to self-report. The subjects also had various academic backgrounds similar to the other two groups. No subject used a hearing aid.

The subjects in the three groups were between the ages of 18 – 84 years at the time of the study. There was a significant difference in age between the groups ($F [2,27] = 5.14$, $p < .05$) with the Native group ($M = 24.2$ years) significantly younger than the School Aged: ($M = 43.2$ years) and Late Learner group ($M = 43.0$ years). There was no significant age difference between the School Aged and Late Learner groups. However, this difference in age was necessary to control for the number of years of ASL experience across the three groups. The Native group's average length of ASL experience was 24.2 years, the School Aged group was 37.6 years, and the Late Learner group was 32.9 years and there was no significant difference among the groups for average years of ASL experience. The groups were balanced as much as possible for sex; the Native group consisted of 6 males and 4 females, the School Aged group consisted of 7 males and 3 females, and the Late Learner group consisted of 4 males and 6 females

Grammatical Judgement Stimuli

All the ASL stimuli of varying levels of complexity were developed by the researcher, a Deaf native signer, along with another research assistant who was also a Deaf native signer of ASL. A pilot stimulus list was first created and then videotaped by the investigator and subsequently judged by three other ASL signers within the Montreal Deaf community for grammaticality. All judges agreed with the grammatical status of the majority of the stimuli. There were some disagreements about whether some stimuli were ungrammatical. When the three judges disagreed about whether a sentence was ungrammatical, it was changed or corrected until all agreed that it was ungrammatical. After this pilot work, the investigator professionally videotaped the stimuli for experimental use. All signs were high frequency and selected expressly to avoid confusion in signs due to regionalism. The stimuli contained no fingerspelling.

The basic control across all the stimuli was the number of morphemes, which ranged from 6 to 9 for each sentence. The number of signs was not counted, only the number of morphemes, which included grammaticalized facial expressions. All sentences, except the Relative Clause, had one verb. Relative Clause sentences had two verbs, one in each of two clauses. The verbs of all the syntactic categories, except classifier constructions, were of two types, either plain or inflected (Padden, 1981, 1983; 1990; Supalla, 1982; Wallin, 1996). For some syntactic categories, only plain verbs were used, and for others only inflected verbs were used, and for others both types were balanced. The grammatical and ungrammatical sentence types are explained below. Examples of

grammatical sentences from each category are shown in Table 4. Examples of ungrammatical stimuli from each category are shown in Table 5.

Simple sentences. Simple sentence consisted of only uninflected signs. All verbs were plain and had no agreement inflections (as none was required). Grammaticalized facial expressions and any other kind of inflection were not used. There were no agreement loci within the signing space except for pronouns (PT-1); there were no classifiers or SASS. All the sentences had from 6 to 8 morphemes ($M = 6.6$). A total of 184 morphemes were used for 14 grammatical and 14 ungrammatical sentences. All the grammatical sentences were made ungrammatical by moving the verb to another position in the sentence, which made them ungrammatical. As previously described, pilot testing showed that signers found these stimuli ungrammatical. Appendix B.1 lists all the simple sentences stimuli.

Negative sentences. Negative sentences also consisted of only uninflected signs. No inflected signs were used in the sentence except for the negative marker. No agreement loci were used within the signer space except for possessive pronouns (POSS-1 & POSS-3); there were no classifiers or SASS. There were two types of negative inflections, (1) the 'NOT' sign which was placed before the verb and (2) the negative, non-manual facial morpheme. Half of the sentences had the NOT sign and half used only the negative facial morpheme. All the sentences had from 6 to 8 morphemes ($M = 6.7$). A total of 188 morphemes were used for 14 grammatical and 14 ungrammatical sentences. The grammatical sentences were made ungrammatical by moving the negative 'NOT' sign to another location in the sentence to make them ungrammatical. For those sentences

with the negative facial morpheme, the negative facial morpheme appeared at the start of the sentence and continued during the sentence before the verb appeared. For sentence #55 (ungrammatical) the facial marker started on the preceding phrase instead of at the beginning of the sentence. Pilot testing showed that signers found these stimuli ungrammatical. Appendix B.2 lists all the negative sentence stimuli.

Directional verb sentences. Directional verb sentences consisted of uninflected signs with one verb inflected for person and number. There were no Classifiers or SASS. The verbs were directional verbs that used the signer space to indicate person and number. There were two types of directional verbs used: (1) body-anchored verbs were used for the half of the sentences and (2) unanchored verbs were used for the other half of the sentences (Padden, 1981; Padden, 1983; Newport & Supalla, 1978; Supalla, 1982). Body-anchored verbs require that the verb contact with the body (face, arms or torso) and therefore blocks person and number inflections. Unanchored verbs do not contact the body so that they can take person and number inflections. These sentences required two persons for verb agreement; agreement order among first, second, third persons was controlled as shown in Table 6. All the sentences had from 6 to 8 morphemes ($M = 6.8$). A total of 190 morphemes were used for 14 grammatical and 14 ungrammatical sentences. The grammatical sentences were all made ungrammatical by moving the verb phrase (i.e., verb + person/number inflection) to another phrase. Pilot testing showed that signers found these stimuli ungrammatical. Appendix B.3 lists all the directional verb sentences stimuli.

Wh sentences. The Wh (question) sentences consisted of uninflected signs and a Wh marker. There were no Classifiers or SASS. Half the verbs used were inflected and half the verbs were plain. There were two types of Wh markers, (1) the Wh non-manual facial morpheme was used for the half of the sentences, and (2) the signs 'WHY' and 'WHO' were used for the other half of the sentences. For the Wh facial marker, the sentences used the Wh facial morpheme without any Wh sign. The other half of the sentences used the Wh sign, which was placed at the end of the sentence. The Wh facial marker sentences were all Open Wh except one grammatical sentence, #85, and its ungrammatical counterpart #99. The Open facial Wh refers to eyebrows raised and Closed Wh refers to eyebrows furrowed. This was balanced as much as possible with sign Wh questions (# 6 used Wh Open and #8 used Wh closed). All the sentences had from 6 to 8 morphemes ($\underline{M} = 7.0$). A total of 196 morphemes were used for 14 grammatical and 14 ungrammatical sentences. The grammatical sentences were made ungrammatical by moving the Wh facial marker or sign to another phrase which made them ungrammatical. Pilot testing showed that signers found these stimuli ungrammatical. Appendix B.4 lists all the Wh sentences stimuli.

Relative clause sentences. Relative clause sentences consisted of two verb clauses using neither Classifiers nor SASS. The verbs used were both inflected and plain and used these were used equally across all 14 sentences. As with the negative sentences, there were two types of RC markers, (1) a RC facial morpheme, and (2) 'THAT' and 'ITSELF' sign markers. For half the sentences the RC facial marker was used and for the other half of the sentences the RC signs were used. The main characteristic of the RC

facial marker is that the RC subordination is made with facial expression only without using any RC signs. The RC facial markers were all positioned in the first part of the sentence. The RC signs were used in the second part. All the sentences had from 6 to 9 morphemes (M = 7.9). A total of 220 morphemes were used for 14 grammatical and 14 ungrammatical sentences. The grammatical sentences were made ungrammatical by switching the RC facial marker and it's accompanying clause to the second part of the sentence. In the case of the RC signs, they were moved to another, earlier phrase to make the sentence ungrammatical. Pilot testing showed that signers found these stimuli ungrammatical. Appendix B.5 lists all the relative clause sentences stimuli.

Classifier sentences. The classifier sentences consisted of two clauses; the first was the ground and the second was the figure. The second clause contained a verb of motion. The ground was first introduced into space followed by the figure, then the verb of motion was produced. There were three types of classifiers used, CLASS-1 (animate and vehicle), CLASS-2 (inanimate and object), and SASS. All the sentences had from 6 to 9 morphemes (M = 7.7). A total of 216 morphemes were used for 14 grammatical and 14 ungrammatical sentences. The grammatical sentences were made ungrammatical by scrambling the spatial order of the classifiers, which made them ungrammatical. Pilot testing showed that signers found these stimuli ungrammatical. Appendix B.6 lists all the classifier predicate sentences stimuli.

Equipment and Materials

The ASL sentences were videotaped with a professional SONY digital videocamera, model DCRVX-1000. The movie files were then transferred to an Apple

8100/80AV computer with a Radius videocard and RCA in/out video connection. Adobe Premiere 4.2 was used for editing and movie compression was performed with Movie Cleaner Pro 1.2 with the following settings: 30 frames per seconds, Cinepak, millions of colors, 340 x 280 pixels, 300K/sec maximum data rate. The Quick Time movies were then integrated into PowerLaboratory software (Chute & Daniel, 1996) and recorded onto a CD-ROM. During the experiment, PowerLaboratory was installed on the PowerBook hard drive for optimal performance and speed. During testing, the computer battery was never used; a 120v. source was always used. This avoided spinning down the hard drive and dimming the screen.

The grammatical judegment task was created and presented on an Apple G3 PowerBook portable computer, 292Mhz processor speed, 96MB RAM, 14-inch active matrix color screen, and PowerLaboratory 1.0.3 experimental software (Chute & Daniel, 1996). The program allowed the experimenter to design the task with QuickTime movies in ASL. It also allowed for computerized collection of the data in terms of response accuracy and latency. A Gravis MacGame Pad, a command pad, with four colored buttons (blue, green, yellow and red) was attached to the computer. For the experiment, only the RED button (incorrect), placed on the left, and the GREEN button (correct), placed on the right, were used. The other colored buttons were disabled. The response latency for each stimulus was recorded by the computer in milliseconds when either the RED or GREEN button on the GamePad was pressed. The results of the experiment were saved automatically after each of the four sessions in specific subject folders.

The computer measured response latency from the onset of the stimuli to the subject's button press. Because response latency could not be measured by the computer within a video clip, the length of time in milliseconds from the onset of the stimulus to the onset of the ungrammaticality was measured separately for each ungrammatical sentence. The length of time from the onset of the stimulus to the onset of the ungrammaticality was subtracted from each subject's response time. This yielded response latency from the point of the ungrammaticality for each stimulus pair, the grammatical and ungrammatical versions.

Procedure

ASL was used during all testing. The subjects were tested individually in a non-distracting environment; the experimenter was not in the subject's view during the procedure (except for the practice session), that is, the experimenter sat behind or beside the subject during testing. Subjects varied in the time needed to complete the task, the time ranging from approximately fourteen minutes to one hour. All subjects were informed about the experiment (tasks, freedom to withdraw) and asked if they wished to participate in the study. The contents of the consent form were given in ASL for the subjects if so requested. In order to complete the background questionnaire on the subject's language and educational background, the subjects were interviewed by a Deaf experimenter who was fluent in ASL. The Background questionnaire is given in Appendix C. The consent form is given in Appendix D

Following the interview, the subject was asked to complete a practice session using 8 ASL stimuli, which were similar to the experimental stimuli (see Appendix A).

The stimuli were presented in the center of the computer screen with a black background around the movie frame. There was no focus signal or blank screen between stimuli. There was a pause of 1000ms before the computer started to show the ASL sentence. Each stimulus began with a still picture which was the first frame of the signed stimuli. Subjects generally sat two feet from the screen. The subject was required to press one of either two colored buttons, the RED one if they judged the stimulus to be ungrammatical or the GREEN one if they judged it to be grammatical. Subjects were instructed to focus on the syntactic structure of the sentence (facial expressions, sign order and spatial arrangements) and not on sign variation or semantic interpretation. The task was given in four parts. Subjects were given a 3 to 5 minute break between each part. Each part consisted of 48 stimuli randomly drawn from from the total 168 stimuli.

