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Grammatical processing in American Sign Language: Age of first-language acquisition effects in relation to syntactic structure

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Sentence processing in American Sign Language (ASL) was investigated as a function of age of first language acquisition with a timed grammatical judgement task. Participants were 30 adults who were born deaf and first exposed to a fully perceptible language between the ages of birth and 13 years. Stimuli were grammatical and ungrammatical examples of six ASL syntactic structures: simple, negative, agreement verb, wh-question, relative clause and classifier sentences. As delay in exposure to a first language increased, grammatical judgement accuracy decreased, independent of ASL syntactic structure. The signers were less accurate and responded more slowly to ungrammatical as compared with grammatical stimuli, especially the early and delayed first-language learners in comparison to the native learners. The results held across grammaticised facial expressions, signed markers and verb type. These results, in conjunction with previous findings, indicate that the onset of first language acquisition affects the ultimate outcome of syntactic knowledge for all subsequent language acquisition.

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Whether and how variation in age of acquisition affects ultimate language attainment and processing is a complex question with important theoretical and applied ramifications. One situation that frequently produces significant delays in the age when children are first exposed to perceptible language is congenital deafness (Mayberry, 1994, 2002). Several studies have found that the delayed exposure to language associated with congenital deafness affects the ability to comprehend and produce sign language in adulthood (Emmorey, Bellugi, Friederici, & Horn, 1995; Mayberry & Eichen, 1991; Mayberry & Fischer, 1989; Newport, 1990). Nonetheless, our understanding of the phenomenon remains fragmentary. How does the onset of linguistic experience affect language processing in adulthood? The goal of the present study is to investigate how age of American Sign Language (ASL) acquisition affects grammatical processing of syntactic structures in adulthood. Before explaining the study, we describe the research leading to it.

The age when spoken, second languages are learned varies widely in the population. Numerous studies have capitalised on this situation to investigate whether age of acquisition (AoA) affects the outcome of second-language learning (for example, see Birdsong, 1999). Research results arising from this paradigm are contradictory, however. Some studies have found large effects associated with AoA (e.g., Johnson & Newport, 1989) while other studies have found few or negligible effects (e.g., Flege, Yeni-Komshian, & Liu, 1999). Factors such as the linguistic relationship of the first language to the second one, and the extent to which the second language is used in schooling account for some of the conflicting results (Birdsong & Molis, 2001; for a review see Mayberry & Lock, 2003).

Learning a second language is different from the acquisition of ASL by individuals who are born deaf in at least two important ways. The first, and most obvious, factor is that the sensory and motor modalities of ASL are visual and manual in contrast to the aural and oral modalities of spoken languages (although there are visual components in speech perception and reading). If the effects of AoA on language processing originate in the auditory and oral modalities and brain centres that integrate and interpret this sensory and motor information, then the acquisition and processing of sign languages should not show AoA effects. However, research has not found this to be the case.

Mayberry and Fischer (1989) found ASL narrative-shadowing accuracy to decrease as a linear function of increasing age of ASL acquisition. The same patterns characterised performance on ASL sentence shadowing and recall accuracy. Mayberry and Eichen (1991) further found that the recall errors for syntactically complex ASL sentences increased as a linear function of age of ASL acquisition. The linguistic type of lexical and morphological errors were also highly sensitive to AoA. Later learners tended to make lexical substitutions that were phonological in nature and strip inflections from verbs, whereas earlier learners tended to make semantic substitutions and alter verb inflections or lexicalise them. On a battery of expressive and receptive tests, Newport (1990) found performance on a number of ASL syntactic structures to decline with increasing age of ASL acquisition with the exception of basic word order. Finally, Emmorey, Bellugi, Friederici, and Horn (1995) investigated AoA effects on ASL verb-agreement and temporal aspect inflections. On a sign monitoring task, native learners were sensitive to verb agreement and temporal aspect inflections, but early and late learners were sensitive only to temporal aspect. AoA showed no effects on a grammaticality judgement task.

The less obvious and second contrast between ASL acquisition by individuals who are born deaf and second-language learning by individuals who hear normally is that ASL is typically acquired as a delayed *first* language (L1) rather than as a *second* language (L2). This discrepancy arises from the nature of the language environment of babies who are born hearing and those born deaf. Babies born with normal hearing are immersed in spoken language nearly without exception. Babies born severely (> 70–89 dB) or profoundly (> 90 dB) deaf are isolated from spoken language. Unless the parents use sign language (i.e., < 10% of the parents of children who are deaf; Schein & Delk, 1974), most children who are born deaf are not exposed to a sign language until their deafness is diagnosed and they receive special services and/or enroll in a school that uses some form of sign language, or seek out sign language themselves. The confluence of these social and biological factors means that many children who are born severely or profoundly deaf first experience a fully perceptible language at ages much older than is typical for children who hear normally (Mayberry, 1994, 2002). Thus, variation in age of ASL acquisition often, but not always, constitutes variation in age of L1 acquisition rather than L2 learning.

Previous research has found the ultimate outcome of delayed L1 and L2 acquisition to be quite different. Mayberry (1993) compared the recall of syntactically complex ASL sentences by individuals who were first exposed to sign language between the ages of 9 and 13 after little previous language acquisition (because they were born profoundly deaf and exposed to sign language only in late childhood) to that of individuals who were exposed to ASL as a L2 at the same age. The L2 learners' grammatical recall of ASL was significantly more accurate than that of the delayed L1 learners, showing that AoA has greater effects on the outcome of L1 compared with L2 acquisition (Mayberry, Lock, & Kazmi, 2002).

These findings suggest that early L1 acquisition is necessary for subsequent L2 learning to be successful. Mayberry and Lock (2003) tested this hypothesis by investigating the English syntactic processing of four groups of adults who had had contrasting types of early L1 and L2 experience. One *hearing* group was exposed to English from birth while another *hearing* group was first exposed to a variety of spoken languages other than English from birth; they subsequently learned English as a L2 in school when they immigrated to Canada. One *deaf* group was exposed to ASL from birth and subsequently learned English as a L2 in school at the same ages as the *hearing* L2 group. The second *deaf* group was exposed to scant perceptible language in early childhood, because they were exposed only to spoken language which they could neither hear nor lip-read, and first began to learn ASL and English in schools that used sign language at the same ages as the two L2 groups, one *deaf* and one *hearing*. Mayberry and Lock (2003) investigated the groups' grammatical judgements of five English syntactic structures. The structures varied with respect to the age when hearing children typically master them over the course of English development, namely, simple, dative and conjoined structures that are typically acquired at earlier ages in comparison to passive and relative clause structures, which are fully mastered at older ages.

As predicted by the hypothesis, the two groups of *second* language learners, *deaf* and *hearing* (whose first languages were *signed* or *spoken*) performed at near-native levels across the English syntactic structures. As also predicted, the delayed L1 group showed low performance levels on the English syntactic structures. When the task was switched from grammatical judgement to sentence-to-picture matching, the performance of the delayed L1 learners improved, but only for the early-acquired structures (simple, dative, and conjoined) and not for the later-acquired structures, passive and relative clause. These findings show that successful L2 learning is contingent upon early L1 acquisition. The findings also suggest that delayed L1 effects may vary as a function of syntactic structure and task.

Although previous research has garnered several findings about the effects of delayed L1 acquisition on ultimate language attainment, additional research is required about how it affects subsequent language acquisition. The goal of the present study was to extend the Mayberry and Lock (2003) findings for English to ASL in order to unify this set of findings. Here we use a timed, grammatical judgement task to investigate the effects of delayed L1 acquisition on the processing of selected ASL syntactic structures.

