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EMPIRICAL STUDY

The Development of Sensitivity to Grammatical Violations in American Sign Language: Native Versus Nonnative Signers

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Factors influencing native and nonnative signers' syntactic judgment ability in American Sign Language (ASL) were explored for 421 deaf students aged 7;6–18;5. Predictors for syntactic knowledge were chronological age, age of entering a school for the deaf, gender, and additional learning disabilities. Mixed-effects linear modeling analysis revealed main effects of each predictor and an interaction between signing status and learning disability. The native signers showed typical syntactic development that varied by chronological age, gender, additional learning disabilities, and age of entering a deaf school. In contrast, the syntactic development of nonnative signers was more variable. It was less tightly related to chronological age and more strongly influenced by the age at which they had entered the school where assessment occurred, which was highly related to length of exposure to a sign language.

Keywords syntax; ASL; assessment; deaf; sign language

Introduction

School-aged deaf children often have difficulty with complex sentences in spoken language and their representation in print, that is, in both production and

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comprehension (Boons et al., 2013; de Villiers, 1988; de Villiers, de Villiers, & Hoban, 1994; Friedmann & Szterman, 2005, 2011; Geers & Moog, 1978; Geis, 1973; Power & Quigley, 1973; Quigley, Smith, & Wilbur, 1974). This difficulty also occurs in children with cochlear implants (Boons et al., 2013; Volpato & Vernice, 2014). One explanation for syntactic deficits in school-aged deaf children is language deprivation[1] during critical periods for first language (L1) syntax acquisition (Calderon, 1998; Friedmann & Szterman, 2005; Yoshinaga-Itano, 2003). For example, deaf adult signers who had late exposure to American Sign Language (ASL) show deficits in sign language syntax comprehension despite years of language use (Boudreault & Mayberry, 2006). To understand these deficits in L1 syntax, it would be helpful to have data on complex sentence acquisition in signing deaf children. Whereas prior studies with children have only examined syntactic abilities in spoken and written language, the uniqueness of the current study was in the exploration of ASL ability. Specifically, this study examined the development of sensitivity to ASL syntactic structures in deaf children who were exposed to a signed language from birth. The developmental path of these native signers was compared to nonnative signing deaf children. This approach built on prior research by examining learners who had acquired ASL at different ages to determine how native versus nonnative signers differ in their knowledge of the syntactic structures of ASL.

Background Literature

Syntax Development of Sign Language

The development of a sign language in deaf children exposed to a signed language from birth parallels the spoken language acquisition of typically developing hearing children (e.g., Chen Pichler, 2012; Corina & Singleton, 2009; Mayberry & Squires, 2006; Newport & Meier, 1985; Petitto, 1987). Signed vocabulary acquisition in deaf children resembles acquisition of spoken words by hearing children (Anderson & Reilly, 2002; Novogrodsky, Caldwell-Harris, Fish, & Hoffmeister, 2014; Novogrodsky, Fish, & Hoffmeister, 2014). For example, Novogrodsky, Caldwell-Harris et al. (2014) found that young signers understood opposite-based relationships at the same age as did typically developing hearing children. Novogrodsky, Fish et al. (2014) further demonstrated that deaf signing children make the same kinds of developmental errors as similarly aged hearing children. Younger signing deaf children made more phonological errors on a test of ASL synonyms than did older children. With age, their errors became semantic in nature. Native signing deaf children also achieve sign language syntax milestones comparable to typically developing hearing children. Deaf children combine signs at 18 to 24 months (Newport & Meier, 1985). They continue to use simple sentences and then start producing more complex sentences (e.g., negation, topic sentences, and questions) between the ages of 3 to 4 years (Hoffmeister, 1978; Maller, Singleton, Supalla, & Wix, 1999).

ASL and other sign languages have unique syntactic characteristics that affect the acquisition of syntactic features. ASL allows variation in word order, in which the subject and/or object appear in noncanonical positions (Chen Pichler, 2012; Coerts, 2000; De Quadros, 2010; Hoffmeister, 1978; Hoffmeister & Wilbur, 1980). Thus, syntactic development requires morphosyntactic markers beyond word order. These markers include facial markers, such as headshake, eye gaze, and raised eyebrows (Anderson & Reilly, 2002; Lillo-Martin, 2000), and spatial location (Meier, 2002). In acquisition, manual features of syntax are often acquired before nonmanual features, but some children do acquire nonmanual features first (Loew, 1984; Meier, 1982; Reilly, 2005).

The nonmanual markers of negation headshakes emerge around 12 to 18 months of age (Anderson & Reilly, 1997, 2002). Nonmanual indicators are paired with manual signs at the age of 20 months. Interestingly, while some children acquire the nonmanual features of negation prior to the lexical sign, the two are not paired until sometime after the lexical sign is acquired (Anderson & Reilly, 1997). For topic sentences, where the object of a sentence is moved to the front (Braze, 2004), the use of facial markers (e.g., raised eyebrows over the topicalized element) emerges approximately at the age of 3;0 (Reilly, McIntire, & Bellugi, 1991). Acquisition of syntactic features marking questions follows a similar developmental path. Native signing deaf children begin using facial markers of raised eyebrows at the age of 1;6 in yes/no questions and furrowed eyebrows for *wh*-questions at the age of 3;6 (Reilly et al., 1991).[2] Their coordination of the nonmanual aspect with the *wh*-sign develops between the ages of 6;0 and 7;0 (Lillo-Martin, 2000). Subject–verb agreement represents another morphosyntactic feature of sign language (Meier, 1982, 2002). It requires association of spatial locations with referents. Meier (1982) investigated the development of verb agreement in ASL with present referents and found that children develop it at the age of 3;0 to 3;6. Acquiring the ability to use agreement with nonpresent referents in spontaneous narratives with multiple characters is present at the age of 4;9 (Loew, 1984).

