Exploring the Effects of Aging on Language Abilities in Deaf Signers

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EXPLORING THE EFFECTS OF AGING ON LANGUAGE ABILITIES IN DEAF SIGNERS

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This chapter provides an account of our efforts to use sentence repetition to assess language capacities in older adult deaf users of American Sign Language (ASL). We discuss how research in deaf signing communities provides a novel means to investigate the effects of chronological aging on human language processing. Four aspects of this work call to mind the contributions of Dr. Helen Neville, who served as a mentor and senior colleague early in my career. First, Helen recognized the unique insights that studies of profoundly deaf individuals can offer in understanding the dynamics of brain plasticity. She was one of the first neuroscientists who boldly related the experience of deafness in humans to burgeoning neuroscientific accounts of brain plasticity in non-human species. Second, Helen was cogent in her investigations of the human capacity for language and the implications this specialization has for brain organization. She marshaled the life experiences of sign-exposed individuals to lay contrast to processes and brain changes that occur as a function of auditory deprivation from those that result from visual language exposure. Third, Helen understood that the particulars of our attempts to characterize behavioral and brain activity at any moment in time were a snapshot of the trajectory of human brain development, which extends through the lifespan. Finally, Helen was a humanist and keenly respectful of working with the Deaf community and its vibrant members.

Language behaviors are subserved by both linguistic and cognitive systems. An active area of research seeks to understand the degree to which age-related language decline represents the degradation of the linguistic system specifically or owes to interactions between cognitive and linguistic factors. In particular, attention, working memory, and executive functions factor significantly in these inquiries (Henderson & Wright, 2016).

To the extent that aging impacts core properties of linguistic systems, we would expect to see commonalities in changes that occur for users of spoken and signed languages. However, differential impacts of aging on spoken and signed language processing may be observed. Such a pattern may be a reflection of differential cognitive processes and resources required as a function of the language modality. Studies of deaf and hearing users of signed language present a unique opportunity to further understand how differences in the time course of language acquisition and sensory experience interact with cognitive aging. Here, we demonstrate how studies of signed languages can serve as a basis to explore the influence of grammatical properties of language form in the context of normative chronological aging (CA).

Studies of spoken language abilities indicate that the core aspects of speech comprehension are generally well preserved across the lifespan, including the automatic access to lexical representations and the online construction of syntactic and semantic representations (Burke & Graham, 2012; Burke & Shafto, 2008; Shafto & Tyler, 2014). However, age-related changes in language use are well documented; for example, older adults appear to use a simplified speech register (Benjamin, 1988; Cooper, 1990; Davis, 1984; Kemper et al., 1989; Kynette & Kemper, 1986; Shewan & Henderson, 1988), and this simplification appears to be progressive with age. Reductions in the complexity of structural properties and information density as a function of aging have been well studied (see Kemper, 2006 for an overview). Studies of language production show that spoken language production declines with aging. Compared to younger speakers, older adults show increased word-finding difficulties, tip-of-the tongue states, and evidence of more speech dysfluencies (e.g., lexical fillers, word repetitions, and lengthy pauses). Mounting evidence points to a problem in phonological retrieval rather than articulatory or motor planning deficits (Burke & Graham, 2012; see Burke & Shafto, 2008 for a review). Whether or not patterns of relative stability in language comprehension with changes in aspects of language use and production holds for users of signed languages is largely unknown. We introduce some prominent issues in the endeavor below.

Studies of the effects of aging on spoken languages 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) functions 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. Multiple factors, including etiological differences in the expression of congenital deafness, choices in educational and rehabilitative practices, parental beliefs, and government policies, comport to influence a deaf child’s exposure to a signed language. Though a multi-factored construct, the influence of the age of language acquisition (AoA) on linguistic and cognitive competencies and educational achievement in deaf children has received considerable attention; however, the impact of AoA as a function of CA in deaf adults is far less studied.