The English structures used in Mayberry and Lock (2003) ranged from earlier to later developing over the course of English acquisition. For the present study, we selected ASL structures that previous research has shown to be mastered relatively earlier and later over the course of ASL acquisition, by which we mean children exposed to ASL from birth (for reviews see Lillo-Martin, 1999; Schick, 2003).

Earlier acquired ASL structures are simple sentences with uninflected signs, negation, and agreement verbs (Mayberry & Squires, in press). Research has found negation and verb agreement to be acquired between 18–36 months in ASL (Anderson & Reilly, 1997, 2002; Meier, 1987) and word order to be acquired by 30 months (for Sign Language of the Netherlands, Coerts, 2000, and ASL, Pichler, 2002). These structures entail basic sentence structure, manual and non-manual negation, and agreement inflections for a subset of ASL verbs.

Relatively later acquired ASL structures are wh-questions, relative clause structures, and classifier predicates (Mayberry & Squires, in press). Although children use elements of these structures at very young ages (Anderson & Reilly, 2002), acquisition of wh-questions and classifier predicates is protracted and not mastered until 4–9 years of age, especially the varieties of word order in wh-questions, the control of non-manual markers, and the control of two hands moving through space in classifier predicates (Lillo-Martin, 2000; Schick, 1990; Supalla, 1982). Because Mayberry and Lock (2003) used English relative clause structures, we included ASL relative clause structures in the present study. Like wh-questions and classifier predicates, relative clauses are probably acquired at older ages in ASL acquisition, although no research to date has investigated the question. Reilly, Bellugi, and McIntyre (1990) investigated the acquisition of conditional structures in ASL and found children to comprehend the manual and non-manual forms of conditionals by 6 years and correctly produce the two forms by 8 years. Similar to relative clause structures, ASL conditionals involve joining two clauses with either manual signs or grammaticised facial expression. Thus, the three selected ASL structures that are mastered relatively later in ASL acquisition, wh-questions, classifier predicates, and relative clauses, involve multiple linguistic units that must be learned and coordinated, including basic sentence structure, movement rules, knowledge of manual and non-manual syntactic markers, subordination, and the coordination of two hands moving through space instantiating multiple syntactic and semantic roles.

In the present study, we ask whether AoA has differential effects on the grammatical processing of earlier as compared with later acquired ASL syntactic structures. This design allows us to integrate the present results with previous findings about the effects of delayed L1 on acquisition of English syntax. To this end, we presented grammatical and ungrammatical examples of six selected ASL structures (simple, negative, and agreement verb sentences, and wh-questions, relative clause and classifier sentences) to adults who were born deaf, used ASL as a primary language, and first began to learn it at ages ranging from birth to late childhood.

METHODS

Participants

Thirty adults who were born severely or profoundly deaf were recruited into the study from the deaf communities of Quebec and Ontario. All participants reported ASL to be their primary language, which they had used daily for a minimum of 12 years. No participant reported successful acquisition of a spoken language prior to learning ASL and none reported the ability to navigate everyday life through exclusive use of speech and speech-reading. Not only was ASL the primary language of all the participants, but also their first exposure to it reflects their initial experience with a language they could fully perceive because they were born profoundly deaf and could not hear the details of spoken language even with hearing aids. It is important to note that the participants are *not* L2 learners of ASL but rather L1 learners (Mayberry, 1993; Mayberry & Lock, 2003; Mayberry et al., 2002). The participants were placed in three groups according to age of first exposure to ASL, as described below and shown in Table 1.

Native learners. Six men and four women first acquired ASL from birth from their Deaf parents and served as the native controls, henceforth NC. According to self-report, all participants were right-handed except one who was left-handed and another who was ambidextrous. Eight participants were enrolled in post-secondary studies; one participant had post-secondary vocational training.

TABLE 1
Background characteristics of the participants

Age of ASL acquisition	*n*	*Females/ males*	*Mean age of ASL exposure (range)*	*Mean years of ASL use (range)*	*Mean chronological age (range)*
Native learners	10	4/6	Birth 0	24.3 (18–41)	24.2 (18–41)
Early ASL learners	10	3/7	5.6 (5–7)	37.6 (14–47)	43.2 (31–62)
Delayed L1 learners	10	6/4	10.3 (8–13)	32.9 (13–71)	43.0 (24–79)

Early learners. Seven men and three women were exposed to ASL when they first enrolled in a school for deaf children between the ages of 5 and 7 years. No participant had acquired spoken English prior to school enrolment. Thus, this group is called the *early language learners*, henceforth, early L1. All participants were right-handed except for one who was ambidextrous. These subjects had academic backgrounds similar to the NC group.

Delayed first-language learners. Four men and six women were exposed to ASL when they first enrolled in a school for deaf children where sign was used between the ages of 8 and 13 years. They had previously attended schools for deaf children using an "oralist" approach that did not expose them to, or allow them to use, any form of sign language. According to self-report, none of these participants was able to navigate daily life through the use of spoken language either receptively or expressively. This group is called the *delayed first-language learners*, henceforth, delayed L1. All these participants were right-handed. They had educational backgrounds similar to the other two groups.

Previous ASL experience. Length of ASL experience was computed by subtracting chronological age at the time of testing from age of first exposure to ASL. Mean length of ASL use was 24.2 years, 37.5 years, and 32.8 years respectively for the NC, early and delayed L1 groups. There were no significant differences among the groups for mean years of ASL experience, as shown by a one-way ANOVA with three levels of years of use, $F(2, 27) = 1.74$, *ns*.

ASL stimuli

The stimuli were grammatical and ungrammatical examples of six ASL syntactic structures ranging from early to later acquired, namely (1) simple and (2) negative sentences, (3) sentences containing agreement verbs, (4) wh-questions, (5) relativised sentences, and (6) classifier sentences. ASL classifier constructions are complex predicates that describe motion, spatial relations, object size, shape and location, and animate handling of inanimate objects. Of the ASL structures investigated here, classifier constructions are the least understood (see Emmorey, 2002). To ensure that syntactic structure, and not sentence length, was the major factor that varied across the syntactic structures, all stimuli were 6–9 morphemes in length, counting grammaticised facial expressions (as explained below) as morphemes. All sentences contained one verb, except for relativised and classifier sentences, which included two verbs, one in each of two clauses (not counting adjectives twice as predicates). For simple and negative sentences, only plain verbs were used, i.e., verbs that do not take person and number inflections. For sentences with agreement verbs, only agreement verbs were used (Padden, 1981, 1983, 1990; Supalla, 1982). For the remaining syntactic structures, the distribution of agreement and plain verbs was balanced. Finally, only highly familiar signs were used. The stimuli contained no finger-spelling with the exception of two familiar lexicalised, finger-spelled loan words, D-O-G and J-O-B, which function as signs in ASL (Battison, 1978). Fourteen grammatical examples and 14 ungrammatical counterparts were created for each of the six ASL syntactic structures for a total of 168 stimuli.

The first author, a native learner of LSQ (Langue des signes québecoise) and L2 learner of ASL who is deaf, created the grammatical and ungrammatical counterparts for each syntactic structure. The stimuli were reviewed by a second signer, a native learner of ASL and L2 learner of LSQ, who is deaf. The goal in creating the ungrammatical stimuli was to produce a grammatical violation that ASL native learners readily recognised as being unacceptable in ASL and not to test competing hypotheses about how various ASL syntactic structures are instantiated. We acknowledge, however, that the delineation of ASL syntax is a young field and that linguists disagree about the rules of ASL syntax, including the structures investigated here.