To conclude, by the time they are in preschool, deaf children typically have experienced two developmental stages. They first preserve the manual features of the syntactic structure and only later coordinate the manual and nonmanual features (Meier, 1982; Loew, 1984), as phrased by Reilly, "hands before faces" (2005, p. 286).

Late Exposure to Sign Language and Development of Syntax

The effect of an L1 (signed language) on a second language (L2) has historically been explored by measuring L2 reading ability of adults exposed to sign language at different ages in childhood. The findings in these studies have been clear: late exposure to sign language for children who have not acquired a complete L1 results in lasting syntactic difficulty in both the signed and spoken language[3] (Galvan, 1999; Mayberry, Chen, Witcher, & Klein, 2011; Mayberry & Lock, 2003; Mayberry, Lock, & Kazmi, 2002). For instance, adult late learners of ASL who were exposed to the language between the ages of 9 to 13[4] performed lower on recall and comprehension tasks of complex syntax, compared to native signers (Mayberry & Eichen, 1991). In another study, adult native signers acquired the meaning of the continuative aspect of verbs (e.g., *running*) in ASL and later could map it to the syntactic structure of the continuative aspect in English, such as present progressive versus simple present (Galvan, 1999). However, nonnative signers were delayed in understanding the continuative aspect of verbs in both their L1 (ASL) and in understanding the continuative aspect of verbs in English (their L2). These results indicated that adults who had experienced late exposure to sign language had difficulty mastering the full syntactic system, particularly in complex sentences.

Research exploring the development of sign language syntax during school ages has been limited compared to the retrospective studies just described. In a recent study on British Sign Language (BSL), school-age deaf children with language impairment were compared with a control group of typically developing deaf children on different types of BSL sentences using a repetition task (Marshall et al., 2014). The control group (signing deaf children without language impairment) included 11 deaf students aged 6;10 to 13;0. Their performance on a repetition task improved with age, suggesting typical syntactic development across school ages. However, the types of errors the control group made were like those of the language-impaired group. Errors made by both groups of deaf children included classifier omissions and incorrect verb agreement. Because no children in the control group were native signers, the authors suggested that processing sign language syntax is difficult for nonnative signing children, even those without language impairment. However, it is difficult to draw any conclusions without data on syntactic development among native signers. It is possible that the errors made by deaf children occurred because of ongoing low-level language input and/or impoverished language input during early childhood.

The current study explored the effect of late exposure on the acquisition of syntax among school-age learners by comparing native and nonnative signers on a syntactic judgment task. The most common educational pathway for deaf children in the United States is placement in a regular school classroom (referred to as mainstreaming or integration) either with or without interpreting. More than half of these mainstream educational programs have three or fewer deaf or hard-of-hearing children (Mitchell, 2004). Most mainstreamed deaf students receive only spoken language input (Mitchell & Karchmer, 2005). Approximately 20% attend signing programs in separate classrooms in hearing schools and residential schools for the deaf; some of these are bilingual programs. In all programs, children receive some specific intervention services. For example, a mainstream environment with deaf teachers who use ASL for some subjects each day or a day program for the deaf, which uses sign-supported speech. Only bilingual programs systematically use sign language as the language of instruction. It is common for deaf children to switch into a signing school from these mainstream programs after experiencing academic and/or emotional problems (for additional discussion, see Henner, Caldwell-Harris, Novogrodsky, & Hoffmeister, 2016, and Henner, Hoffmeister, Fish, Rosenburg, & DiDonna, 2015). Many of these transfers happen as late as middle school or high school. Students who transfer into a signing school may have had prior exposure to ASL in their previous school, either from teachers or via interpreting in mainstream classes. Because of the variability in sign language proficiency in mainstream programs, it is generally not possible to determine how much ASL exposure had occurred before the nonnative signers enrolled in their current signing school. We therefore had to assume in the present work that the first consistent exposure to academic-level ASL began on admittance to the school for the deaf where assessment was conducted.

Syntactic Judgment Task and Its Sensitivity to Language Knowledge

The target task used with deaf children was a syntactic judgment task. In this task, a child hears (in spoken language), sees (in signed language), or reads (in the written modality) a sentence and is asked to decide if the sentence is correct or incorrect in the language (e.g., *The girl have playing in the water*). The task includes grammatical sentences and ungrammatical sentences, as in the example above (Ambridge, 2011).[5] This is a metalinguistic task that reflects language mastery. It requires that children use their implicit grammatical knowledge to assess the form and validity of a sentence in addition to its meaning. Studies targeting hearing participants of varying abilities have demonstrated links between syntactic judgment abilities and language knowledge. For example, scores on a syntactic judgment task of *wh*-questions were lower for hearing children with language impairment than for younger, language-matched children without language impairment (van der Lely, Jones, & Marshall, 2011). Similar results were obtained for a syntactic judgment task with *be* copula/auxiliary and *do* auxiliary in *wh*- and yes/no questions (Rice, Hoffman, & Wexler, 2010). Among hearing bilinguals, syntactic judgment scores have correlated with language abilities, and their length of exposure to the L2 affected their performance on the task (Paradis, 2010). Among deaf students, syntactic judgment tasks have been used for assessing spoken language in the written modality (Quigley et al., 1974) and for assessing the syntactic competence of deaf adults (Chamberlain & Mayberry, 2008).