The 168 ASL stimuli were six ASL sentence structures with 28 examples of each with 14 grammatical examples and 14 ungrammatical counterparts. The 168 ASL stimuli were randomized in a fixed order and then separated in four sections. The purpose of this was to allow subjects to take a break inbetween sections if they so desired. Some subjects elected to take no breaks and others did. Subjects were informed that the computer recorded response accuracy and latency, which required them to be careful, but they were also asked not to pause unnecessarily. They were told to just do their best. The subjects held the Game Pad in both their hands and were instructed to hold it in the same way throughout the experiment. Subjects reponded with their thumbs as in a video game. For the left-handed subjects, the game pad was simply flipped 180 degrees to

ensure uniformity of reaction time with respect to hand dominance. The left-handers used the green button (correct) with their dominant hand, as did the right-handers.

Results

The results of this study are presented as follows. First, the results of the background measures are summarized. Second, the grammatical judgement task performance (both accuracy and latency data) is presented. Data were analyzed with repeated measures analyses of variance, A', and latency normalization. For ease of data reporting, the age of acquisition groups will continue to be given as: (1) the native learners of ASL, N, (2) the school aged learners of ASL, SA, and (3) the late learners of ASL, L. For tabular and graphic purposes, the syntactic sentence types are denoted as 'S', 'Neg.', 'V', 'Wh', 'RC', 'CL', for simple, negative, directional verbs, question, relative clause sentence, and classifier structures, respectively. The ASL syntactic structures were selected to reflect increasing complexity based on linguistic theory and the ASL acquisition literature. Thus, the order of syntactic types given above is from simple to more complex. The sentence legality is denoted as 'G' and 'U', for grammatical and ungrammatical ASL sentence structures, respectively.

Background Measures

In order to determine if age of ASL acquisition was related to self-assessment of ASL and Spoken English skills, the deaf subjects who participated in the study completed two rating scales. The rating was on a scale of 0 to 5, where 0 meant "not at all" and 5 meant "excellent." The N Group rated themselves at a mean of 4.85 in sign language skill and a mean of 4.85 in fingerspelling skill, but at a mean of 1.25 for spoken skill (Table 1). The SA Group rated themselves at a mean of 4.9 in sign language skill and a mean of 4.25 in fingerspelling skill but at a mean of 1.1 for spoken skill (Table 2). The L group rated

themselves at a mean of 4.3 in sign language skill and at a mean of 4 in fingerspelling skill but at a mean of 2.6 for spoken skill (see Table 3).

Figures 1 to 3 shows that, in signing skills, the N group had a higher mean self-rating score than the SA and L groups. However, there was an opposite effect on spoken skill; the L group gave themselves a higher mean oral rating than the two other groups, as also shown in Figures 1 to 3.

Grammatical Judgement

The hypotheses under investigation in the present study predict that the Native group will outperform the other groups (school aged and late) on the grammatical judgement task. Also, it is predicted that the school-aged group should outperform the late group. The native group should make fewer errors than the other two groups and their time response latencies should be quicker too. The hypotheses also predict that increasing syntactic complexity will increase judgement errors and response latency. Also, age of acquisition should interact with syntactic complexity (Lock, 1996; Mayberry, 1993; Mayberry & Eichen, 1991; Mayberry & Fischer, 1989; Newport, 1990, 1991)

Accuracy. Table 7 shows the groups' judgement accuracy on the grammatical judgement task as a function of syntactic structure and legality. The accuracy scores were analyzed with two 3 x 6 x 2 repeated measures analyses of variance (ANOVA) for both subjects and items. The between-subjects factor was age of sign language acquisition, with three groups (N, SA, and L). The first within subjects factor was type of

grammatical structure, with six levels (S, Neg, V, Wh, RC, and CL). The second within-groups factor was legality, with two levels, G and U.

The results showed a main effect for age of acquisition ($F_{Subjects}$ [2,27]=11.63, $p <$ .001; F_{Item} [2, 156]=100.43, $p <$ .001). Thus, age of acquisition showed strong effects on the ability to perform grammatical judgements in ASL as shown in Figure 2. The native group made fewer errors than the two other groups with a mean of 36.5 errors from 168 total sentences (21.7%). The school aged group made 53.5 mean errors (31.8%). The late learner group made a average of 68.2 errors (40.6%). Each group performed significantly differently from the other (Student/Newman/Keuls; $p <$ .05).

There was a significant main effect for syntactic structure ($F_{Subjects}$ [5,135]=8.48, $p <$ .001; F_{Items} [5,78]=2.89, $p \leq$ .05). There was also a main effect for legality ($F_{Subjects}$ [1,27]=36.51, $p <$ .001; F_{Items} [1,78]=3.02, $p <$ .001). The effect of syntactic structure interacted with legality ($F_{Subjects}$ [5,135]=14.01, $p <$ .001; F_{Items} [5,78]=3.02, $p <$ .05). The interaction between syntactic structure and legality is shown in Figure 3. The interaction was such that the subjects made significantly more errors on the ungrammatical as compared to grammatical stimuli on all syntactic structures except Neg and Cl structures (Student/Newman/Keuls, $p <$.05).

There was no significant interaction between group and syntactic category ($F_{Subjects}$ [10,135]=0.97, p = n.s.; F_{Items} [10,156]=1.13, p = n.s.). As shown in Figure 3, syntactic complexity affected all the groups' performance in the predicted fashion except for CL structures. Although CL structures are reported in the literature as being highly complex and acquired late by children, the subjects made fewer errors on these structures

compared than the other presumably complex structures, namely Wh and RC (Student/Newman/Keuls, $p<.05$).

Latency. Table 8 shows the groups' response latency results for the grammatical judgement task as a function of syntactic structure and legality. Response latency was analyzed for correct responses only. The latency results were analyzed with two 3 x 6 x 2, repeated measures analyses of variance (ANOVAs) for both subjects and items. Again, the between-subjects factor was age of sign language acquisition with three levels, (N, SA, and L) and the within-groups factor was type of grammatical structure with six levels, (S, Neg, V, Wh, RC, and CL) and legality (G and U).

There was no significant effect for age of sign language acquisition for the subject analysis but there was for the item analysis ($F_{Subjects}$ [2,27]=0.82, p=n.s.; F_{Items} [2, 156]=23.44, $p< .001$). This means that there was not an overall effect of age of acquisition on response latency but that there were effects for some items. There was a significant main effect for syntactic category ($F_{Subjects}$ [5,135]=14.11, $p< .001$; F_{items} [5,78]=2.56, $p< .05$). The effect of syntactic category interacted with age of acquisition for the item analysis but not the subject analysis ($F_{Subjects}$ [5,135]=1.48, p=n.s; F_{items} [5,78]=1.99, $p< .05$), as shown in Figure 4. This means that there was not an overall interaction between age of acquisition and syntactic category on response latency but there was an effect for some items.

There was no main effect for legality. However, there was an interaction between syntactic category and legality and this is shown in Figure 4. The interaction was such that the subjects were significantly slower on the ungrammatical as compared to

grammatical stimuli for all syntactic categories except Neg and RC structures (Students/Newman/Keuls, $p<.05$).

A' analysis. The purpose of the A' analysis was to examine the percentage of hits and false alarms the subjects made. A' is an index of grammatical sensitivity which allows us to take into account the subject's guessing behavior. The formula used for A' analysis was: $0.5+[(y-x)(1+y-x)]/4y(1-x)]$, taken from Linebarger, Schwartz, and Saffran (1983). The x is the proportion of false alarms (ungrammatical incorrect answers) and y is the proportion of hits (grammatical correct answers). A' data were computed separately for each subject and then analyzed with a two-way (3 x 6) ANOVA. The between-subject factor was age of acquisition and the within-group factor was type of syntactic structure.

Table 9 shows the A' results. There was a significant effect of age of acquisition ($F_{Subjects}$ [2,27]=10.05, $p<.001$) showing that the A' values decreased as age of ASL acquisition increased (see Figure 5). Each group's performance was significantly different from the other (Student/Newman/Keuls, $p<.05$). There was also a significant main effect of syntactic structure ($F_{Subjects}$ [5,135]=7.75, $p<.001$) that did not interact with age of acquisition. Post-hoc testing showed that the effect was due to the Neg and RC structures. As Figure 6 shows, there was a linear trend by which performance declined from simple to complex sentence structures, except for the CL structure.

Response time normalization. To control for individual response time tendencies, the response latency data for each subject were normalized with the formula 'U-G/U' (U= ungrammatical and G= grammatical). The formula represents the mean percentage

decrease in response time to grammatical versus ungrammatical stimuli (Leonard & Baum, 1998). A positive value means that the response times were faster to grammatical than to ungrammatical sentences and a negative value shows the opposite.

Table 9 shows the response latency normalization results. The normalized response latency data were analyzed with a two-way ANOVA. The between-subject factor was age of acquisition and the within-group factor was type of syntactic structure. There was a significant effect of age of acquisition as shown in Figure 7 ($F_{Subjects}$ [2,27]=4.39, $p<.05$). Normalized response latency increased as age of ASL acquisition increased. Post-hoc testing showed that the effect was primarily due to the late learners who showed significantly greater normalized response latency than the other two groups. Specifically, they showed significant quicker reaction times for grammatical as compared to ungrammatical stimuli. There was also an effect of syntactic structure ($F_{Subjects}$ [5,135]=19.81, $p<.001$). As Figure 8 shows, subjects responded quicker to grammatical than ungrammatical stimuli for the simpler structures (S and V) compared to the more complex ones (WH and CL), except for the two structures where the ungrammaticality early in the sentence (N and RC) (Students/Newman/Keuls, $p<.05$).

Discussion

The present study tested three hypotheses. The first hypothesis was that age of acquisition would affect ASL grammatical processing. The hypothesis predicted that increasing age of acquisition would result in decreasing ASL processing performance. The second hypothesis was that syntactic complexity would affect ASL grammatical processing. The prediction was that increasing syntactic complexity would result in decreasing ASL processing performance. The third hypothesis was that age of acquisition and syntactic complexity would interact to affect ASL grammatical processing; age of acquisition effects on ASL grammatical processing would increase with increasing syntactic complexity.

The three hypotheses were tested with one experiment of ASL grammatical processing. The task was grammatical judgement of ASL sentences. The dependent measures were (1) response accuracy and (2) response latency. The subjects were three groups of 10 subjects each who were deaf users of ASL and who first acquired it at birth, ages 4 to 7, and ages 8 to 13. The ASL stimuli were grammatical and ungrammatical examples of six types of ASL syntactic structures of increasing complexity, simple, negative, directional verb, question, relative clause, and classifier. A language proficiency rating scale was also administered.

Accuracy and latency of the subjects' grammatical judgements were the dependent measures. Accuracy data were analyzed as raw data and then transformed with an A' formula and reanalyzed to control for guessing behavior. Latency data were analyzed for correct responses only and then transformed with a normalization formula and reanalyzed to adjust for individual response tendencies. The data were analyzed with analyses of variance for the factors of age of acquisition and grammatical complexity for all ANOVAs. Analyses of untransformed accuracy and latency data included a third factor of legality (grammatical vs. ungrammatical).