The first step was creation of the grammatical exemplars of the ASL syntactic structures. Next, a violation of the syntactic rule was selected and applied across the grammatical exemplars in the same fashion to produce ungrammatical counterparts. After the potential stimulus set was created, independent grammatical assessments were elicited from three native ASL learners not involved in the stimuli creation. Only stimuli that all three judges unanimously agreed were clearly grammatical and ungrammatical were used in the final experiment. The ASL syntactic structures are explained below and given in Tables 2 and 3.

Simple sentences. Simple sentences consisted of uninflected signs and contained adjectives and adverbial phrases. All verbs were plain and thus contained no agreement inflections. The sentences used no grammaticised facial expressions, as none were required. No spatial loci were used except for the first person-singular pronoun, PT-1. No classifiers were used. The simple ASL sentences were from 6–8 morphemes in length ($M = 6.6$). The grammatical sentences were made ungrammatical with a sign order violation applied in the same fashion across all the simple sentences by moving the verb to an incorrect position in the sentence.

Negative sentences. Negative sentences consisted of uninflected signs and only plain verbs were used. No spatial loci were used except for the

TABLE 2
Examples of the grammatical ASL syntactic structures

Syntactic structure	*Grammaticised facial expression*	*Example*[1]
Simple	None	FOUR BOYS FROM DEAF SCHOOL CHAT Four boys from the school for the deaf are chatting.
Negative	NOT Sign	Neg . CAR OLD WATER WIPER NOT WORK The old car's windshield spritzer doesn't work.
	Negative Facial Marker	Neg . JAIL SOME PEOPLE THIN EAT Some thin people in jail don't eat.
Agreement Verb	None	MAN BALL BLUE 3-THROW-1 The man was thrown the blue ball.
Question	Facial Marker	Quest? . MEDICAL SCIENCE MAGAZINE PTE-2 READ? Do you read medical science journals?
	WHY and WHO Sign	Wh . POSS-2 UNCLE J-O-B QUIT WHY? Why did your uncle quit his job?
Relative Clause	Topicalisation Facial Marker	RC . RECENTLY DOG CHASE CAT COME HOME The dog that recently chased the cat came home.
	THAT and ITSELF Sign	RC . MANi 3-CALL-BY-TTY-3 FRIENDj THATi CRY The man who was crying called a friend.
Classifier	None	ROPE MONKEY CL:/1/i CL:/Vc/i [SWING] The monkey swings on a rope trapeze.

[1] The first line in capital letters gives a gloss for the ASL stimuli. Grammaticised facial expressions and their scope are noted above the gloss. Person inflections are shown with hyphenated numbers and locative inflections are indicated with the appended letters *i* and *j*. English translations are given below the ASL gloss.

first and third, singular possessive pronouns, POSS-1 and POSS-3. No classifiers were used. Two types of negative markers were used, signed versus grammaticised facial expressions, which are considered to have equivalent syntactic status (Anderson & Reilly, 1997; Klima & Bellugi, 1979; Liddell, 1980). The sign NOT was placed before the verb or the negative grammaticised facial expression [headshake] co-occurred with the verb without the NOT sign. Half of the sentences used the NOT sign and half used the negative facial morpheme. The negative sentences were from 6–8 morphemes ($M = 6.7$) in length. The grammatical negative sentences were made ungrammatical by separating the NOT sign from the verb, or

TABLE 3
Examples of the ungrammatical ASL syntactic structures

Syntactic structure	*Grammaticised facial expression*	*Example*[1]
Simple	None	FOUR BOYS FROM CHAT DEAF SCHOOL The four boys from chatting a deaf school.
Negative	NOT Sign	Neg NOT CAR OLD WATER WIPER WORK Doesn't the car old spritzer windshield work.
	Negative Facial Marker	Neg . JAIL SOME PEOPLE THIN EAT Don't in jail some people thin eat.
Agreement verb	No	3-THROW-1 MAN BALL BLUE He throws me the man the ball blue.
Question	Question Facial Marker	Quest? . MEDICAL SCIENCE MAGAZINE PTE-2 READ? Medical science journals read you?
	WHY and WHO Sign	Wh . POSS-2 WHY UNCLE J-O-B QUIT? Your why uncle job quit?
Relative clause	Topicalisation Facial Marker	RC . COME HOME RECENTLY DOG CHASE CAT Come home recently the dog chased the cat.
	THAT and ITSELF Sign	RC . MANi 3-CALL-BY-TTY-3 THATi FRIENDj CRY The man called him who friend crying.
Classifier	None	CL:/1/i MONKEY ROPE CL:/Vc/i [SWING] The trapeze the monkey the rope swings.

[1] The first line in capital letters gives a gloss for the ASL stimuli. Grammaticised facial expressions and their scope are indicated above the gloss. Person inflections are shown with hyphenated numbers and locative inflections are indicated with the appended letters *i* and *j*. Because these are examples of the ungrammatical ASL stimuli, the English translations given below the gloss are approximate only.

separating the negative facial morpheme [headshake] from the verb, and placing it with the first noun phrase.

Agreement-verb sentences. Agreement-verb sentences contained verbs inflected for person and number. No classifiers were used. Two types of agreement verbs were used: (1) body-anchored verbs were used in half of the sentences and (2) unanchored verbs were used for the remainder (Meier, 1987; Padden, 1981; Padden, 1983). In body-anchored verbs, the place of articulation is at the body (face, arms, or torso); some of these verbs can take inflections and some cannot, whereas all unanchored agreeing verbs take person and number inflections. The inflections used were person (first, second, and third) all in singular form. These sentences were from 6–8 morphemes ($M = 6.8$) in length. The grammatical, agreement-verb sentences were all rendered ungrammatical with a sign-order violation by moving the verb phrase (i.e., verb + person/number inflection) to another phrase.

Wh-questions. Wh-question sentences consisted of uninflected signs and a question marker and no classifiers. Half the verbs were agreement and half were plain. There were two types of question markers. (1) The signs WHY and WHO were used for the half of the sentences along with the obligatory grammaticised facial expression. (2) The wh-question, grammaticised facial expression [raised head and furrowed eyebrows] was used in half of the sentences without any wh-question signs (Liddell, 1980; Neidle et al., 2001). The grammatical sentences were made ungrammatical by separating the wh-question facial marker, or the wh-question sign and the accompanying facial marker, from the original clause. The wh-question sentences were from 6–8 morphemes ($M = 7.0$) in length.

Relativised sentences. The relative clause sentences consisted of two clauses with no classifiers. The verbs were both agreement and plain. As with the negative and wh-question sentences, there were two types of RC markers. (1) A RC grammaticised facial expression was used for half of the sentences. (2) THAT and ITSELF sign markers were used for the other half of the sentences. The main characteristic of the RC grammaticised facial expression is that the subordinated clause is accompanied by the RC facial expression (Liddell, 1980). The RC facial markers were all positioned in the first part of the sentence; the RC signs were positioned in the second part. The grammatical sentences were made ungrammatical by either switching the RC facial marker and accompanying clause with the second clause of the sentence or separating the RC signed marker from the original clause. These stimuli were from 6–9 morphemes ($M = 7.9$) in length.