In one of the first studies of complex ASL syntax, Boudreault and Mayberry (2006) used a syntactic judgment task to test 30 adults who were born deaf and were first exposed to a fully perceptible language between birth and 13 years. The task examined participants' knowledge of six ASL sentence structures: simple, negative, inflecting verb (equivalent to the agreement structure in the current study), *wh*-questions, relative clauses, and classifier sentences. The older the adults were when first exposed to sign language, the worse their grammaticality judgment performance. In another study with an additional measure of reading skill, skilled readers of English demonstrated good receptive control (performance of 76% and above) over the six ASL syntactic structures, while nonskilled readers had poor test scores (Chamberlain & Mayberry, 2008). These studies demonstrated that ASL syntactic judgment tasks can reliably measure overall syntactic competence and that they are associated with syntax knowledge. In the current study, we explored the development of metalinguistic syntactic skills with school-aged native and nonnative signers.

The Current Study

We targeted three interrelated issues. The first issue focused on the development of metalinguistic syntactic competence. We predicted that task scores would increase with age in both native and nonnative signers. Furthermore, we expected that native signers would perform better than nonnative signers. The second issue focused on the factors that might account for the most variance in those scores. Four variables were tested: chronological age, age of entering a school for the deaf (representing consistent ASL experience among peers and adults), learning disability, and gender. We expected that chronological age and age of entering a school for the deaf would predict unique variance in syntactic knowledge, consistent with prior research. We predicted that participants who had a learning disability would have impaired grammatical judgment abilities. We also anticipated that gender would predict additional unique variance in syntactic knowledge, consistent with the literature on deaf children (Herman & Roy, 2006; Hermans, Knoors, & Verhoeven, 2010). Finally, we wanted to see if all our predictor variables—chronological age, age of entering a school for the deaf, gender, and learning disability—would affect the performance on the syntax judgment test differently for native and nonnative signers. Previous studies with similar populations have shown that native and nonnative signers approach the acquisition of ASL vocabulary differently. We expected that the above factors would affect nonnative signers differently from native signers.

Method

Participants

A total of 591 deaf students between the ages of 7;6 and 18;5 years were tested at schools for the deaf across the United States (Table 1). Data from 421 were analyzed for this study. Age 7 was chosen as the first year of testing because it is the age when children are better able to use their metalinguistic abilities to solve increasingly difficult language tasks (Bialystok, 1986). Parental hearing status was used to categorize students as likely to have a signing environment fostering native knowledge of ASL. This categorization was based on the findings that signing was used in 97% of homes containing two deaf parents and in 81% of homes containing one deaf parent (Mitchell & Karchmer, 2005). In total, 169 students were classified as 'native' signers, defined as having at least one deaf parent. The remaining 252 students were classified as 'nonnative' signers, and were presumed to have first been systematically exposed to ASL upon entering the educational system. Although the native signing group was smaller than the nonnative signing group, it was 40% of the total sample. In the population at large, it is estimated that only 5–10% of deaf children are born to deaf parents (Mitchell & Karchmer, 2005). Of the native signers, 74 (43%) were female and 95 (57%) were male. Of the nonnative signers, 106 (42%) were female while 146 (58%) were male.

Table 1 Number of students by age group and signing status

	Age group										
Signing status	7–8	9	10	11	12	13	14	15	16	17	18
Native	13	16	27	26	15	15	23	12	8	6	8
Nonnative	15	29	27	25	21	23	24	18	23	22	25

Materials

The main task was a video-based, receptive multiple-choice subtask of an ASL assessment instrument presented on a computer (Hoffmeister et al., 2013; see also Henner et al., 2016). Two native signers developed 27 syntactic sentence stimuli to vary within nine syntactic structures. The sentence structures included: topicalization, subject-verb-object, complement, relative clause, verb agreement, negation, conditionals, *wh*-questions, and rhetorical questions (following Boudreault & Mayberry, 2006). The task was designed to be in a multiple-choice grammaticality judgment format. Each stimulus item consisted of a correct sentence and three foils representing different violations. Glosses for a sample complement structure are presented in Example 1, where (a) is a gloss of the correct response, (b) and (c) are foils with word order violations, and (d) is a foil with an incorrect coindexing between FRIEND_i and HE_j. Following standard presentation, ASL is represented using glosses roughly corresponding to translated meaning in caps, and third-person referential pointing is marked using the letters X_i and X_j. Items varied in types of foils, for example, in terms of word order or incorrect nonmanual markers.

Example 1

a. Correct response: MY FRIEND_i HE_i THINK WE HAVE TEST TOMORROW.
b. Word order violation: TEST TOMORROW THINK WE HAVE MY FRIEND_i HE_i.
c. Word order violation: TOMORROW MY FRIEND_i HE_i HAVE THINK TEST.
d. Grammatical violation: MY FRIEND_i HE_j THINK WE HAVE TEST TOMORROW.

Face validity of the task was established using a group of seven native signer adults who were not involved in developing the task. This group of native signers examined over 50 different sentences and the corresponding item options. Sentences selected for inclusion in the syntactic judgment task had over 85% agreement among the native signers.

