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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

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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

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

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

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.

[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).

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, ($\chi 2(7)=28.095$, $p < .001$) 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 ($\chi 2(11)=22.828$, $p = .019$). 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, $p = .158$).

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 ($\chi 2(2) = 3.833$, $p = .147$). Relative to the native group, the effect of Chronological Age was

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

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].

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

[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.

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.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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References

Anderson D, & Reilly J (2002). The MacArthur Communicative Development Inventory: Normative Data for American Sign Language. The Journal of Deaf Studies and Deaf Education, 7(2), 83–106. 10.1093/deafed/7.2.83 [PubMed: 15451878]

Cormier K, Schembri A, Vinson D & Orfanidou E (2012). First language acquisition differs from second language acquisition in prelingually deaf signers: Evidence from sensitivity to grammaticality judgement in British Sign Language, Cognition, 124(1), 50–56. 10.1016/j.cognition.2012.04.003 [PubMed: 22578601]

Baltes PB, Lindenberger U, & Staudinger UM (1998). Life-span theory in developmental psychology. In: Lerner RM (ed.) Handbook of Child Psychology: Vol. 1. Theoretical Models of Human Development, 5th edition, Wiley, New York, pp. 1029–143.

Bates D, Mächler M, Bolker B, & Walker S (2015). Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1), 1–48. 10.18637/jss.v067.i01

Burke DM & Shafto MA (2008). Language and aging. In Craik FIM & Salthouse TA (Eds.), The handbook of aging and cognition (pp. 373–443). New Jersey: Lawrence Erlbaum Associates.

Hammill DD, Brown VL, Larsen SC, & Wiederholt JL (1994). Test of Adolescent and Adult Language, 3rd Edn. Austin, TX: PRO-ED.

Hauser P, Paludneviciene R, Supalla T, & Bavelier D (2006). "American sign language - Sentence reproduction test: Development & implications" (2006). Accessed from http://scholarworks.rit.edu/other/596

[8]For an illustration see Figure S3 in Online Supplement.

Hayes GM, & Griffing BL (1967). Guide to the education of the deaf in the public schools of California. California State Dept. of Education, Sacramento. Bureau of Physically Exceptional Children. Pp 40.

Kelly RR, Quagliata AB, DeMartino R, & Perotti V (2016). 21st-Century Deaf Workers: Going Beyond Just Employed to Career Growth and Entrepreneurship. In Marschark M, Lampropoulou V, & Skordilis EK (Eds.), Diversity in Deaf Education. New York, NY: Oxford University Press.

Kemper S (1986). Imitation of complex syntactic constructions by elderly adults. Applied psycholinguistics. 7(3), 277–287.

Kemper S (1987). Syntactic complexity and elderly adults' prose recall, Experimental Aging Research, 13:1, 47–52, DOI: 10.1080/03610738708259299 [PubMed: 3678351]

Kemper S, & Sumner A (2001). The structure of verbal abilities in young and older adults. Psychology and Aging, 16, 312–322. 10.1037//0882-7974.16.2.312 [PubMed: 11405318]

Lombardi L, & Potter MC (1992). The Regeneration of Syntax in Short Term Memory. Journal of Memory and Language, 31, 713–733. 10.1016/0749-596X(92)90036-W

Lou MW (1988). The history of language use in the education of the Deaf in the United States. In Strong M (Ed.), Language Learning and Deafness.75–98 Cambridge, MA: Cambridge University Press.

Mayberry RI (1993). First-language acquisition after childhood differs from second-language acquisition: the case of American Sign Language. Journal of Speech and Hearing Research, 36, 1258–70. [PubMed: 8114493]

Mayberry RI (2010). Early Language Acquisition and Adult Language Ability: What Sign Language reveals about the Critical Period for Language. In Marschark M & Spencer P (Eds.), Oxford Handbook of Deaf Studies, Language, and Education Vol. 2. (pp. 281–291). New York, NY: Oxford University Press.

Mayberry RI, Chen J, Witcher P & Klein D (2011). Age of acquisition effects on the functional organization of language in the adult brain, Brain and Language, 119, (1) 16–29. 10.1016/j.bandl.2011.05.007. [PubMed: 21705060]

Mayberry R & Eichen E (1991). The long-lasting advantage of learning sign language in childhood: Another look at the critical period for language acquisition. Journal of Memory and Language, 30, 486–512. 10.1016/0749-596X(91)90018-F

Mayberry RI, Lock E, & Kazmi H (2002). Linguistic ability and early language exposure. Nature, 417, 38. 10.1038/417038a [PubMed: 11986658]

Mayberry RI & Lock E (2003). Age constraints on first versus second language acquisition: Evidence for linguistic plasticity and epigenesis. Brain and Language, 87(3), 369–384. 10.1016/S0093-934X(03)00137-8 [PubMed: 14642540]

Meade G, Midgley KJ, Sevcikova Sehyr Z, Holcomb PJ, & Emmorey K (2017). Implicit co-activation of American Sign Language in deaf readers: An ERP study. Brain and Language, 170, 50–61. 10.1016/j.bandl.2017.03.004 [PubMed: 28407510]

Meier RP (1991). Language acquisition by deaf children. American Scientist, 79(1), 60–70. 10.1186/1477-7517-9-16

Meyers JE, Volkert K, & Diep A (2000). Sentence Repetition Test: Updated norms and clinical utility. Applied Neuropsychology,7, 154–159. [PubMed: 11125709]

Newport EL (1988). Constraints on learning and their role in language acquisition: Studies of the acquisition of American sign language. Language Sciences, 10(1), 147–172.