A second prominent issue concerns the differences in the signaling modality of spoken and signed languages. While it is well established that both spoken and signed languages constitute full-fledged instances of human language with fully expressive grammatical and symbolic capacities, there are differences in cognitive requirements for the production and processing of oral-aural and visual-manual languages. To the extent that CA differentially affects physical and cognitive processes (e.g., motoric constraints, verbal versus visual working memory, auditory versus visual attention), these factors may differentially conspire to influence the use of spoken and signed languages. For example, there is research to suggest that visuospatial working memory is affected more by age than is performance on verbal working memory tasks (Craik & Rose, 2012; Jenkins et al., 2000; Myerson et al., 2003; Park et al., 2002). Differential age-related vulnerabilities of verbal and non-verbal working memory are especially interesting in light of the characterization of signed language as linguistic systems forged within a visual−spatial modality (Bellugi et al., 1989).

Third, grammar-internal properties of signed (and spoken) languages may influence processing in the face of typical aging. Just as with spoken languages, natural sign languages vary in structural and grammatical form. For example, sign languages tend to be largely mono-syllabic languages, are topic-prominent languages, make use of complex predicative constructions (e.g., classifier forms), and permit omission of pronominal makers (i.e., pro-drop) in selected environments. The impact of typological linguistic differences and grammar-internal properties of signed (and spoken) language use in the face of typical aging has received little attention. In an earlier published study (Corina et al., 2020), we reported test performance from a large cohort of adult deaf signers on an ASL sentence repetition task (ASL-SRT; Supalla et al., 2014). The goal addressed in this initial report was to document how performance on the ASL-SRT varied with chronological age and AoA. In addition, we investigated the potential interaction between these factors. In this chapter, we first briefly recount the methods and main findings from this study. In this context, we discuss how cognitive factors may differentially impact sentence repetition in spoken and signed languages. Next, we extend these initial findings and present additional statistical and descriptive linguistic analyses of error data from the original study. The examination of these data permits some preliminary insights into how the grammatical properties of ASL, specifically grammatical word class, are distinctly susceptible to repetition errors.

Chronological aging and age of acquisition

Three groups of healthy congenitally deaf adult users of ASL (n = 107; ages 45–85, see Table 4.1) were recruited and tested individually on an ASL sentence repetition test. The participants included native signers (n = 33), who had learned ASL from deaf signing parents, and two groups of non-native signers. Early non-native signers (n = 40) were exposed to ASL before the age of 8. Late non-native signers (n = 34) were exposed to ASL after the age of 8, typically in adolescence. Sentence repetition is a complex language task that indexes both linguistic and memory processing. Potter and colleagues (Lombardi & Potter, 1992; Potter & Lombardi, 1990) have demonstrated that verbatim recall of a spoken sentence involves reconstructing the surface representation from a conceptual representation of the sentence using recently activated lexical and syntactic forms accessible in working memory. Therefore, sentence repetition is a task that taxes both linguistic processing and memory functions (Lombardi & Potter, 1992; Potter & Lombardi, 1990).

The ASL-SRT developed by Supalla and colleagues (2014) presents participants with 20 sentences that gradually increase in length, the complexity of morphology, and the number of propositions; Table 4.2 lists word span, syntactic complexity, and content for each item. The test is administered on a laptop computer, where participants view a video of a woman who serves both as an instructor and as a model producing the set of practice and test sentence items. She instructs participants to copy the model's exact signing, stressing the need for a verbatim response. The test is self-paced without a time limit for response: subjects view each sentence only once, but they then have unlimited time to make their response. The responses are video-recorded for subsequent offline scoring. The raters compared each participant's responses to the intended sentence.1 A response was marked incorrect if it deviated from the model sentence beyond a few agreed-upon alternatives (Hauser et al., 2006). Following Supalla and colleagues (2014), the error types reflect incorrect reproductions and not regional pronunciation or accent differences.

Statistical analysis of sentence reproduction data made use of a logistic mixed effects regression model predicting whether or not a sentence was accurately repeated. Predictors were age (continuous), AoA (native, early, or late), and the interaction between these two variables.