Predictors

Four predictors were extracted from background information collected from the schools. Chronological age was chosen because older students were expected to perform better than younger students. Age of entering a school for the deaf represented the age of first systematic and substantial exposure to ASL for nonnative signers. Nonnative students who were enrolled in the parent–infant program (prior to age 3) of the school for the deaf were given an age of 0 as their age of entering the program. The prediction was that nonnative signers who were exposed to ASL at an early age would have ASL grammaticality judgment abilities like those of native signers. Gender was included in the analysis because females often perform better than males on language tasks (Herman & Roy, 2006; Hermans et al., 2010). Hermans et al. (2010), for example, had suggested that gender can be used to establish construct validity in a sign language assessment. The fourth predictor was learning disability. Learning disability was designated by a three-part categorical scale: (a) no additional disabilities, (b) learning disability suspected but not diagnosed,[6] and (c) diagnosed learning disabilities (Table 2). The category used for learning disability required that the school records show a formal diagnosis of learning disability.

The scale of additional disability included a fourth category of students with cognitive/intellectual disability ($n = 80$, 13 native signers and 67 non-native signers). These students were not included in the present study. The rationale for this decision had several motivations. Intellectual/cognitive disability was based on a medical diagnosis of one or more of the following: cognitive delays, developmental disability, autism (along the spectrum), and/or neurological challenges. This category also included severe emotional problems (meaning sufficiently severe to be placed in a special program). Because the cognitive/intellectual disability category included diverse and broad diagnoses that affect language differently, it was not possible to attribute any language difficulties to a single diagnosis. This approach paralleled the method used in a recent study on academic achievement of deaf students from bilingual programs (Hrastinski & Wilbur, 2016). An additional 90 students were not included in the current analysis because schools had not indicated whether students had a disability.

Table 2 Number of students by student disability rating category and signing status

	Student disability		
Signing status	No additional disability	Suspected learning disabilities	Diagnosed learning disabilities
Native	96	37	36
Nonnative	59	92	101

Testing Procedures

Participants completed the task in groups of up to 25 students. A computer platform was used to present the task in four different phases using only ASL via video windows. The first phase was an ASL instructional phase. Participants viewed the following video instructions (presented in ASL in the actual task but translated into English for this article):

> Now you'll take a different test. This test is a syntax test. You will see four different video windows presenting signed sentences. The format will be the same as the previous tests you have taken, with four separate movie windows on your screen. Each movie window will play one sentence. You need to carefully watch each sentence and decide which one of the four sentences is correct. Three of the sentences are wrong—the signing is wrong/incorrect and the way the signs fit together does not make sense. One sentence is right—it is produced correctly, the sign order is correct, facial expressions are correct, everything fits together in the right way. You need to pick that one correct sentence.

The second phase was a practice phase. Participants viewed two practice items and were provided feedback on whether their selection was correct. The third phase was the task itself. For each item, the testing platform presented the four video stimuli composed of one target sentence and three foil sentences. Students were instructed to select the response that best reflected a correct sentence in ASL. After students had made their selections, the final phase consisted of a review phase. Each item was displayed along with the freeze frame of the student's selected response. Participants, if they so chose, could then return to a selected item and confirm their selection or select a different response.

Results

Descriptive Analyses

Following Hayes, Geers, Treiman, and Moog (2009), we divided our analysis into three conceptual parts. The first analysis sought to address the first hypothesis, namely, that performance on the grammaticality judgment task improves with age. Graphic plots of test scores showed deviations from a linear increase in scores as a function of age, so these age trends are first described to provide background for the statistical analyses. Figures 1 and 2 show density plots for scores by age and signing status. Density plots are graphical representations of the distribution of scores: The middle line of the central boxplot indicates the

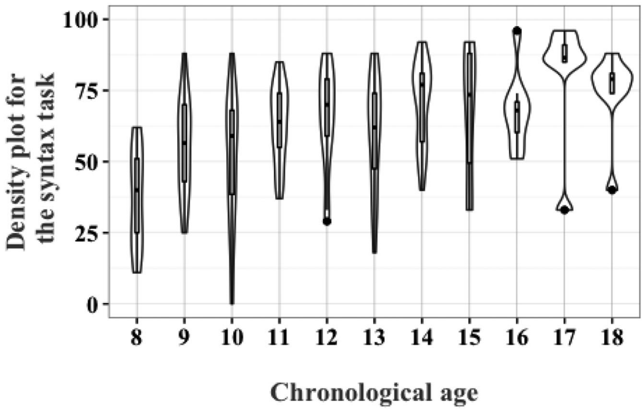

Figure 1 Density plots for native signers by chronological age.