Newport EL, & Meier RP (1985). The acquisition of American Sign Language. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Potter MC & Lombardi L (1990). Regeneration in the Short-Term Recall of Sentences. Journal of Memory and Language, 29, 633–654. 10.1016/0749-596X(90)90042-X

Rudner M, Lena Davidsson L & Rönnberg J (2010). Effects of Age on the Temporal Organization of Working Memory in Deaf Signers. Aging, Neuropsychology, and Cognition, 17(3), 360–383. DOI: 10.1080/13825580903311832

Supalla SJ, & McKee C (2002). The role of Manually Coded English in language development of deaf children. In Meier Richard P., Cormier Kearsy, & QuintoPozos David (eds.), Modality and structure in signed and spoken languages, 143–65. Cambridge, UK: Cambridge University Press.

Supalla T, Hauser PC, & Bavelier D (2014). Reproducing American Sign Language sentences: cognitive scaffolding in working memory. Frontiers in Psychology, 5, 859. 10.3389/fpsyg.2014.00859 [PubMed: 25152744]

Van der Linden M, Hupet M, Feyereisen P, Schelstraete M, Bestgen Y, Bruyer, Lories G, El Ahmadi A, & Seron X (1999). Cognitive mediators of age-related differences in language comprehension and verbal memory performance. Aging, Neuropsychology and Cognition, 6, 32–55. 10.1076/anec.6.1.32.791

Waters G, & Caplan D (2001). Age, working memory and on-line syntactic processing in sentence comprehension. Psychology and Aging, 16, 128–144. 10.1037/0882-7974.16.1.128 [PubMed: 11302362]

Waters GS, & Caplan D (2005). The relationship between age, processing speed, working memory capacity, and language comprehension. Memory, 13, 403–413. 10.1080/09658210344000459 [PubMed: 15952262]

Wellman HM, & Gelman SA (1992). Cognitive development: foundational theories of core domains. Annual Review of Psychology, 43, 337–75.

Wingfield A, Poon LW, Lombardi L, & Lowe D (1985). Speed of Processing in Normal Aging: Effects of Speech Rate, Linguistic Structure, and Processing Time. Journal of Gerontology. 40(5), 579–585. 10.1093/geronj/40.5.579 [PubMed: 4031406]

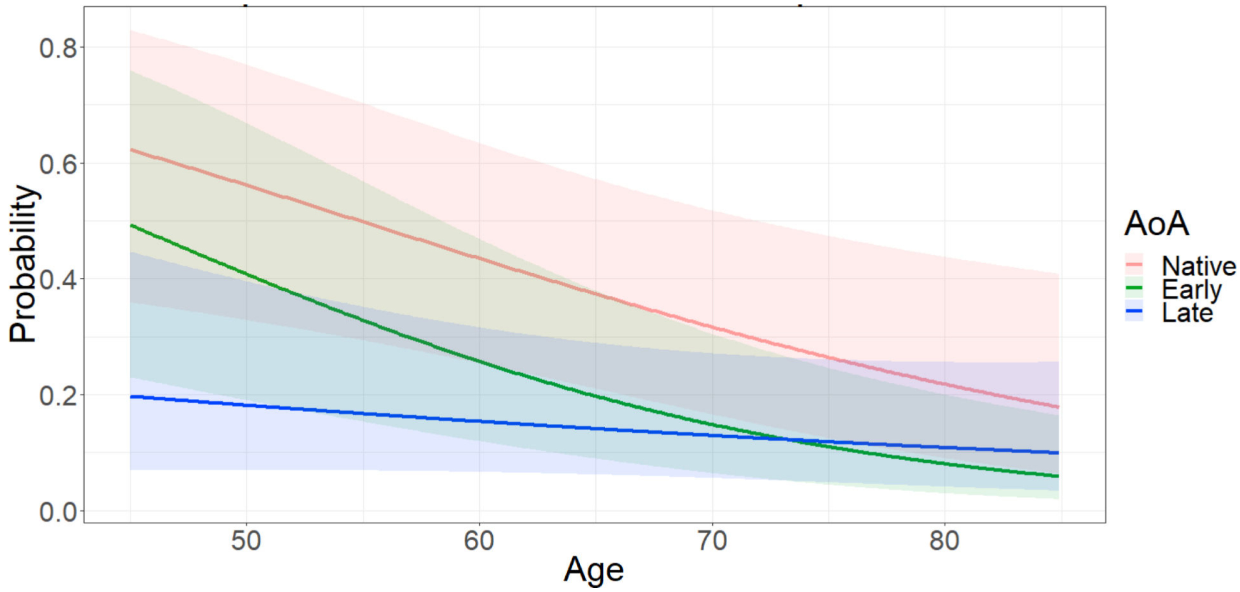

Figure 1. Model 1 predicted values – sentence repetition likelihood

Note. Probability of correct ASL sentence reproduction as a function of chronological age and age of language acquisition. Data from deaf signers exposed to ASL as a native language, in early childhood (< 8 years) and late childhood (> 8 years). Predicted values from model 1 with a 95% prediction interval.

