Effects of Age on American Sign Language Sentence Repetition

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Abstract

The study of deaf users of signed languages, who often experience delays in primary language acquisition, permits a unique opportunity to examine the effects of aging on the processing of a primary language (L1) acquired under delayed or protracted development. A cohort of 107 congenitally deaf adult signers aged 45-85 years, who were exposed to American Sign Language (ASL) either in infancy, in early childhood, or late childhood were tested using an ASL sentence repetition test. Participants repeated 20 sentences that gradually increased in length and complexity. Logistic mixed effects regression with the factors of Chronological Age and Age of Acquisition was used to assess sentence repetition accuracy. Results showed that Chronological Age was a significant predictor, with increased age being associated with decreased likelihood to reproduce a sentence correctly (OR = 0.56, p = .010). In addition, effects of Age of Acquisition were observed. Relative to native deaf signers, those who acquired ASL in early childhood were less likely to successfully reproduce a sentence (OR = 0.42, p = .003) as were subjects who learned ASL in late childhood (OR = 0.27, p < .001). These data show that aging affects verbatim recall in deaf users of ASL and that the age of sign language acquisition has a significant and lasting effect on repetition ability, even after decades of signed language use. These data show evidence for lifespan continuity of early life effects.

Keywords: American Sign Language, deafness, aging, age of acquisition, language modality

Effects of Age on American Sign Language Sentence Repetition

Studies of the effects of aging on language have overwhelmingly been predicated on users of spoken languages who acquire their linguistic abilities under usual conditions of language acquisition. These studies take for granted that the instantiation of language knowledge under study arises from the expected interplay between biological and social-cultural constraints that characterize typical language acquisition. However, the characterization of age-related changes in primary language (L1) function learned under ideal conditions reflects but one possibility. The study of profoundly deaf individuals who have acquired sign language as their primary language presents another eventuality. As 95% of deaf infants are born to parents who are not deaf and do not know a signed language, initial exposure to a signed language may be quite delayed in time, often not occurring until early childhood or beyond. In spite of this many deaf children will go on to become proficient users of a visual-manual language, such as American Sign Language (ASL), and adopt a sign language as their primary and preferred method of communication.

The study of how aging affects language processing of a primary language (L1) acquired under delayed or protracted development is largely unknown. This study provides evidence for two separate age-dependent influences on language processing, an effect of age of acquisition (AoA) and an effect of chronological aging (CA). The study of deaf signers permits a unique opportunity to expand our understanding of the vulnerabilities and resilience of natural language systems during aging.

Deafness and Language

Most deaf children are born to parents who are not deaf and do not know a signed language. For these children the first exposure to a signed language may come through an early

intervention program or, more common to the present study cohort, exposure to other deaf signing children and adults in elementary day and residential school programs. While these students may receive instruction in oral English, ASL is often adopted as their preferred mode of communication and is used principally throughout their life. Thus, many deaf signers acquire their L1 as school-aged children or even later in adolescence. Deaf children with hearing parents stand in contrast to *native-signers*, congenitally deaf individuals who are born into deaf signing families. These deaf children are exposed to ASL from birth and hence acquire their L1 (i.e., ASL) under conditions that mirror hearing infants' language acquisition experiences. Data from native-signing infants show linguistic developmental milestones that are characteristic of the development of spoken languages (Anderson & Reilly, 2002; Meier, 1991; Newport & Meier, 1985).

There are consequences when language acquisition occurs outside the typical sensitive period for language learning. Psycholinguistic research has shown that performance on many types of sign language tasks is affected by AoA (see Mayberry, 2010 for review). Particularly germane to the present study are the data from Mayberry and Eichen (1991), which showed that in the context of sign sentence shadowing, non-native signers were apt to make formational errors in signing often rendering the sentences nonsensical, while native signers tended to make lexical substitutions that nevertheless preserved the overall gist of the sentence content.

However, while sensitive psycholinguistic measures have revealed subtle processing differences between native and non-native signers, more global measures of sign language use have been found to be comparable. Mayberry (1993) reports that in a group of adult signers who have had at least 20+ years of continuous ASL use, that the rate of ASL production, articulatory

execution of sign forms, and lengths of signed responses did not differ as a function of age of language acquisition.

The present study presents data from an investigation of ASL sentence repetition in an older cohort of congenitally deaf users of American Sign Language (ASL). The study included native-signers and two groups of non-native signers (i.e., early and late ASL exposed). The stratification of subjects based on age of exposure to a sign language provides a unique opportunity to examine how aging affects language processing of a primary language (L1) acquired under protracted development.