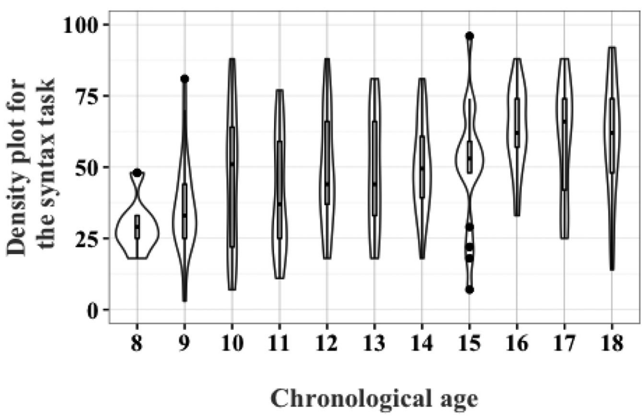

Figure 2 Density plots for nonnative signers by chronological age.

median score; between the median and top of the boxplot is the quartile of data above the median; the area between the median and the bottom of the boxplot is the quartile of data below the median. Minimum and maximum scores are indicated by the bottom and top of the envelope surrounding the central box. Density plots thus provide a quick five-point data summary: minimum score, first quartile scores, median scores, third quartile scores, and maximum scores. The more participant scores cluster around a data point, the larger is the size of the surrounding envelope. Large clusters appear as *density blooms*, which are bulges in distribution (see Henner et al., 2016, for additional information on how to interpret density plots).

The scores of both native and nonnative signers generally improved with age, as shown by the median values in Figures 1 and 2. For both groups, scores increased at ages 9 and 10, compared to the baseline (7–8, indicated as 8 in the figures). The median scores for nonnative signers decreased at age 11 and for subsequent years increased only slowly, with the 10-year-old group's median score of 50% not being reached until age 14. The age trend for native signers also showed a minor decrease in median score at age 13, with an increase, and then another plateau for ages 15 to 16. To understand these dips, it should be borne in mind that this was not a longitudinal sample and that new students entered the schools each year. Dips in median scores reflect the inherent variability of making age comparisons among different groups of students. Based on our experience as educators working with deaf children in schools, dips in median scores may also reflect an influx of students who have arrived at a school for the deaf following academic difficulty at a mainstream school. Many of these new arrivals have little ASL. The result is that as age at testing time increases, there is more opportunity for the cohort being tested to include students who have late exposure to ASL and achieve test scores at or below 25% correct (chance performance). These low scores then decrease the median scores, with the result that age trends show a dip in median scores. A reason for the slight decrease in scores for age 18 compared to 17 is that many students had graduated from high school before age 18. The 18-year-olds who remained in school included a subset of students whose schooling had been delayed a year, possibly due to learning difficulties.

It is also useful to discuss how test score distributions varied for the two signing groups. Native signers' distributions were less variable at each age compared to the distributions of nonnative signers. The scores of the oldest students clustered near the top of the distribution, as can be seen in the density blooms at the top of each plot for students aged 17 to 18. These density blooms for the oldest native signers suggest that early and constant exposure to ASL leads to high and relatively uniform ultimate attainment in syntactic ability. The result is reduced variability in syntactic judgment abilities. In contrast, the distribution of scores of nonnative signers remained spread out across the range of possible scores. However, some nonnative signers attained scores comparable to many native signers. This can be seen in the consistent pattern of nonnative third-quartile scores overlapping with native first-quartile and median scores.

Chronological Age

To analyze age trends statistically, we ran mixed-effects model analyses using the score on the grammaticality judgment task as a dependent variable, the students themselves as a random effect, and age and signing status as fixed effects. Because scores did not always increase with age, we tested how much grammaticality judgment abilities improved relative to the youngest participants in our sample (7–8). Chronological age was entered as a categorical variable to allow us to quantify improvement from the baseline. Model comparisons indicated main effects of chronological age, χ^2 (10) = 102.23, $p <$ .001, and of signing status, χ^2 (1) = 57.43, $p < .001$. The random factors (the students) only contributed to about 3% (*SD* = 15%) of the variance in scores.

Table 3 presents the different beta values for the slopes of the fixed effects, age, and signing status. Scores at each age were compared to scores at the baseline of ages 7 to 8, with a generated *t* value. The *t* value can be thus used as an index of the magnitude of the difference between a score at that age and the baseline. The *t* values in Table 3 generally increase, supporting better performance with age, compared to the youngest age group.

Table 3 Beta values for fixed effects in a mixed-effects model using the syntax test as a dependent variable and chronological age and signing status as predictors

Fixed effects	*Beta*	*SE*	*t*
Chronological age (7–8)			
9	.08	.04	2.36
10	.13	.04	3.63
11	.20	.04	5.19
12	.20	.04	4.95
13	.19	.04	4.68
14	.27	.04	6.78
15	.24	.04	5.61
16	.34	.04	7.82
17	.33	.04	7.31
18	.34	.04	7.82
Signing status (native)			
Nonnative	−.16	.02	−7.87
Random effects	Variance	*SD*	
Students	.03	.15	

Table 4 Beta values for fixed and interaction effects in a mixed-effects model using the syntax task as a dependent variable and chronological age, signing status, age of entering a school for the deaf, gender, and additional learning disability as predictors

Fixed effects	*Beta*	*SE*	*t*
Signing status (native)			
Nonnative	−.18	.08	−2.23
Age (chronological)	.03	.01	6.58
Age (entering deaf school)	−.01	.004	−1.68
Gender (female)			
Male	−.07	.02	−4.20
Student rating (no disabilities)			
Suspected learning disability	−.15	.04	−4.01
Learning disability	−.17	.04	−4.85
Fixed interaction effects			
Signing status (native) × Age (chronological)			
Nonnative	.005	.01	0.78
Signing status (native) × Age (entering deaf school)			
Nonnative	−.01	.005	−1.25
Signing status (native) × Student rating (no disabilities)			
Nonnative: Suspected learning disability	.08	.05	1.86
Nonnative: Learning disability	.10	.05	2.25
Random effects	Variance	*SD*	
Students	.02	.13	

Age of Entering School, Gender, and Learning Disability

The next analysis tested the second hypothesis regarding the following additional predictors: age of entering a school for the deaf, gender, and learning disability (Table 4). We initially added all three variables to the models; however, we did change the next analysis to make chronological age a continuous variable because no granular analysis of year-to-year change was needed. Three interaction effects were also added to the model to examine how signing status interfaced with chronological age, age at entering a school for the deaf, and learning disability.