Hypothesis I: Age of Acquisition Affects ASL Grammatical Processing

The accuracy results showed that there were effects of age of acquisition on ASL grammatical processing. There was a significant main effect for age of acquisition on performance accuracy and there was a significant difference between all three groups (N, SA, and L). The results mean that there is deteriorating performance accuracy with increasing age of first sign language acquisition. The accuracy of the Native group was 78.3%, the School Aged group scored at 68.2%, and the Late Learner group scored at 59.4%. Therefore, the accuracy data supports the first hypothesis that there is an effect of age of acquisition on ASL grammatical judgement performance.

The accuracy data were reanalyzed with an A' formula. The purpose of the A' analysis was to have an index of sensitivity to ASL grammatical structures. The A' analysis takes into account guessing behavior. The results again showed a significant effect for age of first sign language acquisition with significant differences among all subject groups. Grammatical judgement performance declined as the age of ASL acquisition increased. Therefore, sensitivity to ASL syntactic structures detoriated as age of acquisition increased.

The latency results were somewhat different from the accuracy results. There was a partial effect of age of sign language acquisition on response latency. There were significant effects for the item analyses but not the subject analyses. This means that the effects of age of language acquisition did not generalize across all subjects, however, it did generalize across items. One explanation for this partial effect may be the low number of accurate responses from the school-aged and late learner groups because only response latency for correct responses were analyzed. These two groups made a mean of 36.2% of incorrect responses (SA: 31.8% and L: 40.6%). By contrast, the native group provided nearly twice as many correct responses for the latency analyses, yielding a more robust data sample.

However, when the response latency data were normalized to take into account each subject's response latency tendencies to both grammatical and ungrammatical items, there was a significant effect for age of sign language acquisition on response latency. This

effect was primarily due to the late learner group who had slower mean normalized response latencies compared to the other two groups (native and school-aged). This means that the late learners were slower than the other two groups to reject ungrammatical stimuli. Thus, age of sign language acquisition affected grammatical performance accuracy to a greater degree than response latency, but both aspects of ASL grammatical judgement were predicted by age of acquisition. These results fit the first hypothesis.

A sign language proficiency rating scale was administered to the subjects prior to the experiment. The results of the rating scale showed that, in general, the subjects were aware of their ASL mastery. The late learner group gave themselves poorer ASL mean ratings compared to the school-aged and native groups. The native group gave higher mean ratings than the other groups and the experimental results showed that they were correct in their ASL proficiency assessment. It is very interesting that these deaf individuals were aware of their sign language mastery at some level, which was unconsciously affected by the factor of age of acquisition.

The findings of the present study may be interpreted as evidence that there is a critical period for sign language acquisition: as age of acquisition increased, ASL grammatical sensitivity declined for performance accuracy and increased for response latency. The accuracy results were more robust than the latency results. Previous research on critical period effects in sign language have previously shown age of acquisition effects. Studies conducted by Mayberry and Fischer (1989) on sentence memory and narrative shadowing, Newport (1991) on verb morphology, Mayberry & Eichen (1991) and Mayberry (1993) on sentence-recall, and Lock (1996) on second language grammatical processing based on age of first acquisition of ASL all found significant effects of age of acquisition on ASL performance accuracy. The present results show similar findings. The present results also extend these previous findings by comparing and contrasting the effect on a range of syntactic structures, as discussed below.

The present results are somewhat different from those of Emmorey (1991) and Emmorey et al. (1995). These two previous studies found age of acquisition effects on response latency but not on accuracy for ASL verb morphology. The present study replicates these studies by also finding age of acquisition effects for response latency. It is not clear why the previous studies did find effects for response accuracy in contrast to the present study. One possibility is that the present study included many more syntactic structures and many more examples of each structure so that a larger amount of data was collected from each subject (hence greater variability in the data). However, the present study is in keeping with previous research, nearly all of which has found effects for response accuracy.

Hypothesis II: Syntactic Complexity Affects ASL Grammatical Processing

A novel apsect of the present study was that it used grammatical and ungrammatical examples of six different types of ASL syntactic structures of increasing complexity, simple, negative, directional verbs, questions, relative clauses, and classifiers. Three of these syntactic structures included examples of syntactic rules in signs vs. grammaticalized facial expressions, negatives, questions, and relative clauses. The second hypothesis predicted that judgement accuracy would decline with increasing complexity and that response latency waould increase with increasing complexity. The majority of the results fit the hypothesis. Main effects of syntactic complexity emerged for both response accuracy and latency (but did not interact with age of acquisition). Legality, grammatical vs. ungrammatical, had an effect too. There was an interaction between syntactic complexity and legality for both sets of data. The results showed that the ungrammatical items were harder than the grammatical sentences. This was true for all the syntactic structures except for negatives and classifiers where there was no effect of legality.

There was also a significant effect for syntactic complexity for the A' analysis. The A' results showed that there was a linear trend for syntactic complexity; accuracy declined with increasing syntactic complexity, going from simple to complex structures, except for

the classifier structures. Performance on the classifier structures was better than for the other complex sentences structures (questions and relative clauses). This finding suggests that classifer structures may not be as complex as previous work has proposed.

The results also showed an effect of increasing syntactic complexity on response latency. In general, the more complex the syntactic structure, the slower the response. There was no interaction between the factors of age of acquisition and syntactic complexity for the subject analysis, but there was an interaction between complexity and age of language acquisition for the item analysis. The finding suggests that some items in some syntactic categories were not equally difficult across the groups. The finding that response latency tended to increase with increasing syntactic complexity shows that ASL linguistic description has psychological reality for deaf signers. The more linguistically complex the ASL sentence, the more time required to process it. This finding was less clear for the results for response time normalization. This may be because the ungrammaticality for two syntactic structures, negatives and relative clauses, appeared at the beginning of the stimuli whereas the ungrammaticality for the other structures appeared later. If these two syntactic types are excluded, the response time normalization results showed that the more compex structures (questions and relative clauses) required more time for the subjects to reject ungrammatical stimuli compared to grammatical ones than did the simpler structures (simple and directional verb).

The present study's ranking of syntactic complexity was based both on ASL linguistic description and on the language development literature in ASL. The results showed that there was a linear trend in terms of syntactic complexity for the accuracy analyses. These results parallel ASL developmental stages as reported in the literature (Newport & Meier, 1985) except for the classifier structures, which require more study and analysis. ASL classifiers are regarded as being highly complex and noted as being acquired quite late. However, the subjects' performance on this syntactic category was more in keeping with the simpler structures (simple, negative, and directional verb) than the complex

structures, (question and relative clause). One possible explanation is that ASL classifiers are not as grammatically complex as linguists have proposed. Another possibility is that the classifier examples used in the present study were overly simple. An attempt was made, however, to have the same number of morphemes across all the syntactic types. When morpheme length is controlled, classifier structures are not harder than negative or directional verb sentences. ASL classifiers perhaps should be rethought as ranging from simple to complex as a function of the number of involved morphemes and not as uniformly complex.

The results of this study further suggest that other aspects of ASL syntactic structure should be studied in more depth. There were no significant legality effects for negative and relative clause structures. This may have been due to the unorthodox use of the facial markers in the ungrammatical examples; the facial marker preceded the signed sentence. This may have made the deaf subjects more sensitive to these ungrammatical manipulations than those of the other syntactic categories.

Hypothesis III: Age of Acquisition and Syntactic Complexity will interact in ASL Grammatical Processing

Age of sign language acquisition did not interact with syntactic complexity. This means that the effects of age of acquisition did not vary systematically across various syntactic structures. In general terms this means that the simplest syntactic structures were easiest for all groups. This also means that the most complex syntactic structures were also the hardest, regardless the age of acquisition. Therefore, age of acquisition effects are not dependent upon syntactic complexity according to the present results. There is an effect of age of acquisition even on simple structure and not only on complex ones. One possible explanation for the difference between this study's results and that of Lock's study (1996) is that ASL was the subjects' primary language. Lock (1996) found complex structures to be much harder for Late learners than Early learners but this was for their second language, English.

In summary, the present results show clearly that there are significant effects for age of sign language on grammatical judgement performance in a very important way. The later deaf individuals acquire sign language, the poorer they perform on grammatical judgement for response accuracy and (to a lesser extent) latency. Therefore, the results of this study support the hypothesis that there is a critical period for language acquisition.

Finally, although the subjects had many years of ASL experience, there were large effects of age of acquisition on ASL grammatical processing. These results mean that the effects of the critical period is important and irreversible.

Implications for the Education of Deaf Children

The critical period for language acquisition is an essential concept in deaf education settings. The critical period is a very important issue for a bilingual approach to education. The general principles of bilingual education for deaf children are based on the idea that first language acquisition in sign language is necessary in order to provide full language accessibility to deaf children before they acquire a written, second language. As Lock's study (1996) and Mayberry's (1993) study showed, the effects of age of first language acquisition also affected second language acquisition. When deaf individuals acquire ASL at later ages, the second languages acquired (English) tend to be learned less well. First language acquisition is critical and is the foundation of all future language and cognitive development in deaf children. Mayberry (1993) showed that deaf individuals who acquired their first language on a normal time schedule acquired their second language better than those who acquired their first language at older ages. In addition, the self-confidence deaf children have in their languages in educational settings and in everyday life has significant effects on the remainder of their lives. The important point, which cannot be overemphasized, is that language must be acquired at the right time and with good language input.

Future Research

This study was done with real time, computerized video stimuli and the subjects made their grammatical judgement with a game pad. This represents a technological breakthrough for sign language studies. This is one of the first studies to use one device (a computer) for both stimulus presentation and response measurement. Also, use of a video game pad provided a natural way for subjects to respond with their thumbs.

From a technical standpoint, one thing could be improved. This would be to double the video window size to 640 X 480 pixels from 320 X 240 pixels. There were technical limitations such as memory and picture quality which limited window size to 320 X 240 pixels. Also, the G3 PowerBook monitor resolutions were limited to 1024 X 768 pixels. If the monitor resolutions were 640 X 480 pixels, it might be feasible that the experiment could run with a video window at a resolution of 320 X 240 pixels which is the half of the screen. However, the subjects had no problems viewing the video window in the present study.

This study focused on grammatical processing. It is necessary to extend this study by investigating another grammatical task such as comprehension and production of ASL syntactic structures. Additional studies in these areas will provide stronger evidence for the critical period hypothesis. By using comprehension and production tasks, we can determine whether the effects of age of acquisition on ASL grammatical processing generalize to tasks other than grammatical judgement. It is important to determine whether syntactic complexity has similar effects on these tasks to fully understand the effects of the critical period on grammatical knowledge and processing.

Another important area for future research is the linguistic nature of classifier structures and grammaticalized facial markers in ASL grammatical processing. The results of the present study suggest that psycholinguistic paradigms, coupled with modern computer technology, can yield many new and important insights into the linguistic processing of these unique syntactic structures.

In summary, the results of this study provided evidence that grammatical processing of ASL sentences is affected independently by age of sign language acquisition and syntactic complexity. The effects of age of acquisition on ASL grammatical processing did not interact with syntactic complexity. The importance of the timing of sign language acquisition was demonstrated by comparing the grammatical processing of different groups of age of acquisition. This study increases the evidence from previous critical period studies on sign language acquisition. It is very important to understand that the language problems caused by late learning are not inevitable in the deaf population but are avoidable if we understand better how the critical period affects the outcome of language acquisition.