Classifier sentences. The classifier sentences consisted of two clauses; the first clause was the ground and the second clause was the figure (Wallin, 1996). The second clause used a verb of motion and the first clause used a verb of location. The ground was first introduced into space followed by the figure; then the verb of motion was produced. Three types of classifiers were used, semantic, handle, and size and shape specifiers (Schick, 1990; Supalla, 1982). The grammatical sentences were made ungrammatical by scrambling the temporal order of the classifiers. It is important to note that classifier sentences were the most difficult of all the ASL structures used here to make ungrammatical, which no doubt reflects a lack of understanding about these sign language structures. Switching the temporal order of the classifiers was the only violation that all judges agreed rendered the sentences unacceptable. Any other proposed alteration served only to change the meaning of the classifier sentences but not render them unacceptable in ASL. These stimuli were from 6–9 morphemes ($M = 7.7$) in length.

Equipment and materials

ASL stimuli computerisation. The ASL stimuli were videotaped with a professional SONY digital video camera, model DCRVX-1000, with 3CCD technology. The movie files were then transferred to an Apple 8100/80AV computer with a Radius video card and RCA in/out video connection. Adobe Premiere 4.2 was used for editing and movie compression. Movie Cleaner Pro 1.2 was used with the following settings: 30 frames per second, Cinepak, millions of colours, 340×280 pixels, 300K/s maximum data rate. Quick Time movies were then integrated into PowerLaboratory software (Chute & Daniel, 1996).

Testing equipment. The grammatical judgement task was presented on an Apple G3 PowerBook portable computer, 292 Mhz processor speed, 96 MB RAM, 14-inch active matrix colour screen. The computer recorded response accuracy and latency by way of a Gravis MacGame Pad with four coloured buttons (blue, green, yellow, and red). Only the RED button (incorrect) and the GREEN button (correct) were used; the other buttons were disabled.

Response latency was measured from the onset of the stimuli to the subject's button press. Because the computer clock could not be turned on within a video clip, and each stimulus was one video clip, we measured the duration in milliseconds from the onset of the stimulus to the first ungrammatical element for each ungrammatical stimulus. We then subtracted this number from each subject's response latency for both the ungrammatical and grammatical counterpart of each stimulus pair to measure response latency to the ungrammatical element.

Procedure

ASL was used throughout all testing. Participants were tested individually in a non-distracting environment. The experimenter was not in the participant's view during the experiment (except for the practice session). Informed consent was obtained in ASL by a deaf experimenter. The experimental procedure was explained, followed by a practice session consisting of eight ASL stimuli, four grammatical and four ungrammatical stimuli presented randomly. Participants were instructed to focus on detecting errors in the structure of the stimulus (including facial expressions, sign order, and spatial arrangements). Participants were told that the computer recorded response accuracy and latency and that they should respond carefully but not pause unnecessarily. Participants held the Game Pad in both their hands and were instructed to hold it in the same way throughout the experiment. They responded with their thumbs as in a video game. For left-handed subjects, the game pad was turned 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.

Stimuli were presented in the centre of the computer screen with a black background around the movie frame. The 168 stimuli, 14 grammatical and 14 ungrammatical counterparts of 6 ASL syntactic structures, were presented in a fixed, random order. The stimuli were presented in four blocks of 48 stimuli each with a pause of a few minutes between the blocks. There was an interval of 1 s from the participant's button press to the onset of the next ASL stimulus.

RESULTS

The groups' performance on the grammatical judgement task was analysed for response errors, response A′, and response latency for correct responses. In addition, we analysed response accuracy in more detail to investigate possible effects for syntactic marker type (signed versus facial expression) and verb type (plain versus agreement) on the signers' grammatical judgement performance.

Response accuracy

Error rate. The participants' response errors on the grammatical judgement task were analysed with two, 3 × 6 × 2 repeated measures analyses of variance, one for subjects and one for items. The between-subjects factor was age of ASL acquisition with three levels of group, NC, Early, and Delayed L1. The within-subjects factors were (1) grammatical structure with six levels of type (simple, negative, agreement verb, wh-question, relative clause, and classifier), and (2) grammatical status with two levels, grammatical and ungrammatical.

The results showed a main effect for AoA, F_{Subjects} (2, 27) = 11.63, $p <$ .001; F_{Items} (2, 156) = 100.43, $p <$ .001, that did not interact with syntactic structure, F_{Subjects}(10, 135) = 0.97, *ns*; F_{Items}(10, 156) = 1.33, *ns*, or with grammatical status in the analysis by subjects, F_{Subjects}(2, 27) = 2.09, *ns*;

$F_{\text{Items}}(2, 156) = 14.81$, $p < .001$. Mean error rates were 22% for the NC, 32% for the EL1, and 41% for the DL1. Each group performed significantly differently from the other (Student/Newman/Keuls; $p < .05$). Syntactic structure showed a main effect, $F_{\text{Subjects}}(5, 135) = 8.48$, $p < .001$; $F_{\text{Items}}(5, 78) = 2.89$, $p < .05$, that interacted with grammatical status, $F_{\text{Subjects}}(5, 135) = 14.01$, $p < .001$; $F_{\text{Items}}(5, 78) = 3.02$, $p < .05$, with a main effect for grammatical status, $F_{\text{Subjects}}(1, 27) = 36.51$, $p < .001$; $F_{\text{Items}}(1, 78) = 3.02$, $p < .001$. The nature of the interaction between syntactic structure and grammaticality was that the participants made more errors on the ungrammatical as compared to the grammatical stimuli across the ASL structures except for the negative and classifier structures where there were no differences (Student/Newman/Keuls, $p < .05$). This was especially apparent for the delayed L1 group whose performance was the primary source of the interaction between grammatical status and AoA in the item analysis reported above (Student/Newman/Keuls, $p < .05$).

Response A′. In order to control for guessing and thus obtain a clearer picture of the groups' sensitivity to ASL syntactic structures, we computed an A′ score for each participant for each of the six grammatical structures. A′ is a form of signal detection theory that takes guessing behaviour into account by comparing the ratio of hits (correct judgements of ungrammatical stimuli) and false alarms (incorrect judgements of grammatical stimuli) as a function of chance. A′ varies from 0.5, suggesting little sensitivity to the grammatical rule, to 1.0 suggesting high rule sensitivity. The formula used for the A′ analysis was $0.5 + [(y - x)(1 + y - x)]/4y(1 - x)]$, taken from Linebarger, Schwartz, and Saffran (1983). *X* is the proportion of false alarms (incorrect responses to ungrammatical items) and *y* is the proportion of hits (correct responses to grammatical items).