Model comparisons showed significant effects of signing status, χ^2 (1) $= 27.20, p < .001$; chronological age, χ^2 (1) $= 116.02, p < .001$; age of entering a school for the deaf, χ^2 (2) $= 20.90, p < .001$; gender, χ^2 (1) $= 17.22, p < .001$; and disability status, χ^2 (4) $= 37.79, p < .001$. Interaction effects between signing status and chronological age were not significant, χ^2 (1) $= .59, p = .44$, nor were they for age on the date of entry, χ^2 (1) $= 1.56, p = .42$. However, there was a significant interaction effect between signing status and learning disability, χ^2 (2) = 6.17, p = .04. The results shown in Table 4 indicated that chronological age accounts for a 3-point increase in the task scores for each year. Nonnative signers, on average, scored 18 points lower than native signers. Each year participants delayed entering the school for the deaf, their scores decreased, on average, by 1 point. Males, on average, scored 7 points lower than females. Finally, students with suspected learning disabilities scored 15 points lower than students without disabilities. Students with learning disabilities scored 17 points lower on average, compared with students without disabilities. Thus, having a learning disability and being suspected of having one were both associated with a substantial decrease in test scores. The significant interaction term indicates that the effect of a learning disability diagnosis varied according to signing status.

Separate Analyses for Native and Nonnative Signers

To better understand the interactions between signing status and other variables, we modeled syntax results separately for native and nonnative signers. Therefore, the final analysis addressed the third hypothesis by exploring whether native versus nonnative signers' syntactic development was influenced by chronological age, age of entering a school for the deaf, gender, and learning disability (Table 5). Model comparisons for native signers showed main effects of age, χ^2 (1) = 70.65, $p < .001$; gender, χ^2 (1) = 7.87, p = .005; and

Table 5 Beta values for fixed effects in a mixed-effects model using the syntax task as a dependent variable and chronological age, signing status, age of entering a school for the deaf, gender, and additional learning disability as predictors, for native and nonnative signers

	Native signers			Nonnative signers		
Fixed effects	*Beta*	*SE*	*t*	*Beta*	*SE*	*t*
Age (chronological)	.03	.005	7.04	.04	.004	8.95
Age (entering deaf school)	−.006	.004	−1.79	−.01	.003	−4.05
Gender (female)						
Male	−.07	.03	−2.79	−.08	.02	−3.08
Student rating (no disabilities)						
Suspected learning disabilities	−.15	.03	−4.41	−.06	.03	−1.96
Learning disabilities	−.18	.03	−5.09	−.07	.03	−2.31
Random effects	Variance	*SD*		Variance	*SD*	
Students	.02	.12		.02	.14	

learning disability, χ^2 (2) = 33.11, $p < .001$. For the native signers, there was no main effect of age of entering a school for the deaf. For each year native signers aged, they could expect a 3-point increase on the task. Males, however, scored on average 7 points lower than females. Native signers with a suspected disability scored on average 15 points lower, compared with students without disabilities, and those diagnosed with learning disabilities scored 18 points lower on average, compared with those without any disabilities.

Model comparisons for nonnative signers showed main effects of age, χ^2 (1) = 70.66, $p < .001$, gender, χ^2 (1) = 9.56, $p = .002$, and age of entering a school for the deaf, χ^2 (1) = 16.22, $p < .001$. There was no main effect of learning disability (suspected or diagnosed). As nonnative signers aged, they could expect to score at least 4 points higher every year on the task. For each year they delayed entering a school for the deaf, they scored 1 point lower. The data also showed similar gender results, with males scoring lower than females.

Summary of Results

To summarize, the findings revealed that performance on the grammaticality judgment task improved with age for both groups of signers. However, whereas the slopes for chronological age and gender were relatively similar for native and nonnative signers, there were key differences in how age of entering a school for the deaf and additional learning disabilities affected the two groups. Age of entering a school for the deaf did not affect the scores of native signers but significantly affected the scores of nonnative signers. Additional learning disability strongly affected the scores of native signers but only weakly affected the scores of nonnative signers. The weak effects of disability for nonnative signers explained the significant interaction terms between signing status and learning disability in the analysis targeting the second hypothesis (Table 4).

Discussion

This study examined the development of ASL syntactic knowledge using a grammaticality judgment task with 421 deaf students aged 7;6 to 18;5 years. To our knowledge, this is the largest study to date targeting ASL syntactic skills in signing deaf children. Syntactic knowledge increased with age for both native and nonnative signers. The effect of gender was similar across the two groups. The effects of age of entering a school for the deaf and additional learning disabilities displayed different patterns in the two groups. Whereas the age of entry had a negative effect only on nonnative signers, learning disabilities demonstrated a strong effect on native signers and a weaker effect on nonnative signers, which is a novel finding with substantial implications for assessing deaf children.