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Table 1

Characteristics of the Native Group

Subject	Sex	Age	Age of ASL Exposure	Years of ASL	Dominant Hand	Hearing Aid	Communication Rating			Highest Level of Education
							Sign	Finger Spelling	Oral	
N1	M	20	0	20	L	N	4	5	2	College in progress
N2	M	26	0	26	R	N	5	4	0	High School
N3	F	19	0	19	R	N	5	4.5	0.5	BA in progress
N4	F	18	0	18	R	N	5	5	2	BA in progress
N5	M	41	0	41	R	N	4.5	5	0	Voc. Training
N6	F	21	0	21	R	N	5	5	2	BA in progress
N7	M	24	0	24	R	N	5	5	0	BA
N8	M	25	0	25	R	N	5	5	1	BA in progress
N9	F	22	0	22	R	N	5	5	3	College
N10	M	26	0	26	R+L	Y (one)	5	5	2	BA in progress
Mean		24.2	0	24.2			4.85	4.85	1.25	

Table 2

Subject Characteristics of the School Aged Group

Subject	Sex	Age	Age of ASL Exposure	Years of ASL	Dominant Hand	Hearing Aid	Communication Rating			Highest Level of Education
							Sign	Finger Spelling	Oral	
SA1	M	52	7	45	R+L	N	5	5	1	Voc. Training
SA2	F	53	7	46	R	N	5	5	2.5	Voc. Training
SA3	M	24	7	17	R	N	4	2	0	High School
SA4	M	31	4	27	R	N	5	5	0	BA
SA5	F	33	5	28	R	N	5	5	0	High School
SA6	M	40	6	34	R	N	5	3	1	High School
SA7	M	32	5.5	26.5	R	Y (two)	5	3.5	1.5	BA
SA8	M	45	5	40	R	N	5	5	3	BA
SA9	M	62	5	58	R	N	5	4	2	Voc. Training
SA10	F	60	5	55	R	N	5	5	0	High School
Mean		43.2	5.65	37.6			4.9	4.25	1.1	

Table 3

Subject Characteristics of the Late Learner Group

Subject	Sex	Age	Age of ASL Exposure	Years of ASL	Dominant Hand	Hearing Aid	Communication Rating			Highest Level of Education
							Sign	Finger Spelling	Oral	
L1	F	26	13	13	R	N	4	3	2	Voc. Training
L2	M	31	12	19	R	N	5	3	1	High School
L3	F	24	12	12	R	N	4.5	3	3	BA in progress
L4	F	28	13	15	R	N	4	4	3	BA
L5	M	79	8	71	R	N	5	5	2	High School
L6	F	26	13	13	R	N	5	4	2	High School
L7	M	84	8	74	R	N	4	5	2.5	Voc. Training
L8	M	46	8	38	R	N	4	4	5	BA
L9	F	44	8	36	R	N	4	4	2	High School
L10	F	42	8	34	R	N	3.5	5	3	High School
Mean		43	10.3	32.9			4.3	4.0	2.6	

Table 4

Syntactic Structure Types Used for Grammatical Judgement Task [1]

Sentence Structure Type	Sub Structure Type	Grammatical Examples
1. Simple	No	FOUR BOYS FROM DEAF SCHOOL CHAT
2. Negative	a. NOT Sign	CAR OLD WATER WIPER NOT WORK (Neg)
	b. Negative Facial Marker	JAIL SOME PEOPLE THIN EAT (Neg.)
3. Directional Verb	No	MAN BALL BLUE 3-THROW-1
4. Wh	a. Wh Facial Marker	MEDICAL SCIENCE MAGAZINE PTE-2 READ? (Wh)
	b. WHY and WHO Sign	POSS-2 UNCLE J-O-B QUIT WHY? (Wh)
5. Relative Clause	a. Topicalization Facial Marker	RECENTLY DOG CHASE CAT COME HOME (RC)
	b. THAT and ITSELF Sign	MANi 3-CALL-3 FRIENDj THATi CRY (RC)
6. Classifier	No	ROPE MONKEY CL:/1/i CL:/Vc/i [SWING]

[1] To see the examples, please use the CD attached to this thesis (Mac version only).

Table 5

Syntactic Structure Types Used for Ungrammatical Judgement Task [1]

Sentence Structure Type	Sub Structure Type	Ungrammatical Examples
1. Simple	No	FOUR BOYS FROM CHAT DEAF SCHOOL
2. Negative	a. NOT Sign	Neg NOT CAR OLD WATER WIPER WORK
	b. Negative Facial Marker	Neg JAIL SOME PEOPLE THIN EAT
3. Directional Verb	No	3-THROW-1 MAN BALL BLUE
4. Wh	a. Wh Facial Marker	Wh MEDICAL SCIENCE MAGAZINE PTE-2 READ?
	b. WHY and WHO Sign	Wh POSS-2 WHY UNCLE J-O-B QUIT?
5. Relative Clause	a. Topicalization Facial Marker	RC COME HOME RECENTLY DOG CHASE CAT
	b. THAT and ITSELF Sign	RC MANi 3-CALL-3 THATi FRIENDj CRY
6. Classifier	No	CL:/1/i MONKEY ROPE CL:/Vc/i [SWING]

[1] To see the examples, please use the CD attached to this thesis (Mac version only).

Table 6

Directional Verb Sentence Agreement Order

Agreement Order	Number of Grammatical Sentences	Number of Ungrammatical Sentences
1>2	2	2
1>3	2	2
2>1	4	4
2>3	0	0
3>1	2	2
3>2	2	2
3>3	2	2

Table 7

Grammatical Judgement Errors by Group, Syntactic Category and Legality (Across Subjects)

	GROUP					
	Native		School Aged		Late	
	Mean	SD	Mean	SD	Mean	SD
Simple G	1.1	0.876	2.0	1.414	2.4	1.776
Simple U	3.4	2.066	6.5	3.375	8.7	3.466
Neg G	2.6	1.578	3.8	2.098	4.8	2.530
Neg U	1.9	1.370	4.1	3.247	5.5	1.650
Verb G	2.0	1.333	2.9	1.853	2.9	1.729
Verb U	3.1	1.449	6.4	3.406	7.9	2.601
Wh G	2.0	1.155	3.3	2.946	4.0	1.886
Wh U	6.0	2.211	7.0	2.309	9.0	2.539
RC G	4.4	2.951	4.5	2.915	5.3	2.669
RC U	4.2	3.293	4.9	2.685	7.0	3.670
CL G	1.1	1.197	2.7	1.947	3.0	1.886
CL U	4.7	2.111	5.4	2.989	7.7	2.003

Table 8

Grammatical Judgement Response Latency (for Correct Responses) by Group, Syntactic Category and Legality

	GROUP					
	Native		School Aged		Late	
	Mean	SD	Mean	SD	Mean	SD
Simple G	4860.2	663.8	5038.6	760.3	4553.1	372.5
Simple U	4858.7	1220.2	5256.2	916.5	5623.8	1152.5
Neg G	5305.8	1091.4	5839.6	1492.2	5103.9	777.2
Neg U	4303.8	546.8	5138.0	977.8	5116.5	1171.2
Verb G	4683.4	1060.6	4871.0	955.7	4138.4	606.5
Verb U	4481.0	1035.8	5074.9	954.6	4565.2	913.8
Wh G	4426.9	1164.7	4423.7	967.5	3989.9	427.7
Wh U	4580.7	1248.4	5109.9	1567.9	5294.7	1560.5
RC G	5163.0	796.1	5617.9	1351.8	4729.4	496.8
RC U	4801.3	611.0	4763.8	674.6	4302.9	641.7
CL G	5037.2	1033.2	5605.8	1541.1	4802.5	507.2
CL U	5568.9	889.7	5907.6	783.5	5741.2	692.4

Table 9

A' and Response Time Normalization (%)

	Simple		Neg		Verb		Wh		RC		CL	
	A'	%	A'	%	A'	%	A'	%	A'	%	A'	%
Native	0.91	-0.03	0.90	-0.23	0.89	-0.05	0.81	0.02	0.75	-0.08	0.87	0.10
School Aged	0.79	0.03	0.80	-0.14	0.74	0.02	0.69	0.11	0.73	-0.18	0.78	0.06
Late	0.66	0.17	0.70	-0.02	0.66	0.08	0.57	0.23	0.53	-0.12	0.68	0.16