The A′ scores were analysed with a 3×6 analysis of variance for subjects. The between subjects factor was age of ASL acquisition (with three levels of group). The within-subjects factor was syntactic structure (with six levels of type). Grammaticality was not a factor because it was incorporated into the A′ formula in the form of "hits" and "misses" as explained above. AoA showed a significant main effect, $F(2, 27) = 10.05$, $p < .001$) that did not interact with syntactic structure, $F(10, 135) = 0.63$, n.s. Mean A′ scores were .86 for the native learners, .76 for the early learners, and .63 for the delayed L1 learners, as shown in Figure 1. Each group's performance was significantly different from the others' (Student/Newman/Keuls, $p < .05$). Syntactic structure showed a main effect, $F(5, 135) = 7.75$, $p < .001$, independent of AoA. There was an apparent trend for mean A′ to decline across the ASL structures as a function of earlier versus later acquired structures, as Figure 2 shows. The effect was due to the contrast between the negative sentences, for which mean A′ scores

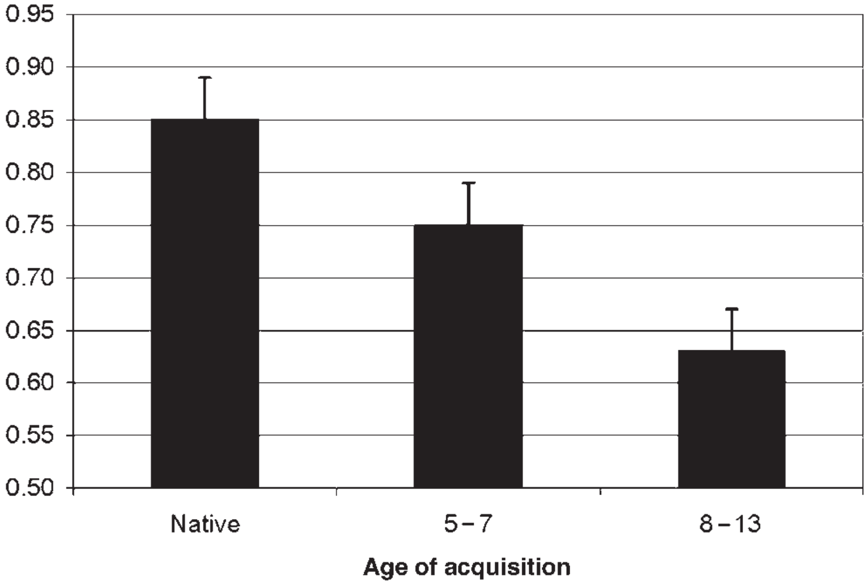

Figure 1. Mean A′ scores for the three groups who first acquired ASL at three increasingly older ages.

were the highest overall, and the relative clause sentences, for which the mean A′ scores were the lowest overall (Student/Newman/Keuls, $p < .05$).

AoA effect size. To further analyse the effect of AoA on ASL grammatical judgements, we measured the magnitude of the AoA effect on the A′ scores for each syntactic structure. From analyses of variance performed on each structure separately, we computed an *r* contrast (Rosnow & Rosenthal, 2003). AoA showed the following effect sizes on the syntactic structures: simple sentences, $r = .51$; negative sentences, $r = .53$; agreement verb sentences, $r = .48$; wh-questions, $r = .43$; relative clause sentences, $r = .32$; and classifier sentences, $r = 39$.

Response latency

We analysed the participants' response latency, although grammatical judgements are clearly strategic in nature and do not reflect on-line syntactic processing. Response latency was measured from the onset of the grammatical violation for the ungrammatical stimuli, and from the same locus for the grammatical stimuli. The latency data for correct responses were analysed with two $3 \times 6 \times 2$, repeated measures analyses of variance for subjects and items. The between-subjects factor was AoA (with three

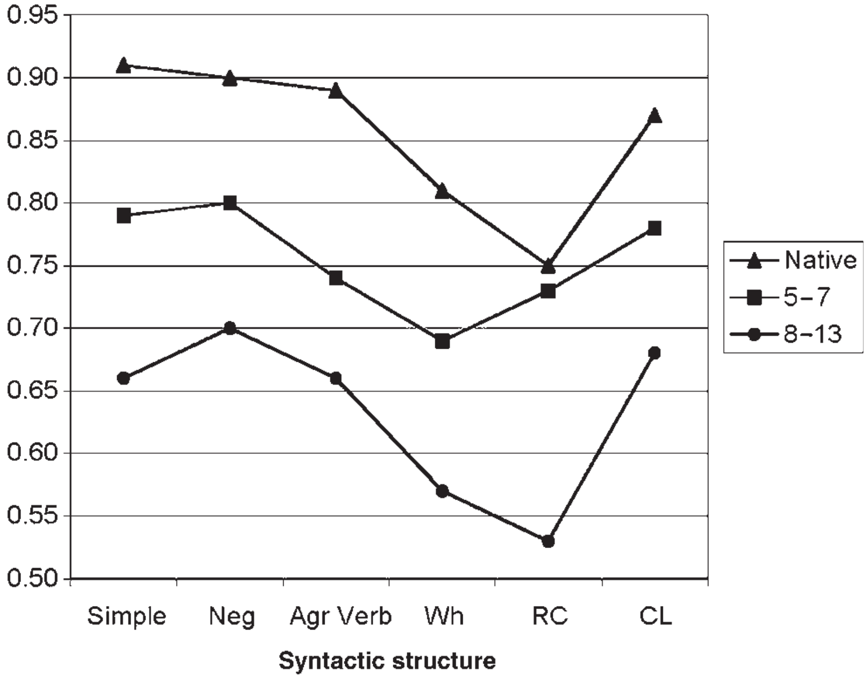

Figure 2. Mean A′ scores for the three groups as a function of syntactic structure. Note that the interaction between AoA and syntactic structure is not significant but is shown here for illustrative purposes.

levels of group). The within-subjects factors were syntactic structure (with six levels of type), and grammatical status with two levels (grammatical and ungrammatical).

AoA showed no significant effects in the subject analysis but did in the item analysis, $F_{\text{Subjects}}(2, 27) = 0.82$, *ns*; $F_{\text{Items}}(2, 156) = 2.75$, $p < .001$, indicating that, although AoA did not show an overall effect on response latency, it had effects on some items. There was a main effect for syntactic structure, $F_{\text{Subjects}}(5, 135) = 14.11$, $p < .001$; $F_{\text{Items}}(5, 78) = 2.56$, $p < .05$, which did not interact with AoA in the subject analysis, $F_{\text{Subjects}}(5, 135) = 1.48$, *ns*, but did in the item analysis, $F_{\text{Items}}(10, 156) = 2.14$, $p < .05$. There was also an interaction between syntactic structure and grammatical status, $F_{\text{Subjects}}(5, 130) = 18.52$, $p < .0001$; F_{Items} $(5, 78) = 5.54$, $p < .001$, but no main effect for grammatical status. The nature of the interaction was that the participants responded more quickly on the grammatical as compared with the ungrammatical stimuli across the syntactic structures except for the negative and relative clause structures where response times did not differ (Students/Newman/Keuls, $p < .05$), as shown in Table 4.

TABLE 4
Mean grammatical judgement response time (in milliseconds) as a function of ASL syntactic structure and grammatical status

	ASL structure					
	Simple	*Negative*	*Agr Verb*	*Wh-Quest*	*Relative clause*	*Classifier*
Grammatical						
Mean	4817.31	5416.39	4564.25	4280.16	5170.06	5148.52
(SD)	(633.07)	(1160.93)	(920.11)	(900.99)	(988.23)	(1125.03)
Ungrammatical						
Mean	5246.24	4852.80	4707.03	4913.95	4622.63	5739.25
(SD)	(202.97)	(985.49)	(972.74)	(1402.62)	(661.84)	(5739.25)

Signed versus grammaticised facial markers

Recall that three of the ASL syntactic structures, negation, wh-questions, and relative clauses, were instantiated with a signed marker for half the stimuli and a grammaticised facial expression for the remaining stimuli. We asked whether signers judged these signed and grammaticised facial markers similarly, and whether AoA influenced their judgements. To answer the question, we analysed the participants' accuracy data with analyses of variance for the factors of AoA (with three levels of group), syntactic structure (with three levels of structure), marker type (signed and grammaticised facial expression), and grammatical status (grammatical and ungrammatical).