TABLE 4.1 Participant characteristics

ASL experience			
	Native	*Early*	*Late*
Age group n		*n*	*n*
45–54	9 (6 female)	9 (9 female)	8 (5 female)
55–64	10 (6 female)	10 (6 female)	9 (4 female)
65–74	9 (4 female)	9 (4 female)	8 (7 female)
75–85	5 (5 female)	12 (9 female)	9 (5 female)

TABLE 4.2 ASL-SRT items with sentence content and inflections

Item	*Word span*	*Syntactic complexity*	*Sentence content and infections*	*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 competent in math.*
11	7	Copular object	WASHINGTON #DC HAVE MANY GOVERNMENT BUILDING, CL: huge-object-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-of-ground, HIT TREE	*The motor cycle skidded of 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 fying 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 fowers 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 = reflexive pronoun, CL: = classifier predicate, rep = repeated, #D-C, fingerspelled letters, -arc = arced movement of the sign path. From "Effects of age on American Sign Language sentence repetition" by D.P. Corina, et al, 2020, *Psychology and Aging, 35*(4), 529–535 (https://doi.org/10.1037/pag0000461) *Source: Copyright 2020 by the American Psychological Association.*

The results of the model (see Table 4.3) show that increased age and later ASL acquisition decreased the likelihood of ASL sentence reproduction. Interested readers are encouraged to consult the original paper (Corina et al., 2020), whose findings we summarize in Table 4.3.

The study revealed that ASL sentence repetition was a challenging test for deaf participants. The ability to fully repeat single and multi-clausal ASL sentences decreased as a function of chronological age ($p < 0.001$), with increased age being associated with decreased likelihood to reproduce a sentence (see Figure 4.1). A comparison of our findings with those reported by Supalla and colleagues (2014) is shown in Figure 4.2. As shown, school-age (10–14 years) and young adult native signers (15–30 years) correctly reproduce approximately 14/20 sentences, while 45-year old native signers reproduce approximately 12/20 sentences and 85-year-old signers produced roughly 4/20 sentences.

Figure 4.1 further illustrates the performance of the three groups as a function of AoA. In the model, the effect of AoA was significant ($p = 0.019$); relative to the native signers, those who acquired ASL early were less likely to successfully reproduce a sentence ($p < 0.003$), as were subjects who learned ASL later ($p < 0.001$). However, there was no difference between the late and early AoA groups ($p = 0.158$). Although the late learners appear to show a shallower decline than do both the native and early signers, the interaction between age and AoA did not reach significance. Rather, the efects of AoA and CA appear independent.

Two important findings that emerge from these data are that typical aging does impact ASL sentence repetition ability in this deaf cohort and that AoA was correlated with repetition ability. We consider the implications of each of these findings in turn.

TABLE 4.3 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

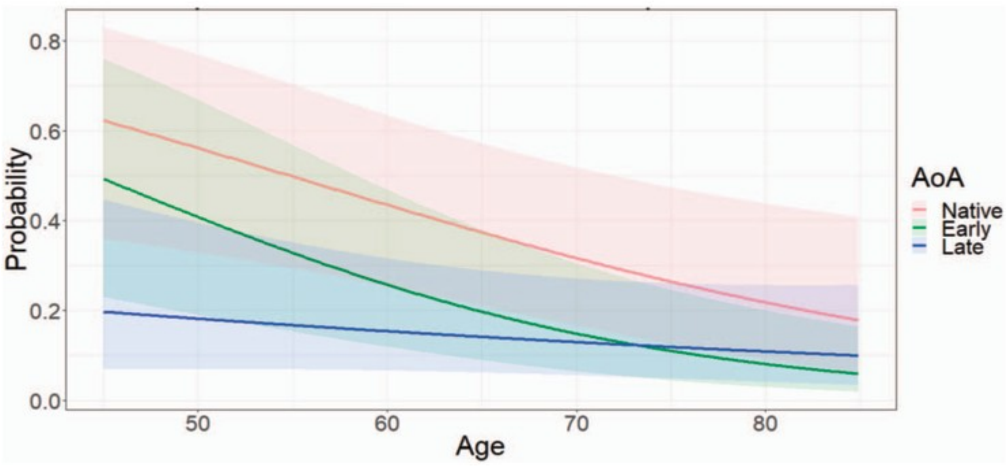

FIGURE 4.1 Model 1 predicted values – sentence repetition likelihood. Probability of correct ASL sentence reproduction as a function of chronological age and AoA. Data from deaf signers exposed to ASL as a native language, in early childhood (<8 years) and late childhood (>8 years). Predicted values from model 1 with a 95% prediction interval. *Source: From "Effects of age on American Sign Language sentence repetition" by D.P. Corina et al., 2020, Psychology and by the American Psychological Association. Aging , 35(4), 529–535 (https://doi.org/10.1037/pag0000461). Copyright 2020*