Figure 1

Self Rating Measurement by Group

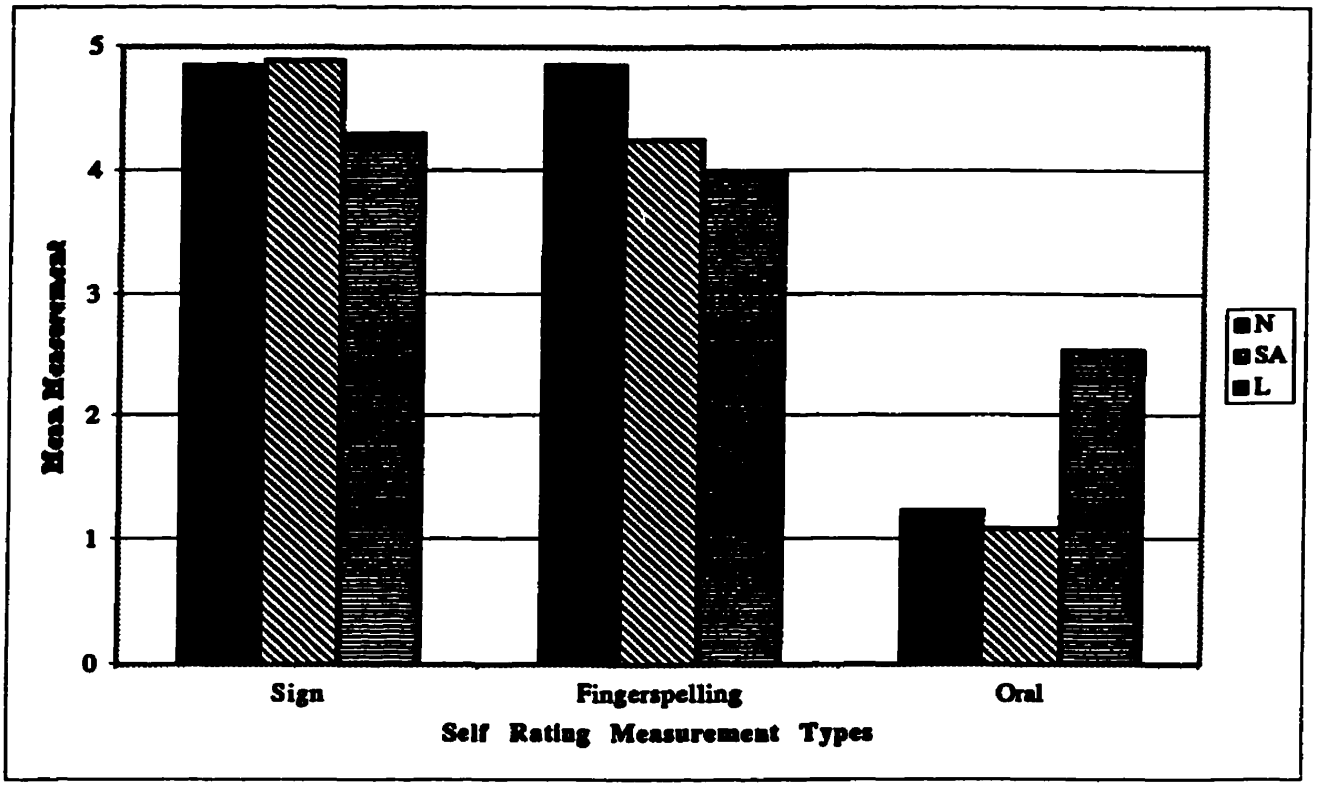


Figure 2

Group Accuracy of Grammatical Judgement

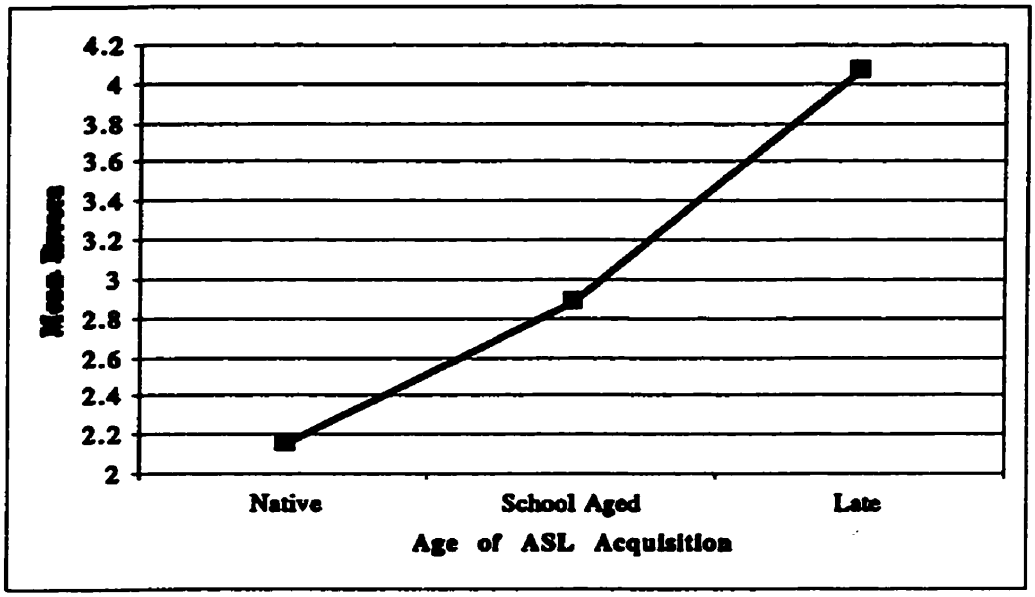


Figure 3

Sentence Category by Legality Interaction for Grammatical Judgement Accuracy

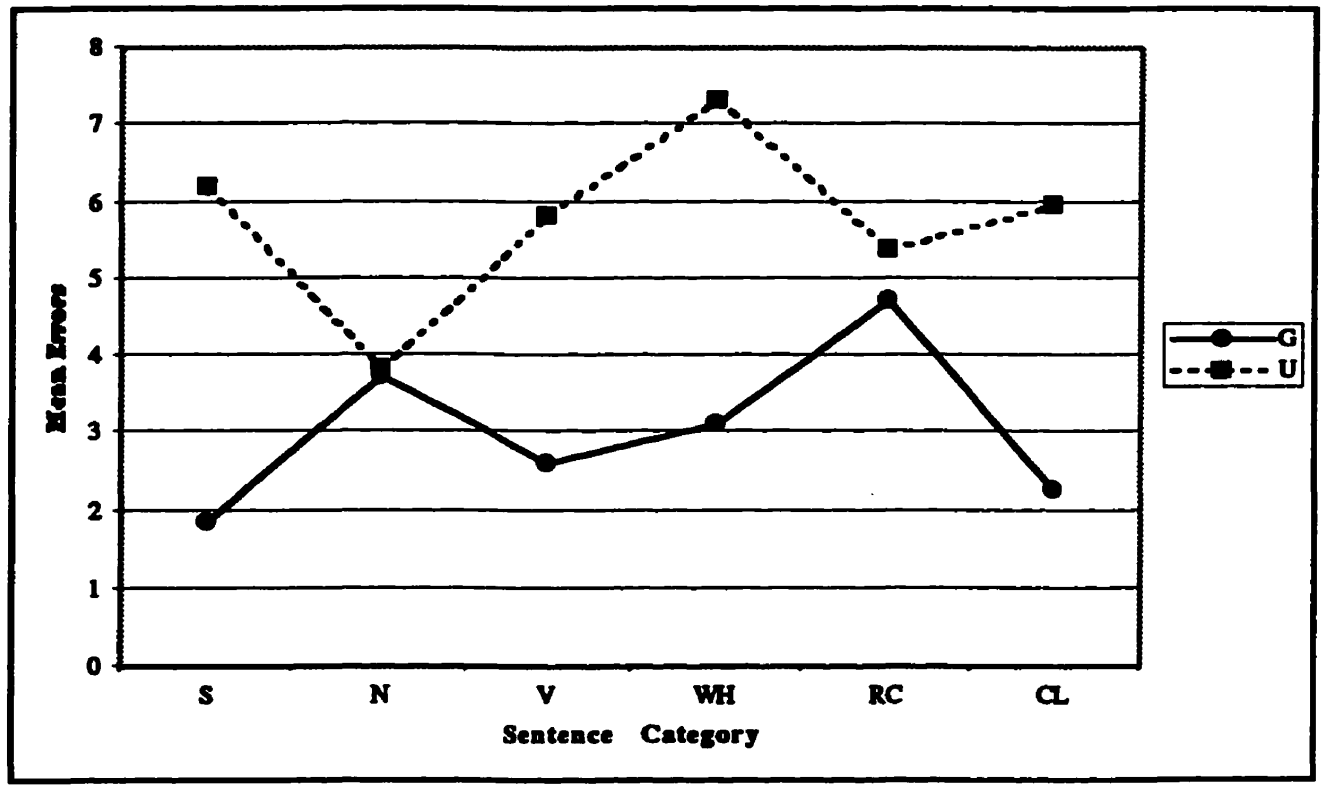


Figure 4

Sentence Category by Legality Interaction for Grammatical Judgement Latency

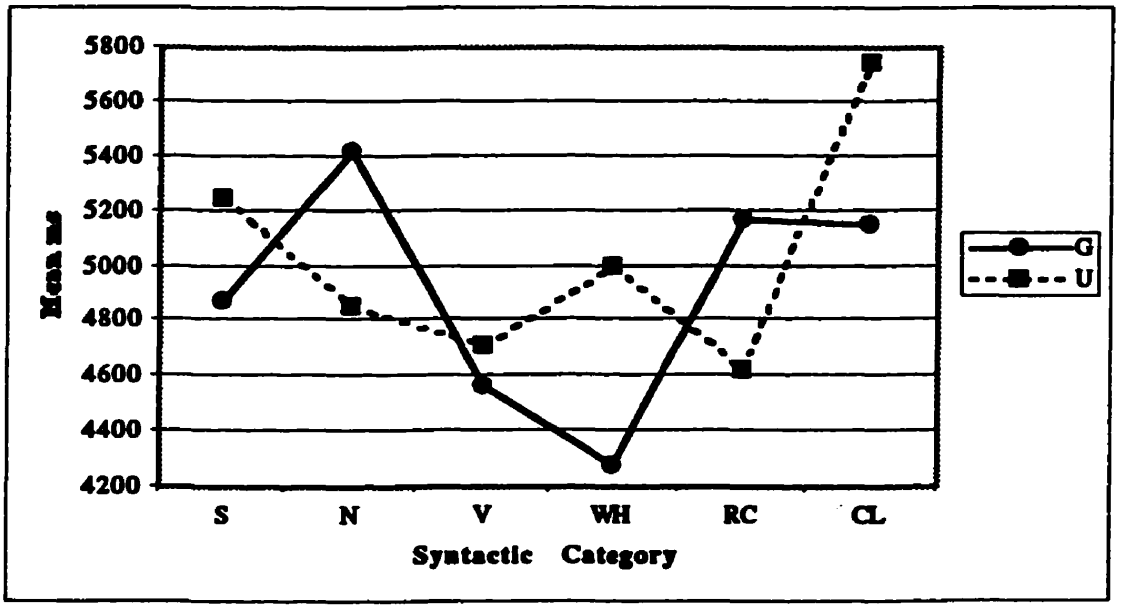


Figure 5

A' by Subject Group

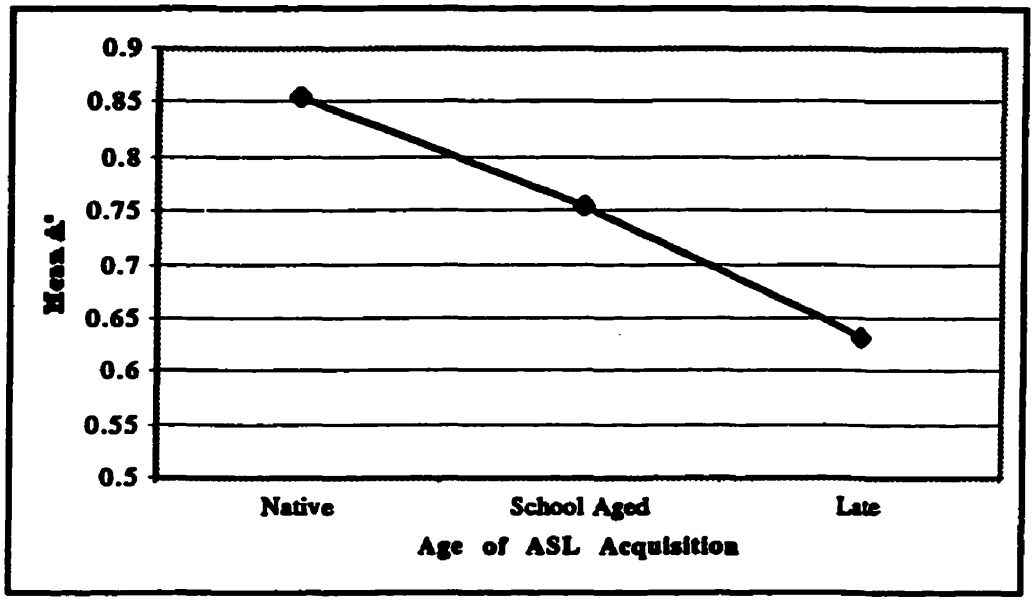


Figure 6

A' by Sentence Category

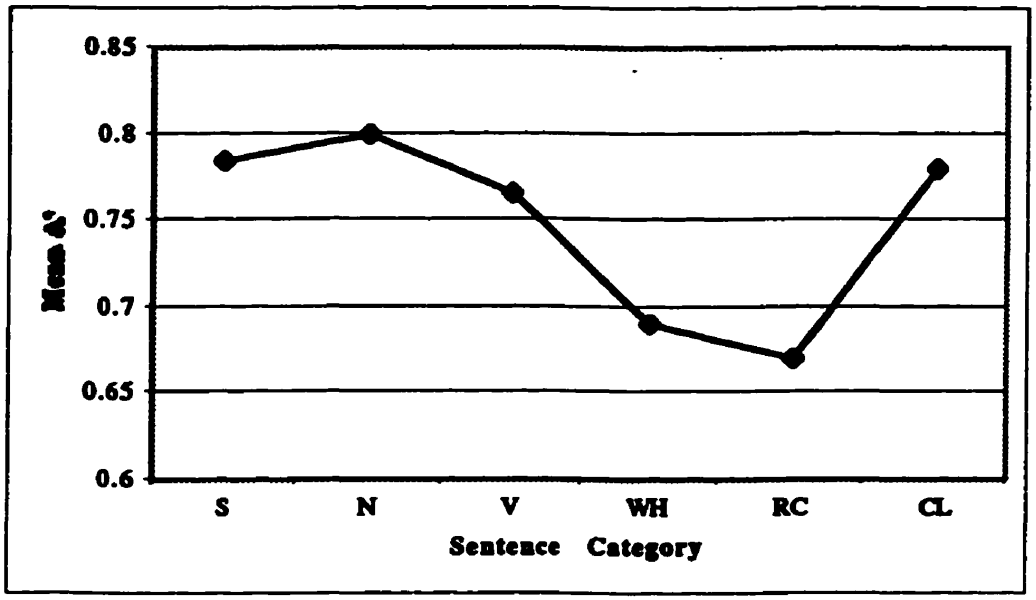


Figure 7

Response Time Normalization by Subject Group

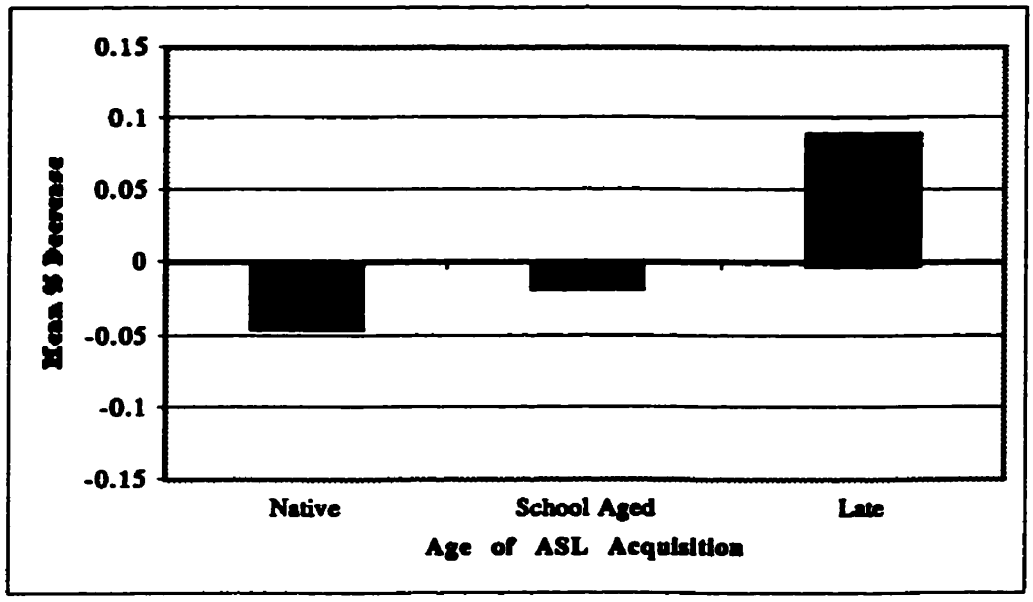
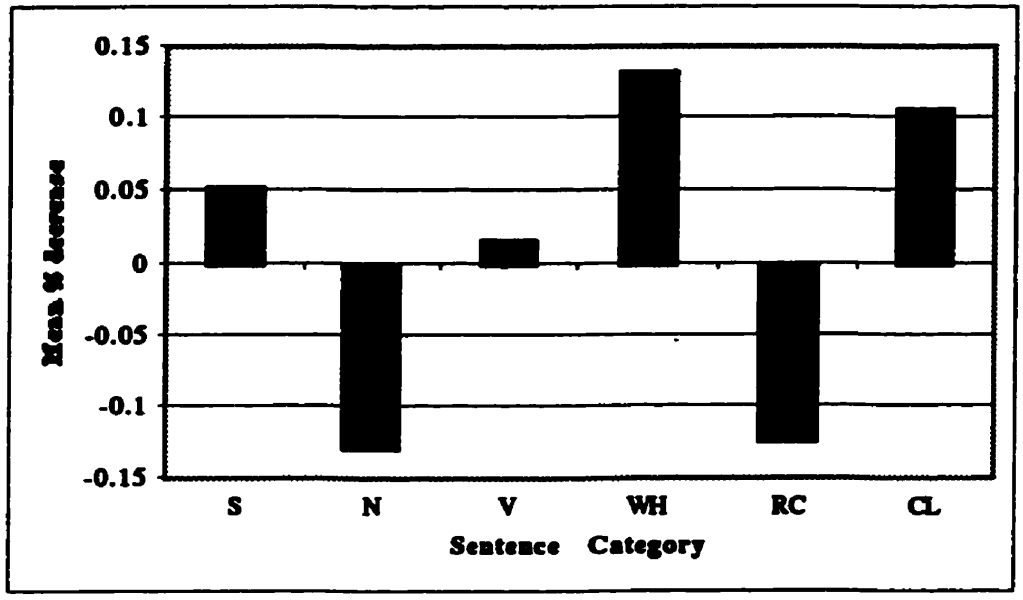


Figure 8

Response Time Normalization by Sentence Category



APPENDIX A

ASL Practice Task Stimuli

Grammatical:

	Stimuli	Verb	Verb Propretie	Morphems	Sentence Type
1	MAN TALL MAD	(IS)	Plain	3	Simple
2	BOY PT-3i GIRL PT-3j FIGHT WHY	FIGHT	Inflected	6	Wh
3	BOY BALLON BLOW	BLOW	Plain	3	Simple
4	POSS-1 SISTER NOT DRINK COFFEE	DRINK	Plain	5	Neg.

Ungrammatical:

	Stimuli	Verb	Verb Propretie	Morphems	Sentence Type
5	MAD TALL MAN	(IS)	Plain	3	Simple
6	BOY PT-3i WHY FIGHT GIRL PT-3j	FIGHT	Inflected	6	Wh
7	BALLON BLOW BOY	BLOW	Plain	3	Simple
8	POSS-1 NOT SISTER DRINK COFFEE	DRINK	Plain	5	Neg.

APPENDIX B.1

ASL Grammatical Judgement Task Stimuli

Simple Sentences Grammatical:

	Stimuli	Verbs	Verb Types	Morph
1	IN OFFICE OLD MAN WHITE HAIR THINK.	THINK	Plain	7
2	WINTER SNOW COLD WATER LAKE FREEZE	FREEZE	Plain	6
3	FOUR BOYS FROM DEAF SCHOOL CHAT	CHAT	Plain	6
4	PT-1 REMEMBER LONG-TIME-AGO GIRL LITTLE BLUE DRESS CUTE	REMEMBER	Plain	8
5	PTE-1 WORK FINISH BEER COLD DRINK	DRINK	Plain	6
6	SCHOOL FINISH GIRL YOUNG PLAY WITH DOLL	PLAY	Plain	7
7	EVERY YEAR MOST PEOPLE CELEBRATE X-MAS	CELEBRATE	Plain	6
8	DURING WAR MANY WOMEN WORK FACTORIES	WORK	Plain	7
9	SOME COLLEGE STUDENTS RUN EVERY-NIGHT	RUN	Plain	6
10	MOST BABIES HUNGRY TIRED, CRY ALL DAY	CRY	Plain	7
11	BEFORE PT-1 POOR STUDENT PT-1 WALK	WALK	Plain	6