Consistent with the above findings, the results showed a significant main effect for AoA, $F_{\text{Subjects}}(1, 27) = 7.99$, $p < .002$; $F_{\text{Items}}(2, 36) = 39.31$, $p < .001$, that did not interact with syntactic structure, $F_{\text{Subjects}}(4, 54) = 1.68$, *ns*; $F_{\text{Items}}(4, 78) = .78$, *ns*, marker type, $F_{\text{Subjects}}(2, 27) = 3.02$, *ns*; $F_{\text{Items}}(2, 80) = 1.14$, *ns*, or grammatical status, $F_{\text{Subjects}}(2, 27) = 1.70$, *ns*; $F_{\text{Items}}(2, 78) = 2.16$, *ns*. There were significant main effects for syntactic structure, $F_{\text{Subjects}}(2, 54) = 10.55$, $p < .001$; $F_{\text{Items}}(2, 18) = 4.74$, $p < .02$, and grammatical status, $F_{\text{Subjects}}(1, 27) = 7.38$, $p < .01$; $F_{\text{Items}}(1, 18) = 14.85$, $p < .001$, that further interacted with one another, $F_{\text{Subjects}}(2, 54) = 12.67$, $p < .001$; $F_{\text{Items}}(2, 18) = 7.87$, $p < .01$. Although there was no main effect for marker type, it entered into a two-way interaction with grammaticality, $F_{\text{Subjects}}(1, 27) = 22.64$, $p < .001$; $F_{\text{Items}}(2, 36) = 4.21$, $p < .02$, and a three-way interaction with grammaticality and syntactic structure, $F_{\text{Subjects}}(2, 54) = 6.93$, $p < .002$; $F_{\text{Items}}(4, 36) = 4.28$, $p < .01$. Thus, the signers judged the signed and grammaticised facial markers in a varied fashion depending upon the particular ASL syntactic structure and its grammatical status, as Figure 3 shows.

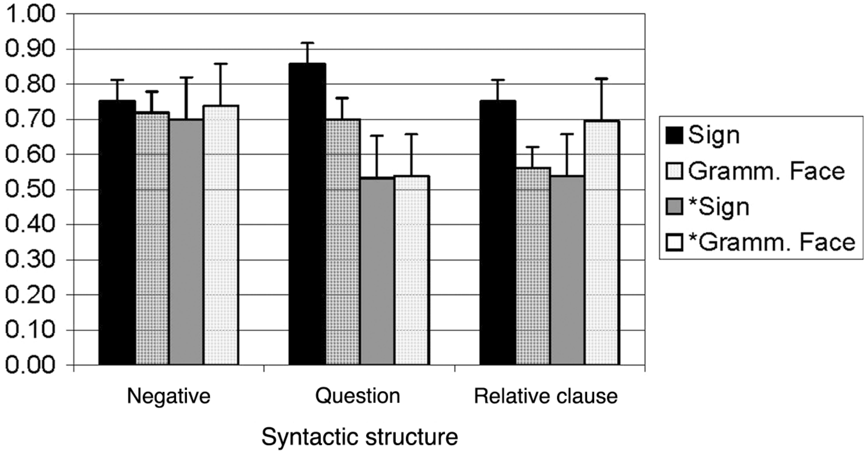

Figure 3. Mean grammatical judgement accuracy on three ASL structures (negative, wh-question, and relative clause) that have dual marking (signed or grammaticised facial expression) as a function of grammatical status (grammatical and ungrammatical – indicated by *) and syntactic marker type.

Post-hoc analyses of the three-way interaction for marker type, syntactic structure, and grammatical status showed the following results (Student/Newman/Keuls, $p < .05$). First, for the negative structure, judgement accuracy for the signed and grammaticised facial markers did not differ as a function of grammaticality. However, for the wh-questions, accuracy was highest for the signed marker in grammatical sentences compared with all other conditions; accuracy for the facial wh-question marker in grammatical sentences was higher than that for either signed or facial markers when the stimuli were ungrammatical, which, in turn, did not differ. For the relative clause sentences, judgement accuracy was highest, and no different, for the signed marker in grammatical sentences and the facial marker in the ungrammatical context. Conversely, there were no differences in judgement accuracy for the facial relative clause marker in grammatical sentences in comparison to the signed marker in ungrammatical stimuli (see Figure 3).

Verb type

Recall that the ASL stimuli used two types of ASL verbs throughout, plain and agreement, except for classifier sentences, which used verbs of motion and location. To determine whether verb type influenced grammatical judgement, we analysed accuracy as a function of verb type.

First we analysed together the ASL structures containing one verb. The simple and negative stimuli each contained one plain verb; the agreement verb sentences each contained one agreement verb. We analysed performance on these structures with an analysis of variance for the factors of verb type (plain and agreement), grammatical status (grammatical and ungrammatical), and AoA (with three groups). Verb type showed no main effect, $F(2, 54) = 0.68$, *ns*, but interacted with grammatical status, $F(2, 54) = 21.80$, $p < .001$, which showed a main effect, $F(1, 27) = 24.97$, $p < .001$. The interaction was due to the fact that there were more errors on the ungrammatical than grammatical stimuli for both plain and agreement verbs in the simple and agreement-verb structures, but there were no differences in the negative structure (Student/Newman/Keuls, $p < .05$), as Figure 4 shows. The effect was primarily due to the early and delayed L1 groups, who made more errors overall on the ungrammatical as compared with the grammatical stimuli, as shown by the interaction between grammatical status and AoA, $F(2, 27) = 3.45$, $p < .05$; Student/Newman/Keuls, $p < .05$, and in Figure 4. There was a significant effect of AoA, $F(2, 27) = 15.22$, $p < .001$, that did not interact with verb type, $F(4, 54) = 0.43$, *ns*.

In a second analysis, we asked whether verb type influenced performance on the wh-question stimuli. Recall that half the stimuli contained plain verbs and half contained agreement verbs. We analysed performance on the wh-question stimuli with an analysis of variance for

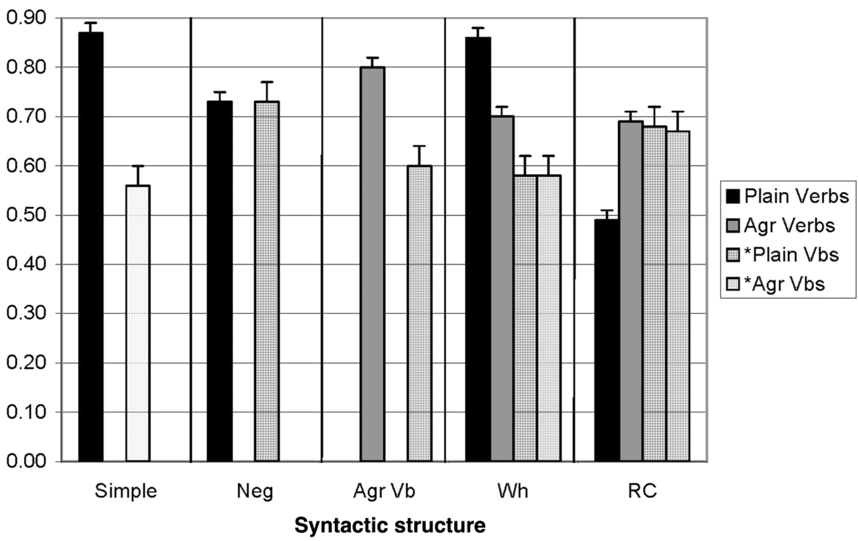

Figure 4. Mean grammatical judgement accuracy across the five ASL structures that included plain and/or agreement verbs as a function of grammatical status (grammatical and ungrammatical – indicated by *). See the text for the number of instances of each verb type across the syntactic structures.

the factors of verb type (plain and agreement), grammatical status (grammatical and ungrammatical), and AoA (with three groups). Verb type showed no main effect, $F(1, 30) = 1.50$, *ns* and a non-significant trend to interact with grammatical status, $F(1, 30) = 3.72$, $p = .06$. There was a significant main effect for grammatical status, $F(1, 30) = 8.76$, $p < .001$, as Figure 4 shows. AoA showed a significant effect, $F(2, 30) = 9.02$, $p < .001$, that did not interact with verb type, $F(2, 30) = 1.32$, n.s. or grammaticality, $F(2, 30) = 1.64$, *ns*.