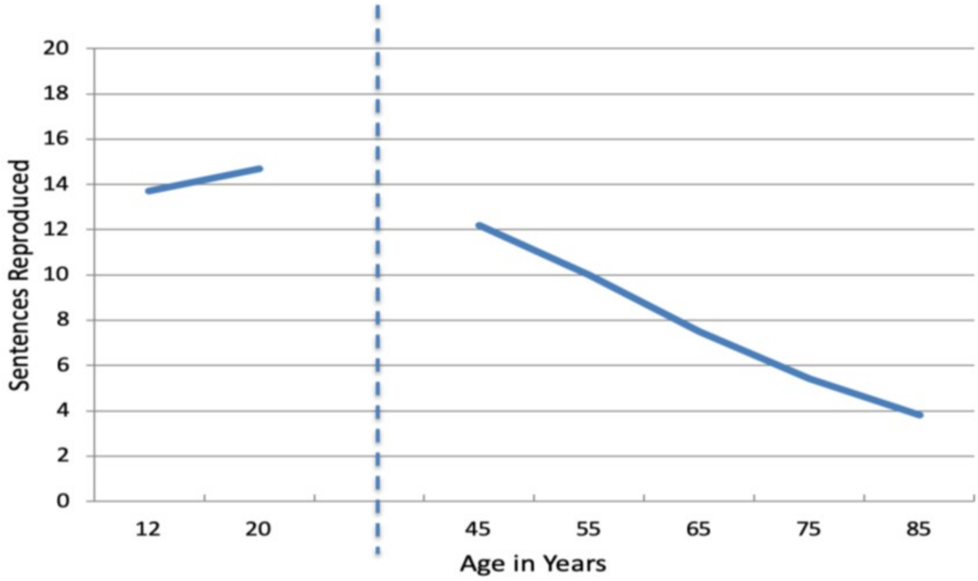

FIGURE 4.2 Comparison of ASL sentence repetition performance in younger and older deaf native signers. Sign language sentence repetition performance in young ASL native signers (n = 50) adapted from Supalla et al. (2014; left panel) compared to sentence repetition performance in a cohort of older native adult signers (n = 33; right panel). *Source: From "Effects of age on American Sign Language sentence repetition" by D.P. Corina, et al., 2020, Psychology and by the American Psychological Association Aging , 35(4), 529–535 (https://doi.org/10.1037/pag0000461). Copyright 2020*

The decline in sentence repetition as a function of chronological age is broadly consistent with cross-sectional data that indicate linear declines in declarative memory and visual–spatial abilities beginning in the early twenties (Rönnlund & Nilsson, 2008; see also Nyberg et al., 2012). However, there appears to be a sharp decline in ASL sentence repetition in the older cohort. Verbatim ASL 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 et al., 1985; Potter & Lombardi, 1990). For example, Meyers et al. (2000), tested 104 healthy participants who ranged in age from 16 years to 86, and found no influence of age on repetition performance on a 22-item clinical sentence repetition test (Spreen & Strauss, 1998).

The Corina and colleagues (2020) study was not designed to directly evaluate the effects of language (i.e., ASL versus spoken English) and hearing status on verbatim sentence repetition; therefore, we must view comparisons with prior studies of spoken language repetition with caution. Nevertheless, this reported difference between spoken and signed language repetition is noteworthy, and may be a reflection of language-specific processing factors. Prior studies comparing memory functions in deaf signers and hearing users of spoken languages provide some basis for understanding the current data.