The Current Study

Off-line measures of language ability that tax working memory show age-related declines in typical hearing populations (Burke & Shafto, 2008; Kemper & Sumner, 2001; Van der Linden et al., 1999; Waters & Caplan, 2001, 2005). Hence, we predicted that ASL sentence repetition will also result in decreased performance as a function of CA. In addition, given the reported psycholinguistic processing differences of native and non-native signers, we hypothesized that later age of sign language acquisition will result in poorer performance for non-native signers. Finally, we evaluated the interaction between these factors to assess whether these factors conspire to reduce or exacerbate problems in ASL sentence repetition performance in the context of aging.

Method

Participants

One hundred seven healthy congenitally deaf users of American Sign Language (aged 45-85 years) were recruited and tested on an ASL sentence repetition test. Subjects were divided into three groups based on their age of ASL acquisition[1]: native signers (n = 33, 21 female, M_{age}

= 62 years, (SD 10.73), age range: 46-85 years) early signers who were exposed to American

Sign Language before the age of eight[2] (n = 40, 28 female, M_{age} = 65 years (SD = 11.16), age

range: 45-83 years, M_{AoA} = 4.9 years, (SD = 1.59), age range: 2-7 years), and late acquirers of

ASL, exposed to ASL after the age of eight, typically in adolescence[3] (n = 34, 21 female, M_{age} =

66 years, (SD = 12.0), age range: 48-84, M_{AoA} = 13.4 years, (SD 4.31), age range 8-25 years).

All subjects provided informed consent as required by The Salk Institute,

Institutional Review Board IRB Protocol #09-0002. The majority of subjects (n = 100) were

recruited and tested during participation at the Deaf Seniors of America (DSA) conference in

Baltimore MD, August 2013. The remaining subjects (n =7) were recruited through outreach

efforts and tested at the Salk Institute, La Jolla CA.

Detailed individual information regarding educational levels and occupations of these

participants is not available. However, independent historical and demographic data permit a

broad characterization of this deaf subject population. Notably, all but the youngest participants

in this sample were exposed to school systems that actively discouraged the use of signing[4].

Procedure

The American Sign Language Sentence Repetition test (ASL-SRT), (Supalla, Hauser, &

Bavelier, 2014), was developed by adapting the approach used in the spoken-language Test of

Adolescent Language 3 (TOAL-3), Speaking/Grammar subtest (Hammill, Brown, Larsen, &

Wiederholt, 1994). Like the TOAL-3, this test presents 20 sentences that gradually increase in

sentence length, complexity of morphology, and number of propositions. Table 1 lists word span,

syntactic complexity, and content for each item. The first 10 test items are single clause

sentences with a variety of argument-predicate relations. Items 11–20 contain multiple clauses

with various types of relations among constituents.

---Table 1 here---

The test is administered on a laptop computer, where subjects view a video of a woman who serves as both an instructor and a model producing the set of sentence items. In the video subjects were instructed to copy the model's exact signing, stressing the need for verbatim response. After three practice sentences, a self-paced test session followed. In the test session subjects view each sentence only once, but were given unlimited time to make their response. Subjects were allowed to self-correct or repeat a response before moving onto the next sentence by pressing a key.

Subjects took on average10 minutes to complete the test and responses were video-recorded for off-line scoring. Responses were rated by two native signers (L.F. and S.P) who are experienced ASL researchers[5]. In cases more than one attempt at correct repetition was made, raters were instructed to use the last response for rating purposes. A response was marked incorrect if it deviated from the model sentence beyond a few agreed upon alternatives (Hauser, Paludneviciene, Supalla, & Bavelier, 2006), or if no response was given.

Statistical Analysis

Logistic mixed effects regression model was used to predict sentence repetition accuracy. Predictors were Chronological Age (continuous), AoA (native, early, or late), and the interaction between these two variables. For the main analysis of AoA, the native group was used as the reference group. To control for repeated measures per Subject and Sentence, this model included random intercepts for both Sentence and Subject, as well as by-Sentence random slopes for the effects of Age and AoA. Age was standardized relative to the sample (one standard deviation corresponds to 11.2 years).

Likelihood ratio tests were used to test the significance of effects, and Wald tests were

used to test the significance of model parameters. Significant results are reported using odds

ratios (OR) estimates. All analyses were carried out using the glmer() function from package

lme4 (Bates, Maechler, Bolker, & Walker, 2015) in R (R core team, 2014).

Results

Results (summarized in Table 2) showed that the effect of Chronological Age was

significant, ($\chi2(7)=28.095$, $p < .001$) with increased age being associated with decreased

likelihood to reproduce a sentence (OR = 0.56, $p = .010$). Additionally, the effect of Age of

Acquisition was significant ($\chi2(11)=22.828$, $p = .019$). Relative to the native signers, those who

acquired ASL early were less likely to successfully reproduce a sentence (OR = 0.42, $p = .003$)

as were subjects who learned ASL later (OR = 0.27, $p < .001$). However, there was no difference

between the late and early AoA groups (OR = 1.54, $p = .158$).