The remaining verbs were in the relative clause stimuli, which each contained two verbs. Both plain and agreement verbs were used in these stimuli, but with an unequal distribution. Eight stimulus pairs (grammatical and ungrammatical) contained one plain and one agreement verb; three stimulus pairs contained two plain verbs; and three stimulus pairs contained two agreement verbs. A statistical analysis of verb type in relative clause structures was thus not possible due to the limited numbers of some types of verbs pairs. For comparative purposes, however, we grouped the verb pairs of the relative clause stimuli into two categories: (1) pairs where one or both verbs were in agreement, and (2) pairs where both verbs were plain. Visual inspection of the data in Figure 4 suggests that verb type was not a factor in performance on the relative clause stimuli. Even though the relative clause structures contained two verbs, the patterns shown in Figure 4 suggest that accuracy levels on these stimuli, where one or more of the verbs in a pair was inflected for agreement, was comparable to performance on the wh-question stimuli. The wh-question stimuli contained only one verb each and verb type was evenly distributed.

DISCUSSION

Detailed analyses of signers' grammatical judgements of six syntactic structures ranging from earlier to later acquired over the course of childhood ASL development yielded several findings. First, AoA showed large effects on response accuracy but not response latency. AoA effects were apparent for all the ASL structures sampled and did not interact with the effects of syntactic structure. Syntactic structure showed effects that were only weakly related to earlier versus later acquired in ASL development; negative structures were the most accurate overall and relative clause structures were the least accurate overall. Grammatical status showed large effects that interacted with AoA and syntactic structure; the signers made more errors on ungrammatical compared with grammatical examples across all the structures except for negative and classifier structures, and this was especially so for the early and delayed L1 learners. The effects of grammatical status on response accuracy were also evident in response latency. The signers responded more quickly to the grammatical stimuli compared with the ungrammatical counterparts across the syntactic structures, except for the negative and relative clause structures. These results held across ASL structures that have dual marking (signed and grammaticised facial markers) and ASL verb type (plain and agreement verbs). Together the results extend to ASL the previous findings of Mayberry and Lock (2003) for English. We discuss these points first and then explain how the present results fit with previous findings on the effects of delayed L1 acquisition on grammatical processing.

First, the results of the present study demonstrate that delayed L1 affects syntactic knowledge in the primary language, while the results of previous research demonstrated that delayed L1 affects syntactic knowledge in the secondary language (Mayberry & Lock, 2003). Age of L1 acquisition affected grammatical processing independent of syntactic structure in both the present and previous studies, despite the fact that the target languages were different, ASL and English respectively. The results of these studies together demonstrate that delayed L1 acquisition has deleterious effects on the development of syntactic knowledge for any subsequently acquired language.

In the present study, the mean A′ scores of the most delayed L1 learners ranged from .57 to .70 on the ASL syntactic structures sampled, namely, simple, negative, agreement verbs, wh-question, relative clause, and classifier sentences. This performance was reminiscent of the Mayberry and Lock (2003) findings. In English, the most delayed L1 learners sometimes performed at near-chance levels on the syntactic structures sampled (namely, simple, dative, conjoined, passive, and relative clause sentences), with mean A′ scores ranging from .55 to .65. Recall that an A′ score of .50 reflects no sensitivity while an A′ score of 1.00 reflects high sensitivity to a given grammatical rule (Linebarger et al., 1983). The fact that the results of the two studies are highly similar, the previous one for English and the present one for ASL, provides compelling evidence that early language acquisition is necessary for subsequent language acquisition to be successful.

The effects of delayed L1 acquisition on syntactic knowledge may be related to a mismatch between brain maturation and the onset of language acquisition. The present results demonstrate that delayed L1 acquisition produces a different ultimate outcome from delayed L2 learning (Mayberry et al., 2002; Mayberry & Lock, 2003). Although L2 learners often show weaknesses in their second language related to the age when they first began to learn it, they nonetheless possess native-like syntactic skills in their L1, which they experienced from birth. Delayed L1 learners, by contrast, do not show native-like syntactic skills in any language, not in the primary language they use daily, in this case ASL, as the present results show, and not in the secondary language they were taught daily in school, in this case English (Mayberry & Lock, 2003).

The response accuracy of the native ASL learners was not perfect across the structures. However, the native learners showed very high performance on several structures. Their A′ scores were .90 for the simple, negative, and agreement verb structures. The native learners showed lower A′ scores for the wh-question and relative clause structures, but the trend was not significant. The non-significant trend could reflect greater processing demands associated with more complex syntactic structures in ASL grammatical judgement. It could also reflect our lack of understanding about the underlying rules of these particular structures (Neidle et al., 1998; Petronio & Lillo-Martin, 1997). A third possibility is that some of these stimuli were unnatural despite the fact that we carefully manipulated the grammaticised facial expressions and sign markers across the grammatical and ungrammatical examples of these two structures, an issue we return to below. The fact that the negative structure also had non-manual marking, but the native learners' accuracy was nonetheless quite high, argues against this explanation. However, it is clear that grammatical judgement in sign language can be used as an experimental tool to adjudicate these issues in future research.

The effects of delayed L1 acquisition were strong for the accuracy of grammatical judgements but not apparent in response latency. Response latency was highly sensitive to grammatical status, however. This shows that response latency is a sensitive measure of syntactic processing in ASL grammatical judgement. These results differ from those of Mayberry and Lock (2003) where AoA acquisition showed significant effects on response latency for grammatical judgement of English structures. The stimuli were presented in print, and disappeared from the screen with the button press, which probably encouraged speedy responses. For the present study, the response latencies were quite large. The time measurement necessarily began at the onset of each ASL stimulus, in case participants made judgements before the end of the stimulus, but this rarely occurred, and the stimuli did not disappear from the screen with a button press. Response latencies remained large even though we subtracted the length of time from the onset of the grammatical violation to the end of the stimulus (for each ungrammatical stimulus and the same locus in the grammatical counterpart) from each participant's response time. Despite this control, the response latencies reported here included time spent watching the ASL stimuli in addition to decision time. This may explain why AoA showed no effects on response latency.

Whether slowed language processing is one effect of delayed L1 acquisition, and whether the origin is lexical or syntactic in nature, or some combination of the two, is an important question the present results do not address. Hildebrandt and Corina (2002) found late learners of ASL to show phonological processing performance unlike that of native learners. Mayberry and Witcher (2004) found age of ASL acquisition to affect lexical identification response time. More research is required to answer this complex question.