Table 1

ASL-SRT Items with Sentence Content and Inflections

Item	Word span	Syntactic complexity	Sentence content and inflections	English translation
1	5	Transitive predication	INDEX-first FINISH BUY OLD HOUSE	*I bought the old house.*
2	5	Adjectival predication	THAT-i TREE TALL	*That tree is tall.*
3	4	Transitive predication	INDEX-i FINISH FIND KEY	*I found the key.*
4	6	Adjectival predication	MY LAST VACATION SEVEN YEARS AGO	*My last vacation was seven years ago.*
5	4	Adjectival predication	THAT MAN NICE SWEET	*That man is sweet and nice.*
6	4	Transitive predication	INDEX-i NOT LIKE INDEX-j	*(She/He) does not like (him/her).*
7	4	Adjectival predication	SUNDAY NEWSPAPER TEND CL: thickness-on-surface	*Sunday newspapers tend to be thick.*
8	4	Adjectival predication	MY DAUGHTER SELF-i AGE-THREE	*My daughter, she (herself) is three years old.*
9	4	Intransitive action	MY DOG CONTINUE+rep BARK	*My dog barked and barked.*
10	4	Adjectival predication	WOMAN SELF-i COMPETENT MATH	*The woman, she (herself) is*
11	7	Copular object	WASHINGTON #DC HAVE MANY GOVERNMENT BUILDING, CL: hugeobject-alternating-ijk	*Washington D.C. has many large government buildings in various locations.*
12	4	Adverbial predication	INDEX-first DRIVE FIVE-HOUR, ARRIVE WORN-OUT	*I drove for five hours and arrived exhausted.*
13	7	Conditional clause with transitive predication, consequence clause with adverbial predication	IF INDEX-i NOT BELIEVE INDEX-self, THAT FINE	*If you do not believe me, so be it.*
14	4	Conjunction of intransitive action and locative predication	MOTORCYCLE CL: vehicle-slide-off-ground, HIT TREE	*The motor cycle skidded off the road and hit a tree.*
15	6	Locative predication, transitive predication, locative predication	WOMAN RIDE-horse HORSE, SEE-i FENCE, CL:jump-over-fence-i	*A woman rides a horse, sees a fence ahead and jumps over it.*
16	6	Locative predication, intransitive action	THREE-OF-US GO-i-rep GRANDMOTHER HOUSE, HELP CLEAN-UP-arc-i	*The three of us regularly go to grandmother's house to help clean.*
17	6	Locomotion, locative predication, POV predication	INDEX-first LIKE GO BIKE PATH CL: trees-go-by	*I like to pedal the bike path and experience the trees flying by.*
18	7	Transitive predication, object complement, adjectival predication	#DAVID GO WATCH-i MAN LECTURE, CL: in-back-of-audience FULL	*David went to watch the man lecture; the auditorium was packed.*
19	9	Transitive predication, transitive predication	SCIENCE TEACHER DISTRIBUTE TEST, INDEX-arc STUDENT HAVE-TO NAME+rep-on-list STAR	*The science teacher gave out the tests, and the students were required to name all the stars.*
20	7	Locative predication, transitive predication	ONE LITTLE GIRL GO OUT, FLOWER CL: pick-up/ put-in-basket+rep-arc	*One little girl went outside, picked flowers and put them in her basket.*

Notes. CAP = lexical sign, INDEX = first person pronoun, INDEX-I = indexical sign to a spatial location, -ijk = distinct spatial locations, INDEX-self = reflective pronoun, CL: = classifier predicate, rep = repeated, #D-C, fingerspelled letters, -arc = arced movement of the sign path.

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Table 2

Model 1 Summary -- Age and AoA on sentence production

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	−0.4815	0.4105	−1.173	0.2408
AoA-E	−0.8759	0.2975	−2.945	0.0032 **
AoA-L	−1.3120	0.3192	−4.110	< 0.0001 ***
AGE	−0.5714	0.2231	−2.561	0.0104 *
AoA-E:AGE	−0.2014	0.2914	−0.691	0.4895
AoA-L:AGE	0.3464	0.2933	1.181	0.2376

Note. Summary of model 1, a logistic mixed effects regression model predicting sentence reproduction with the native group used as the reference group. Includes parameter effect estimates (in log-odds), standard errors, z-values, and p-values (based on a Wald test).