Chronological Age: Syntactic Development Across School Age

As predicted, chronological age influenced performance on the syntactic task for both native and nonnative signers (see Tables 3–5 and Figures 1 and 2). This result for ASL is consistent with findings from other signed languages—Sign Language of the Netherlands (Hermans et al., 2010) and BSL (Marshall et al., 2014)—showing syntactic development with age, and is compatible with research on spoken languages (Sutter & Johnson, 1990).

Chen Pichler (2012) noted that, at the beginning of elementary school, deaf children correctly produce many of the syntactic structures of ASL, including some of the structures tested in this study. For example, deaf children can correctly produce the coordination of *wh*-signs and the nonmanual features between the ages of 6 and 7 (Lillo-Martin, 2000). We do not have production data for our native signers, but it is reasonable to assume that their abilities would resemble those reported by Chen Pichler. Language acquisition in native signers has been shown to follow predictable milestones (Simms, Baker, & Clark, 2013). Averaging across individual differences, native signing children of the same age should have similar production abilities. In our syntactic judgment task, 8-year-old nonnative signers had a median score of 27%, and native signers had a median score of 33%. These relatively low median scores suggest that syntactic production and syntactic judgment are separate abilities for children and that syntactic judgment is probably a more difficult task than syntactic production. Consistent with this, Bialystok (1986,1991) noted that the ability to judge correct grammar requires both language knowledge and analytical ability, which tend to be linked to age. It is also important to consider that little metalinguistic discussion is provided to deaf students in or out of school.

In our sample, by age 8, native signers already showed better performance (in the upper quartiles) in ASL syntactic judgment, compared to nonnative signers. By the end of high school, native signers' median score was 80%, corresponding to adult levels of ASL knowledge, in line with results from Chamberlain and Mayberry (2008). While the syntactic judgment abilities of nonnative signers improved as they aged, they only attained a median score of 67% by the end of high school. Taken together the similarities in the slopes and the differences in median scores at the end of high school, the current results suggest that acquisition rates for sign languages—and specifically for sign language syntax—are relatively consistent regardless of when language learning begins. Those who learn sign language earlier have a head start over those who learn later. In general, our data suggest that late learners, as a group, may never close the gap.

Age of Entering a School for the Deaf Influences Syntactic Sensitivity

Entering a school for the deaf at a later age had a negative effect for nonnative signers but not for native signers. The older nonnative signers were when they entered the school for the deaf, the worse they performed. Students with late entry to a signing school had syntactic difficulties, and for many of these students, those challenges were not resolved by the end of high school. These results echoed findings from research showing that adults exposed to a signed language at later ages have lasting syntactic deficits (Mayberry et al., 2011).

Our data were also consistent with research showing that school-based language supports metalinguistic skills and use of complex syntactic structures, both for monolingual and bilingual students (Whittle & Lyster, 2016). However, the situation of deaf children exposed to ASL after early childhood is different from L2 learning by hearing children. In typical L2 learning, children have already acquired a language, their L1. In the research on deaf children in our study and that of Mayberry et al. (2011), many of the nonnative signers did not have good control of a previously acquired L1. Indeed, key reasons for students being transferred to schools for the deaf at older ages are poor acquisition of spoken language and poor classroom achievement. As mentioned previously, the decrease in syntactic judgment scores for learners aged 12 to 13 likely reflected the influx of deaf students with little prior ASL into schools for the deaf. These children are usually relocated to a signing environment with the assumption that they can at least acquire language in the manual modality. Parents may expect that their child will face a situation similar to the one where an immigrant child is exposed to a new language via immersion at school—challenging in the short term but with rapid acquisition and eventual nativelike attainment. The current findings cast doubt on this assumption. Instead, our findings suggest that late entry to a signing program, in the absence of early exposure to signing in the home or other substantial ASL exposure, often brings with it difficulties with acquiring complex syntax. In essence, when children acquire a signed language at later ages, they may be less sensitive to its syntactic structure (Humphries et al., 2016).

Enrollment in a school for the deaf mattered for nonnative signers but not for native signers. This is consistent with the idea that, lacking good sign language input at home, school becomes a natural environment for sign language acquisition and incidental learning. Those deaf children who enter a school for the deaf late may have experienced language deprivation during the critical period for language acquisition (Calderon, 1998; Friedmann & Szterman, 2005; Yoshinaga-Itano, 2003). Early exposure to a natural language appears to be crucial for late language development. Recently, Davidson, Lillo-Martin, and Chen Pichler (2014) demonstrated a positive effect of sign language on spoken language. They showed that deaf children who had early exposure to a natural sign language and received a cochlear implant had spoken language abilities that exceeded prior reports of the spoken language abilities of implanted children, most of whom had not acquired a sign language. The current results support the claim that early language exposure supports the development of ASL, but also introduces a note of caution: like all languages, ASL is subject to maturational constraints (Henner et al., 2016; Mayberry & Eichen, 1991; Mayberry & Lock, 2003).

When we tested for an interaction effect between signing status and age of entering a school for the deaf, the interaction did not reach statistical significance. This suggests that, while entering schools for the deaf early may be more important for nonnative signers because they likely have not received quality language input at home, native signers may also be harmed by late entry in other ways. For example, native signers who enter schools for the deaf later can show some grammaticality judgment deficiencies when compared to native signers who entered earlier. Henner et al. (2016) argued that school environments foster academic language proficiency for native signers as well. Late-entry native signers may miss out on crucial exposure to academic ASL, which could affect their syntactic judgment abilities. Additional research is necessary to determine which syntactic elements of ASL are linked to academic language proficiency.