We predicted that the signers would perform more accurately on ASL syntactic structures acquired earlier in childhood (simple, negative, and agreement verb structures) compared with those mastered at older ages (wh-questions, relative clause, and classifier predicates). There was little evidence in support of this hypothesis. To the best of our knowledge, this is the first psycholinguistic experiment in sign language to include classifier predicates with other syntactic structures in the stimuli. The present results suggest that when morpheme length is held constant, and handshape, spatial location, and movement path are all counted as separate morphemes, as first posited by Supalla (1982), classifier predicates are not more difficult to process than other ASL syntactic structures. However, it is important to note that, as a linguistic category, classifier predicates in sign languages vary from being simple to highly complex, which is less true of the other ASL structures sampled here.

An important feature of ASL syntax, and three of the syntactic structures we sampled in the present study, is that grammatical markers are displayed on the face and head as well as on the hands and arms. We compared and contrasted the processing of signed and grammaticised facial markers across these three structures. The results showed different processing patterns as a function of structure and grammatical status independent of age of L1 acquisition. The grammaticised facial negative, the headshake, is the functional equivalent of the negative sign, NOT. Interestingly, the results showed no differences in judgement accuracy across the signed and grammaticised facial expression conditions for this structure.

An important difference between the ASL negative and the question and relative clause structures reflected in the present results is that the grammaticised facial marker is morphemic for the negative structure but phrasal and clausal in scope for the question and relative clause structures. For the ASL question structure, the grammaticised facial marker either co-occurred with the phrase being questioned, or a wh-question sign (WHO or WHAT) preceded the phrase. To render these questions ungrammatical, the question sign was separated from the phrase or the grammaticised facial marker was switched and attached to the wrong phrase. Although accuracy levels were higher for the grammatical wh-questions marked with signs compared with those marked with grammaticised facial markers, the accuracy levels were not different for the ungrammatical exemplars of both types of question markers. This suggests that signers process signed and grammaticised facial question markers in a similar fashion, and thus corroborates previous linguistic ASL research (Liddell, 1980), and acquisition and neuropsychological research (Anderson & Reilly, 1997; Corina, 1989; Reilly & Bellugi, 1996; Reilly, McIntyre, & Bellugi, 1990).

The accuracy patterns for the signed and grammaticised facial markers for relative clause structures were less straightforward, however. Ungrammatical signed and grammaticised facial relative clause exemplars consisted of either separating the relative clause sign from its attendant clause or moving the grammaticised facial expression to the wrong clause. The accuracy level for the grammatical signed and ungrammatical grammaticised facial marker stimuli were higher than those for the ungrammatical signed and grammatical facially marked stimuli (see Figure 3). The contrast between the results for the relative clause structures as compared with those for the negative and question structures could be due to an experimental technicality. Perhaps something in the execution of the stimuli was inconsistent across the conditions. It is important to note that all the grammatical and ungrammatical stimuli for the ASL structures were signed by a person and videotaped rather than being written or synthesised, as is commonly the case in psycholinguistic research on spoken language. More research is needed to investigate the language processing characteristics of ASL syntactic rules instantiated via signed and non-manual markers.

Grammatical judgement is one means to assess mastery of syntactic rules. An important question is how performance on the grammatical judgement task relates to other measurements of syntactic ability. The answer can help explain the apparent discrepancies across previous studies investigating the effects of delayed L1 acquisition on syntactic ability. Grammatical judgement is a context-free, abstract test of syntactic knowledge, but mode of presentation can affect the results. For example, Johnson (1992) found L2 performance on the same stimuli to be higher on written as compared with auditory presentation on a grammatical judgement task. Non-linguistic context can also affect performance level. In two case studies of delayed L1 learners, Morford (2003) found evidence of greater syntactic skill in ASL expression compared with comprehension for the same structures. Presumably the delayed L1 learners had more control over what they signed than what was signed to them. Moreover, they showed greater comprehension of syntactic structures with non-linguistic context than without it; specifically, they performed at higher levels matching ASL sentences to pictures compared with repeating the same sentences verbatim.

Morford's (2003) findings show that differing tasks and degrees of non-linguistic support yield varying estimates of syntactic ability in delayed L1 learners. This is consistent with Mayberry and Lock's (2003) results.

Delayed L1 learners performed at low levels on early acquired English structures on a grammatical judgement task. However, with the non-linguistic support of pictures on a sentence-to-picture matching task, they performed at near-native levels on the same early-acquired structures, but not on the later-acquired structures. Not all syntactic structures can be understood with non-linguistic support.

The present findings appear to be inconsistent with those of Emmorey et al. (1995) who found no AoA effects on an ASL grammatical judgement task. The task in the Emmorey et al. study was written grammatical assessments of 40 stimuli on a scale from 1 to 3 after the participants had just seen all 40 stimuli in a sign monitoring task. The task demands of the present study were greater by comparison, specifically, yes/no decisions with a button press to 168 previously unseen stimuli.

The present findings also appear to be inconsistent with those of Newport (1990) who found no AoA effects for basic word order compared with other ASL structures. Basic word order was measured with a comprehension task where participants saw ASL sentences with SVO and pointed to one of two pictures in which the subject and object were reversed (Newport, personal communication). Thus, with non-linguistic support, delayed L1 learners can comprehend basic word order, as Mayberry and Lock (2003) likewise found on a sentence-to-picture matching task. However, when the task requires syntactic processing *de novo*, without non-linguistic cues, delayed L1 learners show low levels of syntactic comprehension across ASL syntactic structures, including basic word order, as shown by the present results. The magnitude of the delayed L1 effect on simple sentences was comparable with that for the other syntactic structures sampled here, as the results of the effect-size analyses showed.

The hypothesis that knowledge of basic-word order is resilient to a lack of linguistic input during childhood has also been proposed by Goldin-Meadow (2003; Goldin-Meadow & Mylander, 1998). Deaf children use consistent ordering patterns to convey the semantic roles of agent, action, and patient in their gesture expression, known as homesign. Whether these children, whose exposure to a fully perceptible first-language is delayed, can master basic word order in subsequent language comprehension is an empirical question. The results of Morford (2003), Newport (1990), and Mayberry and Lock (2003) suggest that the answer is yes with non-linguistic support, but the findings of the present study and Mayberry and Lock (2003) suggest that the answer is no without non-linguistic support, especially if the delay in L1 exposure is prolonged.

Finally, Curtiss (1977) also investigated basic word order in a case of extreme and prolonged social isolation in childhood. Genie used basic word order in spoken expression (p. 167), but her comprehension of basic word order was variable when assessed with a sentence-to-picture matching task. Like Morford's (2003) case studies, Genie's comprehension of basic word order improved over time with repeated viewing of the same pictures with the same test sentences (pp. 125–126; Appendix I). The findings of these studies together suggest that delayed L1 learners have fragile syntactic comprehension of word order that is dependent upon non-linguistic cues and word meaning. By contrast, the syntactic comprehension of early L1 learners is robust in the sense that it is consistent across varying tasks and contexts.

In sum, we have found evidence that delayed L1 acquisition affects the ultimate attainment of syntax. These effects are robust for the task of grammatical judgement and are apparent across a range of ASL syntactic structures. These results hold across ASL syntactic structures instantiated with signed and grammaticised facial markers as well as ASL verb type. Combined with findings of previous research, these results show that delayed exposure to a first language in childhood affects all subsequent language acquisition cross-modally.

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