Hearing individuals exhibit short-term memory performance advantages for speech-based stimuli compared to analogous sign-based stimuli used in testing deaf individuals (Bellugi et al., 1974; Boutla et al., 2004; Conrad, 1970, 1972; see Hall & Bavelier, 2010, and Wilson & Emmorey, 2006 for reviews). This difference has been obtained in within-subject designs, with native ASL-English hearing bilinguals, suggesting that this difference reflects encoding differences of sign versus speech rather than an outcome of deafness per se (Boutla et al., 2004; Rönnberg et al., 2004). An enduring finding in this literature indicates that the spoken language advantage emerges especially when the memory task requires participants to recall stimulus items in adherence to the temporal order of stimulus presentation. Such findings have led some researchers to posit a differential utilization of working memory components used in the service of sign language understanding. Hirshorn and colleagues (2012) suggest that signers make greater use of visual–spatial and episodic storage mechanisms for linguistic processing compared to hearing individuals who depend more strongly on the phonological loop and its rehearsal mechanisms. The ASL-SRT (Supalla et al., 2014) requires verbatim recall, so deviations from the linear ordering of signs in each target sentence is marked as incorrect. The performance of our participants may reflect the difficulty that signers experience with ordered recall of linguistic material (see also Rudner et al., 2010). It remains an open question whether the age-related declines noted may be an indication of age-related vulnerabilities within working memory or episodic storage mechanisms.

Regarding the effects of AoA, these data add to the now substantial literature which indicates native sign language experience affords significant linguistic and cognitive processing advantages. It is noteworthy that, despite decades of experience using ASL as their primary and preferred means of communication, the ability of early and late learners of ASL to faithfully reproduce ASL sentences remains impacted by their initial AoA. This is particularly striking in the comparison between native and early signers, who show a consistent AoA difference well into life despite the relatively modest differences in the ages at which signing was introduced. However, one must be cognizant of the correlational nature of these data. Furthermore, cross-sectional studies in aging are potentially confounded by cohort effects in which apparent differences, often attributed to cognitive aging, instead reflect historical influences, such as educational opportunity, cultural factors, and SES (Hofer & Sliwinski, 2001; Salthouse & Nesselroade, 2002).

Seminal contributions of Helen Neville and others suggest that there is a critical or sensitive period for language acquisition (Chomsky, 1965; Hahne & Friederici, 2001; Hartshorne et al., 2018; Lennenberg, 1967; Newport et al., 2001; Pakulak & Neville, 2011; Weber-Fox & Neville, 1996). The delayed acquisition of second language has pronounced effects on grammatical processing and its representation in the brain (Weber-Fox & Neville, 1996; see also Rossi et al., 2006). Studies using both direct and indirect measures have reported a loss of grammatical sensitivity as a function of age of sign language acquisition (Cormier et al., 2012; Emmorey et al., 1995; Mayberry & Eichen, 1991).

Finally, there were no indications of higher-order interactions in these data; instead, the effects of AoA and CA appeared to be independent. 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 et al., 2002). Moreover, while native language acquisition affords processing advantages in ASL sentence repetition, it does not appear to protect individuals from age-related declines.

Linguistic error analysis

In the assessment of participants' performance reported in Corina and colleagues (2020), the number of correct sentence reproductions served as the dependent variable. Here, we extend the analysis with an examination of omission errors observed during the SRT. Errors of omission were by far the most common error observed, and accounted for approximately 69% of errors. Semantic errors were the next most common, accounting for 17.5% of errors. Morphological and phonological errors accounted for 4.6 and 3.3% of errors, respectively. Transposition and intrusion errors were relatively uncommon, accounting for 3.4 and 1.6% of the errors, respectively. These data show a pattern similar to those reported in Supalla and colleagues (2014), where errors of omission were overwhelmingly more prevalent than morphological, syntactic, lexical, and phonological errors across all signers tested. Errors of omission likely reflect moments of processing overload and capacity limitations.

To further understand these errors, we assessed whether signs that were incorrectly omitted were randomly distributed across word classes, or whether grammatical class influenced the patterns of omissions. In ASL, as with spoken languages, verbs and pronouns carry grammatical and syntactic function, for example, participating in predication and anaphoric co-reference. In contrast, nouns and modifiers carry lexical-semantic meaning, but are devoid of grammatical inflection, as there is no case marking in ASL. Furthermore, it is worth noting that in ASL, verbs and especially pronouns make demands on spatial devices in their usage. Spatially inflecting verbs that signal grammatical roles (e.g., subject and object) require the use of contrastive articulatory space. Pronouns also are directed to locations on the body (i.e., the trunk) and in articulatory space to designate person marking (e.g., first, second, and third). Nouns and modifiers in ASL generally do not have the same requirements for spatial marking. Based upon differences in grammatical and syntactic function, and the difference in the requirements for spatial usage, we chose to examine whether the omissions of verbs and pronouns differed from the omission of nouns and modifiers.