Additional Learning Disabilities Affect Primarily the Performance of Native Signers

Participants were categorized according to whether they were suspected of or were diagnosed with a learning disability. Being in this category reduced scores by 10 to 12 points compared to those without disabilities when both signing groups were combined. However, when each signing group was explored separately, this effect was shown only for the native signers. Native signers with learning disabilities scored on average 15 to 18 points lower than those without a disability. In contrast, the grammaticality judgment abilities of nonnative signers were not influenced by having diagnosed or suspected learning disabilities.

Two explanations are plausible for why the learning disability category did not influence syntactic test scores for the nonnative signers. One is that the diagnostic tasks used to determine whether deaf children have a learning disability may be unreliable for many of the children who experience a high degree of language deprivation. Because their language acquisition is atypical and less dependent on age, it may be difficult to detect a disability against the backdrop of atypical language. A different explanation could be that nonnative signers may have a high rate of learning disabilities. A higher rate could occur because of selection bias, that is, nonnative signers with learning disabilities are the ones who are more likely to be transferred to a signing school for the deaf. Future researchers who study syntactic development using naturalistic learner samples should be forewarned of these possibilities.

The strong effect of learning disability on native signers' performance is in line with findings for children with learning disabilities using spoken languages (Sun & Wallach, 2014). Siegel and Ryan (1988), for example, found that children with learning disabilities performed significantly more poorly than typically developing children on grammatical error correction tasks. The current results add to the growing literature of identifying language difficulties in children using signed language: BSL (Herman, Rowley, Mason, & Morgan, 2014; Marshall et al., 2014; Mason et al., 2010; Morgan, Herman, & Woll, 2007; Woll & Morgan, 2012) and ASL (Novogrodsky, Fish et al., 2014; Quinto-Pozos et al., 2013, Quinto-Pozos, Forber-Pratt, & Singleton, 2011). These findings suggest that reliable assessment tools may need to be developed for specific language backgrounds, such that nonnative signers' scores should be compared to nonnative norms and native signers' scores should be compared to native norms (Herman, Holmes, & Woll, 2001; Mann & Marshall, 2012). More research needs to be conducted to account for the wide variability in age at exposure to a sign language and its impact on learning. We contend that it is language deprivation that causes learning delays, not deafness per se.

Gender Differences in Syntactic Ability

Females demonstrated greater knowledge of ASL syntax than did males, and the size of this effect was similar for both signing groups. This replicates gender differences reported in two prior tests of morphosyntax in signed languages: the Signed Language of the Netherlands (Hermans et al., 2010) and BSL (Herman & Roy, 2006). In general, studies on spoken languages suggest that girls outperform boys on language-based tasks, especially in early childhood (Maccoby & Jacklin, as cited in Hermans et al., 2010; Zink & Lejaegere, 2002), but gender effects can be absent in studies with older students (Hogrebe, Nist, & Newman, 1985). It is worth noting that the size of the gender difference was substantial, with females having an advantage of 7 to 8 points, which is similar to the 10-point advantage of native signers over nonnative signers. One factor contributing to the female advantage in our data is that male students were more likely to be diagnosed with a disability than were female students. As discussed previously, having a learning disability cooccurring with deafness likely negatively impacts ASL syntactic judgment abilities.

Conclusion

The current findings demonstrated increased performance on an ASL syntactic judgment task across ages 7;6 to 18;5 and highlighted the advantage of having access to appropriate sign language input from early in life. Nonnative signers were delayed in their syntactic test scores relative to native signers at all ages. The data also demonstrated that nonnative signers continue to be a highly variable population in terms of language exposure (Singleton & Newport, 2004), such that later exposure to a signed language was associated with a more pronounced negative impact on signers' syntactic judgments. However, researchers need to exert caution when comparing native and nonnative signers, as many nonnative signers in our sample who had adequate exposure to ASL were not significantly different from native signers. A novel finding was that the scores of native signers decreased depending on subgroups of learning disability, while the scores for nonnative signers remained mostly similar, suggesting that learning disability diagnosis may be less accurate in nonnative signers. One way to understand this is that the category of nonnative signers contains individuals with inconsistent language exposure, whose consequences for syntactic development are far more serious than a diagnosed or suspected learning disability. That is, syntactic scores are suppressed so strongly by language deprivation that additional deficits due to a learning disability cannot be detected statistically. To sum up, conclusions regarding language development in deaf children must consider the characteristics of the signing environment, timing of initial exposure (including amount and type of signing), and any additional disability that may hinder language development.

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Notes

1 While language deprivation may appear to be a contentious term, it has recently become a common label for the host of language dysfluency issues that tend to appear in deaf children who have absent or inconsistent language exposure (Hall, 2017; Humphries et al., 2016).
2 Both *wh*-initial and *wh*-in-situ are accepted in ASL (Lilo-Martin, 2000).
3 This phenomenon is called in the literature *semilingualism*, meaning underdevelopment of language in an individual. The concept involves a partial knowledge of two or more languages (Prinz & Strong, 1998).
4 These children had not developed a full L1 prior to their late exposure to sign language.
5 There are different variations of the tasks; for example: (a) the child is asked to make syntactic judgment, (b) s/he is also asked to correct the sentence, (c) s/he reads two sentences and chooses the better one.
6 This rating was used when the educators who completed the questionnaire thought the student had a learning problem but this suspected learning problem had not been formally diagnosed.

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