---Table 2 here --

As shown in Figure 1, results indicate that increased age and later ASL acquisition

decreased the likelihood of ASL sentence reproduction. Despite the appearance to the contrary,

the interaction between AoA and Chronological Age was not significant ($\chi2(2) = 3.833$, $p = .147$). Relative to the native group, the effect of Chronological Age was unchanged for the early

group (OR = 0.81, $p = .489$) and the late group (OR = 1.41, $p = .238$). However, relative to the

late group, the early group showed a larger effect of Chronological Age (OR = 0.57, $p = .048$)[6].

---Figure 1 here---

As prior studies have reported age-related effects on sentence imitation as a function of

syntactic complexity (Kempler,1986, 1987), two additional versions of the overall statistical

model were included, splitting the data into the first and last 10 sentences[7]. The results of the

models showed similar patterns as the overall model. In both models, both levels of AoA were

significant (all p's < .05) with individuals acquiring ASL later in life being less likely to reproduce a sentence relative to individuals who acquired the language early. As in the overall model, Age was also significant for the first 10 sentences, with older adults being less likely to reproduce sentences (p = .001). However, for the last 10 sentences, Age was not significant (p = .11), perhaps due to smaller variability in the reproductions of the final 10 (more difficult) sentences.

Discussion

The data from this sample of deaf signers confirm the expectation that performance on ASL sentence repetition decreases as a function of chronological age. In addition, there are significant and persistent age of acquisition effects. Importantly there was no evidence of an interaction between these factors.

Chronological Age

The data indicate that the ability to fully repeat single and multi-clausal ASL sentences decreased as a function of chronological age. A comparison of our data to data reported by Supalla et al. (2014) is shown in Figure S2 (see Online Supplement). Their data show that school-age (10-14 years) and young adult native signers (15-30 years) show comparable performance, $\bar{x}$ = 13.7 (SD 3.2) and $\bar{x}$ = 14.7 (SD 2.8) respectively. As noted by a reviewer, ASL users' verbatim sentence repetition ability falls to approximately 85% of young adult levels by age 45, to 50% by age 65 and to less than 30% by age 80. This level of performance appears to be qualitatively different from the verbatim recall of spoken language sentences which is reported to be quite good in both young adults and older persons (Lombardi & Potter, 1992; Wingfield, Poon, Lombardi, & Lowe, 1985; Meyers, Volkert & Diep (2000).

Sentence repetition in which the observed sentences must be encoded and then maintained for verbatim recall, is a task that taxes both linguistic processing and memory functions (Lombardi & Potter 1995, Potter & Lombardi 1990). The performance of our participants may reflect the difficulty signers experience with ordered recall of linguistic material (see also Rudner, Davidsson, & Ronnberg, 2010). The current study indicates this difficulty may emerge even when the testing material consists of well-formed ASL sentences rather than the unrelated lists of signs, letters and digits typically used to measure short-term and working memory.

It remains an open question as to whether the age-related declines noted in the present study may be an indication of age-related vulnerabilities within working memory and or episodic storage mechanisms. Independent measures of memory functions would be useful in future testing to help pinpoint the locus of these effects. More broadly these data raise questions as to whether age related cognitive declines in non-linguistic functions, such as working memory, may differentially impact the processing of signed versus spoken languages.

Age of Acquisition

Figure 1 illustrates the performance of the three groups of subjects as a function of Age of Acquisition. Native signers show the best performance followed by early-exposed signers and finally late exposed signers. While the late learners appear to show a shallower decline than both the native and early signers, the interaction between age and Age of Acquisition did not reach significance. Rather, the effects of AoA and CA appear independent.

It is noteworthy that in the cases of early and late learners of ASL, that despite decades of experience using ASL as their primary and preferred means of communication, the ability to faithfully reproduce ASL sentences remains impacted by their initial age of language acquisition.

This is particularly striking in the comparisons between native and early signers, who show a consistent AoA difference into late life as a function of relatively modest differences in the ages at which signing was introduced. Primary language delay appears to establish set-points in the capacities for language processing and these capacities do not catch up merely through years of increased use (see also Mayberry, Lock, & Kazmi, 2002). The present data suggests that language ability, rather than exhibiting a functional resilience, which over decades of consistent use may normalize, instead is subject to stage-like constraints which establishes enduring set-points in linguistic capacities. These findings appear consistent with prior observations that early biological changes occurring in infancy and early childhood often yield domain-specific and predisposed processing capabilities (Wellman & Gelman 1992). Moreover, while native language acquisition affords processing advantages in ASL sentence repetition, it does not appear to protect individuals from age-related declines. Taken together, these data show evidence for lifespan continuity of early life effects.