12	COOKIE CHOCOLATE, SOMETIME MY KIDS HIDE	HIDE	Plain	6
13	WINTER ALL BEAR SLEEP UNTIL SPRING	SLEEP	Plain	6
14	OLD LADY TALL LIVE HOME ALONE WITH CAT	LIVE	Plain	8

APPENDIX B.1 (continued)

Simple Sentences Ungrammatical:

	Stimuli	Verbs	Verb Types	Morph
15	IN THINK OFFICE OLD MAN WHITE HAIR	THINK	Plain	7
16	WINTER FREEZE SNOW COLD WATER LAKE	FREEZE	Plain	6
17	FOUR BOYS FROM CHAT DEAF SCHOOL	CHAT	Plain	6
18	PT-1 LONG-TIME-AGO GIRL LITTLE BLUE REMEMBER DRESS CUTE	REMEMBER	Plain	8
19	PTE-1 DRINK WORK FINISH BEER COLD	DRINK	Plain	6
20	SCHOOL FINISH GIRL PLAY YOUNG WITH DOLL	PLAY	Plain	7
21	EVERY YEAR CELEBRATE MOST PEOPLE X-MAS	CELEBRATE	Plain	6
22	DURING WORK WAR MANY WOMEN FACTORIES	WORK	Plain	7
23	SOME COLLEGE RUN STUDENTS EVERY-NIGHT	RUN	Plain	6
24	CRY MOST BABY HUNGRY TIRED ALL DAY	CRY	Plain	7
25	BEFORE WALK PT-1 POOR STUDENT PT-1	WALK	Plain	6
26	COOKIE HIDE CHOCOLATE SOMETIME MY KIDS	HIDE	Plain	6
27	WINTER ALL BEAR UNTIL SLEEP SPRING	SLEEP	Plain	6
28	OLD LIVE LADY TALL HOME ALONE WITH CAT	LIVE	Plain	8

APPENDIX B.2

Negative Sentences Grammatical:

	Stimuli	Verbs	Verb Types	Morph	Neg. Types
29	CAR OLD WATER WIPER NOT WORK (Neg)	WORK	Plain	7	NOT
30	ALL JEWISH PEOPLE X-MAS NOT CELEBRATE (Neg)	CELEBRATE	Plain	7	NOT
31	POSS-3 WIFE NEW SWEATER NOT WEAR (Neg)	WEAR	Plain	7	NOT
32	POSS-1 HOUSE ADDRESS POSS-1 BROTHER NOT REMEMBER (Neg)	REMEMBER	Plain	8	NOT
33	TODAY YOUNG GRADUATES STUDENTS NOT STUDY (Neg)	STUDY	Plain	7	NOT
34	BOY SWEET CANDY DIFFERENTS NOT LIKE (Neg)	LIKE	Plain	7	NOT
35	KITCHEN BLUE PLATE PLEASE NOT BREAK (Neg)	BREAK	Plain	7	NOT
36	POSS-1 SON BEFORE BABY CRY (Neg)	CRY	Plain	6	Neg. Marker
37	JAIL SOME PEOPLE THIN EAT (Neg)	EAT	Plain	6	Neg. Marker
38	POSS-1 SISTER LAW ALCHOOL BEER DRINK (Neg)	DRINK	Plain	7	Neg. Marker
39	WOMAN FAT FROM WORK EXERCICE (Neg)	EXERCICE	Plain	6	Neg. Marker
40	POSS-3 UNCLE FROM WEST COOK (Neg)	COOK	Plain	6	Neg. Marker
41	KINDERGARDEN CHILDREN AGE 4 5 READ (Neg)	READ	Plain	7	Neg. Marker
42	POSS-1 GRAND-MOTHER BIKE NEW USE (Neg)	USE	Plain	6	Neg. Marker

APPENDIX B.2 (continued)

Negative Sentences Ungrammatical:

	Stimuli	Verbs	Verb Types	Morph	Neg. Types
43	Neg NOT CAR OLD WATER WIPER WORK	WORK	Plain	7	NOT
44	Neg ALL JEWISH NOT PEOPLE X-MAS CELEBRATE	CELEBRATE	Plain	7	NOT
45	Neg POSS-3 WIFE NOT NEW SWEATER WEAR	WEAR	Plain	7	NOT
46	Neg POSS-1 HOUSE NOT ADDRESS POSS-1 BROTHER REMEMBER	REMEMBER	Plain	8	NOT
47	Neg NOT TODAY YOUNG GRADUATES STUDENTS STUDY	STUDY	Plain	7	NOT
48	Neg BOY SWEET NOT CANDY DIFFERENTS LIKE	LIKE	Plain	7	NOT
49	Neg KITCHEN BLUE NOT PLATE PLEASE BREAK	BREAK	Plain	7	NOT
50	Neg_____. POSS-1 SON BEFORE BABY CRY	CRY	Plain	6	Neg. Marker
51	Neg_____. JAIL SOME PEOPLE THIN EAT	EAT	Plain	6	Neg. Marker
52	Neg_____. POSS-1 SISTER LAW ALCHOOL BEER DRINK	DRINK	Plain	7	Neg. Marker
53	Neg_____. WOMAN FAT FROM WORK EXERCICE	EXERCICE	Plain	6	Neg. Marker
54	Neg_____. POSS-3 UNCLE FROM WEST COOK	COOK	Plain	6	Neg. Marker
55	Neg_____. KINDERGARDEN CHILDREN AGE 4 5 READ	READ	Plain	7	Neg. Marker
56	Neg_____. POSS-1 GRAND-MOTHER BIKE NEW USE	USE	Plain	6	Neg. Marker

APPENDIX B.3

Directional Verb Sentences Grammatical:

	Stimuli	Verbs	Verb Types	Agreement Order	Morph	Anchor Types
57	POSS-1 SISTER CLOTHES 1-COPY-3 (+++)	COPY	Inflecting	1>3	7	Not Anch.
58	POSS-1 BEST FRIEND 2-INSULT-1	INSULT	Inflecting	2>1	6	Not Anch.
59	PTE-1 COMPUTER SALE MAN 1-CONVINCE-2	CONVINCE	Inflecting	1>2	7	Not Anch.
60	TEACHERi STUDENTj BOOK THICK 3i-BORROW-3j	BORROW	Inflecting	3>3	7	Not Anch.
61	POSS-1 DOCTOR 2-ADVISE-1 DIET	ADVISE	Inflecting	2>1	6	Not Anch.
62	OLD PEOPLEj GOVERNEMENTi 3i-HELP-2j(+++)	HELP	Inflecting	3>2	8	Not Anch.
63	MAN BALL BLUE 3-THROW-1	THROW	Inflecting	3>1	6	Not Anch.
64	MATH CLASS LARGE TEACHER 2-IGNORE-1	IGNORE	Inflecting	2>1	6	Body Anch.
65	BOYi SMALL MOMj 3j-TELL-3i THANK-YOU	TELL	Inflecting	3>3	7	Body Anch.
66	YESTERDAY SCHOOL SPANISH TEST 1-ANSWER-2(+++)	ANSWER	Inflecting	1>2	7	Body Anch.
67	POSS-1 FRIEND 3-INFORM-1 PARTY TONIGHT	INFORM	Inflecting	3>1	8	Body Anch.
68	POSS-1 NEIGHBOR DOG 2-BITE-1	BITE	Inflecting	2>1	6	Body Anch.
69	PACKAGE HEAVY PTE-1 1-SEND-3 UNCLE	SEND	Inflecting	1>3	7	Body Anch.
70	COWi FARMER-PERSONj HAY 3j-FEED-2i	FEED	Inflecting	3>2	7	Body Anch.

APPENDIX B.3 (continued)

Directional Verb Sentences Ungrammatical:

	Stimuli	Verbs	Verb Types	Agreement Order	Morph	Anchor Types
71	POSS-1 1-COPY-3 (+++) SISTER CLOTHES	COPY	Inflecting	1>3	7	Not Anch.
72	POSS-1 2-INSULT-1 BEST FRIEND	INSULT	Inflecting	2>1	6	Not Anch.
73	PTE-1 COMPUTER 1-CONVINCE-2 SALE MAN	CONVINCE	Inflecting	1>2	7	Not Anch.
74	3i-BORROW-3j TEACHERi STUDENTj BOOK THICK	BORROW	Inflecting	3>3	7	Not Anch.
75	POSS-1 2-ADVISE-1 DOCTOR DIET	ADVISE	Inflecting	2>1	6	Not Anch.
76	3i-HELP-2j(+++) OLD PEOPLEj GOVERNEMENTi	HELP	Inflecting	3>2	8	Not Anch.
77	3-THROW-1 MAN BALL BLUE	THROW	Inflecting	3>1	6	Not Anch.
78	MATH CLASS 2-IGNORE-1 LARGE TEACHER	IGNORE	Inflecting	2>1	6	Body Anch.
79	BOYi SMALL 3j-TELL-3i MOMj THANK-YOU	TELL	Inflecting	3>3	7	Body Anch.
80	1-ANSWER-2(+++) YESTERDAY SCHOOL SPANISH TEST	ANSWER	Inflecting	1>2	7	Body Anch.
81	POSS-1 3-INFORM-1 FRIEND PARTY TONIGHT	INFORM	Inflecting	3>1	8	Body Anch.
82	POSS-1 NEIGHBOR 2-BITE-1 DOG	BITE	Inflecting	2>1	6	Body Anch.
83	PACKAGE 1-SEND-3 HEAVY PTE-1 UNCLE	SEND	Inflecting	1>3	7	Body Anch.
84	COWi 3j-FEED-2i FARMER-PERSONj HAY	FEED	Inflecting	3>2	7	Body Anch.

APPENDIX B.4

Wh Sentences Grammatical:

	Stimuli	Verbs	Verb Types	Open Wh[1]	Morph	Wh Types
85	Wh___, YESTERDAY POSS-1 MOTHER BUY GLASS COLOR	BUY	Inflecting	Yes	7	Wh Marker
86	Wh___, SOUTH AFRICA SNAKES PTE-3(arc sweep) EAT GRASS?	EAT	Plain	No	8	Wh Marker
87	Wh___, FORMER TEACHER FROM UNIVERSITY TEACH SPANISH?	TEACH	Inflecting	No	7	Wh Marker
88	Wh___, SCHOOL STRIKE NEXT WEEK PRINCIPAL INFORM FINISH?	INFORM	Inflecting	No	8	Wh Marker
89	Wh___, NEW CHICKEN BURGER PTE-2 TRY FINISH PTE-2?	TRY	Plain	No	8	Wh Marker
90	Wh___, MAN TALL MUSCULAR EXERCISE EVERYDAY?	EXERCISE	Plain	No	6	Wh Marker
91	Wh___, MEDICAL SCIENCE MAGAZINE PTE-2 READ?	READ	Plain	No	6	Wh Marker
92	Wh___, THIS MORNING BOY LITTLE ij FIGHTij WHY?	FIGHT	Inflecting	Yes	8	WHY Sign
93	Wh___, SOLIDER HIGH-RANK ORDER WAR WHY?	ORDER	Inflecting	Yes	6	WHY Sign
94	Wh___, POSS-2 UNCLE J-O-B QUIT WHY?	QUIT	Plain	Yes	6	WHY Sign
95	Wh___, MANY BUSINESS BANKRUPT(+++) WHY?	(GOING)	Plain	Yes	6	WHY Sign
96	Wh___, HOCKEY CANADA RUSSIA MATCH WHO WIN?	WIN	Plain	Yes	7	WHO Sign
97	Wh___, TOMORROW POSS-2 HOME PARTY INVITE(+++) WHO?	INVITE	Inflecting	Yes	8	WHO Sign
98	Wh___, POSS-1 CLASS DEAF MAN MARRY WHO?	MARRY	Inflecting	Yes	7	WHO Sign

[1] Open Wh refers to eyebrows raised, Not open Wh (closed) refers to eyebrows furrowed.

APPENDIX B.4 (continued)

Wh Sentences Ungrammatical:

	Stimuli	Verbs	Verb Types	Open Wh[1]	Morph	Wh Types
99	Wh_____, YESTERDAY POSS-1 MOTHER BUY GLASS COLOR	BUY	Inflecting	Yes	7	Wh Marker
100	Wh_____, SOUTH AFRICA SNAKES PTE-3(arc sweep) EAT GRASS?	EAT	Plain	No	8	Wh Marker
101	Wh_____, FORMER TEACHER FROM UNIVERSITY TEACH SPANISH?	TEACH	Inflecting	No	7	Wh Marker
102	Wh_____, SCHOOL STRIKE NEXT WEEK PRINCIPAL INFORM FINISH?	INFORM	Inflecting	No	8	Wh Marker
103	Wh_____, NEW CHICKEN BURGER PTE-2 TRY FINISH PTE-2?	TRY	Plain	No	8	Wh Marker
104	Wh_____, MAN TALL MUSCULAR EXERCISE EVERYDAY?	EXERCISE	Plain	No	6	Wh Marker
105	Wh_____, MEDICAL SCIENCE MAGAZINE PTE-2 READ?	READ	Plain	No	6	Wh Marker
106	Wh_, THIS MORNING BOY WHY LITTLE ij FIGHTij?	FIGHT	Inflecting	Yes	8	WHY Sign
107	Wh_, SOLIDER WHY HIGH-RANK ORDER WAR?	ORDER	Inflecting	Yes	6	WHY Sign
108	Wh_, POSS-2 WHY UNCLE J-O-B QUIT?	QUIT	Plain	Yes	6	WHY Sign
109	Wh_, MANY WHY BUSINESS BANKRUPT(+++)?	(GOING)	Plain	Yes	6	WHY Sign
110	Wh_, HOCKEY CANADA WHO RUSSIA MATCH WIN?	WIN	Plain	Yes	7	WHO Sign
111	Wh_, TOMORROW POSS-2 WHO HOME PARTY INVITE(+++)?	INVITE	Inflecting	Yes	8	WHO Sign
112	Wh_, POSS-1 CLASS DEAF WHO MAN MARRY?	MARRY	Inflecting	Yes	7	WHO Sign

[1] Open Wh refers to eyebrows raised, Not open Wh (closed) refers to eyebrows furrowed.