Limitations and Outlook

We note several limitations of our study. While we observe ASL sentence repetition ability declines as a function of age and age of acquisition, the current study lacks the ability to determine additional factors that might underlie this decline. Independent measures of ASL fluency, visual-spatial skills, working memory and episodic memory may be particularly revealing in this regard. An additional weakness lies in the lack of detailed information about the participants' level of education. Education level has been reported to modulate spoken sentence repetition ability (Meyers, Volkert, & Diep, 2000). This leaves open the possibility that education level, as well as differences in educational policy signers may have experienced in the classroom, may be presenting as age effects[8].

Conclusion

This study represents one of the first studies to explore the effects of aging on language abilities in deaf signers. Examining sentence repetition in older signers provides a unique opportunity to assess the impact of age-related changes on primary language ability in cases where (L1) was acquired under delayed or protracted development. Across three groups of adult deaf signers, our data showed expected age-related declines. However, the early language experiences of these signers had a profound effect on sentence repetition performance. Despite decades of ASL use, those adult signers who were first exposed to ASL in early school years (or beyond) show long-lasting performance deficits compared to signers who acquired ASL as a native language. These data suggest that early imbalances in the temporal coordination between biological and cultural factors driving language acquisition (Baltes, Lindenberger, & Staudinger, 1998) can have persistent and long-lasting effects across the lifespan.

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Footnotes

1 Subject's age of sign language acquisition was based on a self-report question in a background questionnaire.

2 The decision to use eight years of age as a cut off for "early" non-native signers is arbitrary, but reflects an age range commonly used in this literature (see for example Newport, 1988; Mayberry & Eichen, 1991; Mayberry & Lock, 2003; Mayberry et al., 2011; Cormier et al., 2012, Meade et al., 2017).

3 The late learning signers in this study differ from those rare cases of severe language deprivation discussed by Mayberry, Davenport, Roth, and Halgren (2018) and Ramirez, Leonard, Davenport, Torres, Halgren, and Mayberry (2016). In contrast to cases of language deprivation, all of the subjects in the present study attended school programs for deaf children and were exposed to adult models of American Sign Language as school-aged children.

4 Participants in the present study attended school programs between 1934-1974. During this period, deaf education in the United States for severely to profoundly deaf youth included public and private day school program, as well as private and state sponsored residential schools. From the 1900's to the mid 1960's, school programs uniformly used oral methods and students

were actively discouraged from using any manual communication (Lou, 1988). In the late 1960's

and early 1970's manual forms of communication started to be used in some school programs

with the adoption of a "Total Communication" (TC) philosophy. Total Communication programs

required teachers to augment spoken English simultaneously with stylized manual signs.

However, it should be noted that these English based sign-systems (e.g. Signing Exact English)

were not ASL (Lou, 1988). As it pertains to our cohorts, subjects aged 45-50 are likely to have

attended primary school programs during which TC was beginning to be used in classrooms.

Subjects in this study who were older than 50 years at the time of testing will have attended oral

schools. As specialized deaf schools admitted hearing-impaired students regardless of their

parents' language status, deaf children's ASL role models were often the small percentage of

classmates who happened to have deaf signing parents or in rare instances non-professional deaf

support staff who worked in some residential programs.

Educational curriculum in elementary school years included instruction in traditional

academics including reading, spelling and arithmetic but also included a strong vocational

component, often by the fifth grade. Vocational educational course work responded to current

regional and societal needs, and included carpentry, agriculture, sewing, weaving, tailoring,

house painting, shoe making, printing, welding, mechanics, and typewriter repair (Hayes and

Griffing, 1967).

School attendance beyond compulsory schooling was often limited for deaf individuals.

Following World War II, only about 400 deaf and hard-of-hearing men and women were

estimated to attend college annually in the United States, with graduation rates never exceeding

more than 50-60 people per year (Kelly, Quagliata, DeMartion & Perotti, 2016). As of 2010,

only 16% of DHH people aged 25-59 years reported they had a bachelor's degree or higher (U.S.

Census, 2010, as reported in Kelly, Quagliata, DeMartion & Perotti, 2016).

5 L.F. scored 80% of the data and the remaining 20% were scored by S.P.

6 To explore the apparent interaction a version of the same model was constructed using

the late ASL signers as the reference group. This model structure allows us to directly examine

whether the OR between the early and late signers was significantly different. As reported this

analysis revealed a modest effect (OR = 0.57, p = .048), however this may reflect a floor effect.

Given the lack of an overall interaction, and the possible floor effect, we remain cautious in

providing a further interpretation of this effect.

7 The structures were the same as the reported model, except that given the reduced

amount of data per model, random slopes had to be removed to allow the models to converge.

8 For an illustration see Figure S3 in Online Supplement.