APPENDIX B.5

Relative Clauses Sentences Grammatical:

	Stimuli	Verbs 1	Verbs 2	Verb Types	Morph	RC Types
113	RC RECENTLY DOG CHASE CAT COME HOME	CHASE	COME	I/P	7	RC Marker
114	RC YOUNG WOMAN PAY CASHIER HURRY	PAY	HURRY	I/P	6	RC Marker
115	RC BOY TALK WITH MAN SIT IN CAR	TALK	SIT	P/P	8	RC Marker
116	RC MOTHERi 3i-FEED-3j BABYj DRINK MILK	FEED	DRINK	I/P	8	RC Marker
117	RC ROCK BOY 3i-THROW-3j GIRLj PUNISH	THROW	PUNISH	I/P	8	RC Marker
118	RC DOG 3-BARK-3 CAT COLOR BLACK	BARK	(IS)	I/P	8	RC Marker
119	RC GIRL 3-PUSH-3 POSS-3 BROTHER ESCAPE	PUSH	ESCAPE	I/I	8	RC Marker
120	RC TEACHERj 3-3 DISPUTE-3 GIRLi THATj STRICT	DISPUTE	(IS)	I/P	8	THAT Sign
121	RC CATi 3-STARE-3 MOUSEj THATi IGNORE BIRD	STARE	IGNORE	I/I	9	THAT Sign
122	RC MANi 3-CALL-3 FRIENDj THATi CRY	CALL	CRY	I/P	8	THAT Sign
123	RC SUPERVISORi COUNT CHILDRENS ITSELFi READ BOOK	COUNT	READ	P/P	7	ITSELF Sign
124	RC MANi GIRLj PLAY BALL THATi FALL	PLAY	FALL	P/P	8	THAT Sign
125	RC WIFEi 3-ADVISE-3 HUSBANDj THATi TEACH ENGLISH	ADVISE	TEACH	I/I	9	THAT Sign
126	RC MONKEYi 3-TEASE-3 BOYj THATi LAUGH	TEASE	LAUGH	I/P	8	THAT Sign

APPENDIX B.5 (continued)

Relative Clauses Sentences Ungrammatical:

	Stimuli	Verbs 1	Verbs 2	Verb Types	Morph	RC Types
127	COME HOME RECENTLY DOG CHASE CAT	CHASE	COME	I/P	7	RC Marker
128	HURRY YOUNG WOMAN PAY CASHIER	PAY	HURRY	I/P	6	RC Marker
129	SIT IN CAR BOY TALK WITH MAN	TALK	SIT	P/P	8	RC Marker
130	DRINK MILK MOTHERi 3i-FEED-3j BABYj	FEED	DRINK	I/P	8	RC Marker
131	PUNISH ROCK BOY 3i-THROW-3j GIRLj	THROW	PUNISH	I/P	8	RC Marker
132	COLOR BLACK DOG 3-BARK-3 CAT	BARK	(IS)	I/P	8	RC Marker
133	ESCAPE GIRL 3-PUSH-3 POSS-3 BROTHER	PUSH	ESCAPE	I/I	8	RC Marker
134	TEACHERj 3-3 DISPUTE-3 THATj GIRLi STRICT	DISPUTE	(IS)	I/P	8	THAT Sign
135	CATi 3-STARE-3 THATi MOUSEj IGNORE BIRD	STARE	IGNORE	I/I	9	THAT Sign
136	MANi 3-CALL-3 THATi FRIENDj CRY	CALL	CRY	I/P	8	THAT Sign
137	SUPERVISORi COUNT ITSELFi CHILDRENS READ BOOK	COUNT	READ	P/P	7	ITSELF Sign
138	MANi GIRLj PLAY THATi BALL FALL	PLAY	FALL	P/P	8	THAT Sign
139	WIFEi 3-ADVISE-3 THATi HUSBANDj TEACH ENGLISH	ADVISE	TEACH	I/I	9	THAT Sign
140	MONKEYi 3-TEASE-3 THATi BOYj LAUGH	TEASE	LAUGH	I/P	8	THAT Sign

APPENDIX B.6

Classifier Sentences Grammatical:

	Stimuli	Verbs (Motion)	Ground	Figure	Morph
141	TREE CL:/5/i CAR CL:/3/j [PASS-BY]	PASS	TREE[2]	CAR[1]	7
142	CAR YELLOW CL:/3/i BLUE CL:/3/j [PARALLEL PARK]	PARK	CAR_i[1]	CAR_j[1]	9
143	ROPE MONKEY CL:/1/i CL:/Vc/i [SWING]	SWING	ROPE[3]	MONKEY[1]	6
144	HAY CL:/5c/i COW CL:/Vc/j [WALKING AROUND]	WALK	HAY[3]	COW[1]	7
145	MOUNTAIN CL:/B+B/i [PATH] CL:/V/i [CLIMB THE HILL]	CLIMB	MT.[3]	CLIMBER[1]	7
146	STEEL POLE CL:/1/i BICYCLE CL:/3/ - /3^{C}/i [HIT]	HIT	POLE[3]	BIKE[1]	8
147	SMALL BOAT CL:/B/i WATER CL:/S-5/ji [WAVE SPLASH BOAT]	SPLASH	BOAT[2]	WAVE[3]	9
148	COMPUTER CL:/1+1/ [SCREEN] NUMBER CL:/4+4/ [RUN DATA]	RUN	SCREEN[3]	DATA[3]	7
149	OFFICE LIGHT CL:/F+F/i DOORBELL CL:/O-5/i [FLASHING]	FLASH	LIGHT[3]	LIGHT[3]	9
150	CHAIR CL:/Vc/i RED BALL CL:/C/ij [BOUNCED ON CHAIR]	BOUNCE	CHAIR[2]	BALL[2]	9
151	RAIN CAR CL:/C+C/ [BIG] CL:/1+1/ [WIPE WINDSHIELD]	WIPE	CAR[1]	WIPER[3]	7
152	BIG WHITE HOUSE CL:/5c/i CL:/1/ [PASS BY]	PASS	HOUSE[2]	HUMAN[1]	8
153	GARBAGE CL:/C+C/ [CAN] MOUSE CL:/Vc/ [CLIMB INSIDE]	CLIMB	GARBAGE[3]	MOUSE[1]	7
154	LITTLE GIRL CL:/1/i PICTURE CL:/0-5/j [FLASH PICTURE]	PICTURE	GIRL[1]	FLASH[3]	8

[1] CLASS: Animate, Vehicle
[2] CLASS: Inanimate, Object
[3] SASS

APPENDIX B.6 (continued)

Classifier Sentences Ungrammatical:

	Stimuli	Verbs (Motion)	Ground	Figure	Morph
155	CL:/3/j [PASS BY] TREE CL:/5/i CAR	PASS	TREE[2]	CAR[1]	7
156	CAR BLUE CL:/3/j [PARALLEL PARK] YELLOW CL:/3/i	PARK	CAR_i[1]	CAR_j[1]	9
157	CL:/1/i MONKEY ROPE CL:/Vc/i [SWING]	SWING	ROPE[3]	MONKEY[1]	6
158	CL:/Vc/j [WALKING AROUND] HAY CL:/5c/i COW	WALK	HAY[3]	COW[1]	7
159	CL:/V/i [CLIMB THE HILL] CL:/B+B/i [PATH] MOUNTAIN	CLIMB	MT.[3]	CLIMBER[1]	7
160	BICYCLE CL:/3/ - /3[C]/i [HIT] STEEL POLE CL:/1/i	HIT	POLE[3]	BIKE[1]	8
161	SMALL BOAT CL:/S-5/ji [WAVE SPLASH BOAT] WATER CL:/B/i	SPLASH	BOAT[2]	WAVE[3]	9
162	NUMBER CL:/1+1/ [SCREEN] COMPUTER CL:/4+4/ [RUN DATA]	RUN	SCREEN[3]	DATA[3]	7
163	CL:/O-5/i [FLASHING] OFFICE LIGHT CL:/F+F/i DOORBELL	FLASH	LIGHT[3]	LIGHT[3]	9
164	CL:/Vc/i RED CL:/C/ij [BOUNCED ON CHAIR] BALL CHAIR	BOUNCE	CHAIR[2]	BALL[2]	9
165	CL:/1+1/ [WIPE WINDSHIELD] RAIN CL:/C+C/ [BIG] CAR	WIPE	CAR[1]	WIPER[3]	7
166	CL:/5c/i BIG WHITE CL:/1/ [PASS BY] HOUSE	PASS	HOUSE[2]	HUMAN[1]	8
167	CL:/Vc/ [CLIMB INSIDE] GARBAGE MOUSE CL:/C+C/ [CAN]	CLIMB	GARBAGE[3]	MOUSE[1]	7
168	LITTLE CL:/1/i GIRL CL:/0-5/j [FLASH PICTURE] PICTURE	PICTURE	GIRL[1]	FLASH[3]	8

[1] CLASS: Animate, Vehicle
[2] CLASS: Inanimate, Object
[3] SASS

Appendix C

McGill

Subject Background Questionnaire

Subject Code_____

Date of Birth (Year/Month/Date) _____

Age _____

Sex (circle one): M F

"What hand do you write with? All the time?"

Handedness (circle one): R L

Age of first contact with sign language _____

"What was the contact?" _____

Length of sign language experience

(Current age minus age of first contact:_____)

Communication in education:

"What type of school did you attend?"

Oral T/C sign hearing (write one in each category)

Preschool _____

Elementary K to 6 _____

Middle School 7 to 8/9 _____

High School 8/9 to 11/12 _____

Highest level of schooling:

High school ____

Vocational training ____

College (years) _____

Communication Background:

"How do you communicate with:"

Oral sign gesture writing (write one in each category)

Parents _____

Hearing people_____

Close friends_____

People at work _____

"Do you use a hearing aid? None One Two (Circle one)

"How well do you understand"

(0 to 5; 0 means not at all; 5 means excellent)

Write one number in each space below

Sign language_____

Fingerspelling _____

Speech (only speech) _____

Reading _____

"Would you be willing to be contacted for future research projects?"

YES NO (circle one)

"How do you prefer to be contacted?"

Phone/TTY Fax Email Letter (Circle one)

Phone_____

Fax_____

Email_____

Mailing address:

Research Group: Native Early Late (circle one)

Appendix D

McGill

INFORMED CONSENT

Title of Research Project:

"Critical period effects on first and second language acquisition"

Name of Participant:_____

Sponsor: Natural Sciences and Engineering Research Council of Canada

PRINCIPAL INVESTIGATOR: Dr. Rachel Mayberry
Mr. Patrick Boudreault
Name of Institution: McGill University
(514) 398-8393 TTY or voice

You are being asked to volunteer in a research project about sign language skills. Before you decide, we will explain the purpose of the study and what you are expected to do. You can watch this information in sign language on videotape if you want.

YOUR PARTICIPATION IS VOLUNTARY

This form gives you information about the study. After you read it and want to volunteer, you need to sign your name on the last page. A copy of this information will be given to you.

Please remember:

- Participating is completely voluntary
- You can decide to stop at any time. You will still be paid for your time.

PURPOSE OF THE STUDY

The purpose of this project is to study language skills in deaf and hearing adults who use sign language to communicate. People learn sign language in different ways. We would like to understand how differences in learning affect language comprehension. To understand this, we need to test different aspects of language comprehension. This information will help us to design better methods for teaching languages to children and adults.

PROCEDURES

The study will involve one, one and a half-hour session. For the task you will see sign language sentences on the computer screen. You will decide if the sentences are correct or not. You will be given a rest break.

RISKS

There are no known risks to you.

BENEFITS

There will be no specific benefits to you personally, but there will be benefit to the future education of deaf children and adults in the area of language teaching.

COSTS TO YOU

There are no costs to you. You will be reimbursed for your time.

CONFIDENTIALITY

All results of this study will be kept strictly confidential. You will be identified by a code, so your name will not appear on any of the reports. You will not be personally identified in any future publications or presentations about this study.

PROBLEMS OR QUESTIONS

If you have any questions about this study, please feel free to contact us at any time.

Rachel Mayberry, Ph.D. (514) 398-4141 (v)
Patrick Boudreault
Lab (514) 398-8123 (v/ttd)
Fax (514) 398-8123

VOLUNTEER STATEMENT AND SIGNATURE

I understand the purpose and procedures of this study and agree to volunteer. I understand that I can withdraw from the study at any time and will still be reimbursed for my time and travel costs.

_____	_____	_____
Name (please print)	Signature	Date
_____	_____	_____
Investigator's name	Investigator's signature	Date