A logistic mixed effects regression model was used to predict sign omissions during the reproduction of sentences. The fixed effects in this model were the same as in model 1 described earlier, but with the addition of word class (verb + pronoun versus noun + adjective) and its interactions with the other variables. The random effect structure for model 2 was similar to the first model, with random intercepts for subject and item (word), by-item random slopes for the effect of CA and AoA, and by-subject random slopes for word class.

The results from the sign omissions analysis parallels the overall pattern of sentence reproduction, where the rate of omitted signs increases with CA and AoA (see Table 4.4). Age was a significant predictor, with older signers producing more word omissions [odds ratio (OR) = 1.65, p = 0.025].

TABLE 4.4 Model 2 summary – age, AoA, and word class on word omission fixed effects

	Estimate	*Std. error*	*z-Value*	*Pr(>|z|)*
(Intercept)	−3.4753	0.3696	−9.402	<0.0001***
AoA-E	0.7045	0.3029	2.326	0.0200*
AoA-L	0.9097	0.3178	2.862	0.0042**
AGE	0.4997	0.2222	2.249	0.0245*
ClassVP	1.0350	0.4958	2.087	0.0368*
AoA-E:AGE	−0.0738	0.2768	−0.267	0.7898
AoA-L:AGE	−0.1818	0.2782	−0.654	0.5133
AoA-E:ClassVP	0.1166	0.2095	0.556	0.5779
AoA-L:ClassVP	0.2110	0.2393	0.882	0.3779
AGE:ClassVP	0.0654	0.1735	0.377	0.7060
AoA-E:AGE:ClassVP	−0.2027	0.1946	−1.041	0.2977
AoA-L:AGE:ClassVP	−0.0378	0.1945	−0.194	0.8459

Notes: Summary of model 2, a logistic mixed effects regression model predicting word omissions. Includes parameter effect estimates (in log-odds), standard errors, z-values, and p-values (based on a Wald test).

Moreover, we observe an effect of AoA with late exposed signers and early signers omitting more signs than the native AoA group (late AoA, OR = 2.48, p = 0.004; early AoA, OR = 2.02, p = 0.02). Word class also showed an overall effect, with verb and pronoun signs being omitted more often than the nouns and modifiers (OR = 2.82, p = 0.037). However, there were no interactions between any of the variables. Figure 4.3 illustrates the probability of omitting noun and modifiers (left panel) and verbs and pronouns (right panel) in the cohort of adult deaf signers.

In the following, we consider selected examples to illustrate error tendencies observed during sentence repetition. Consider the target sentence I DRIVE+ FIVE-HOURS ARRIVE EXHAUSTED ("I drove for 5 hours and arrived exhausted"). This is a multi-clausal sentence and we often observed the omission of the second verb ARRIVE. Interestingly, while only 5/33 (15%) native signers omitted this lexical verb, 9/40 (22.5%) early signers and 12/34 (35.3%) late signers failed to include this lexical verb in their sentence repetition attempts. A common strategy was to treat this sentence as two separate sentences, essentially (I) DRIVE+ FIVE-HOURS, (I) EXHAUSTED ("I drove 5 hours. I'm exhausted"). This strategy may reflect a difference in the initial parse of the target sentence or reflect a memory recall strategy. Serial position effects may also have contributed to this omission of the second verb (Small et al., 2000).

In another example, we observe an 83-year-old late learner incorrectly reproducing this sentence as "FIVE-YEARS SAFE." Note how this repetition attempt fails to preserve the meaning of the original sentence and omits both pronouns and verbs. The substitution of the sign SAFE for the sign DRIVE may be motivated by the formational surface properties of these signs. Both of these signs are two-handed signs that are articulated in a neutral space in front of the signer, with identical closed-fist handshapes, but with different movements. Processing inefficiencies in resolving surface-level details may have led to a misunderstanding of the intended sentence by this late learner or affected the accurate reconstruction of the surface form during the repetition of the sentence.

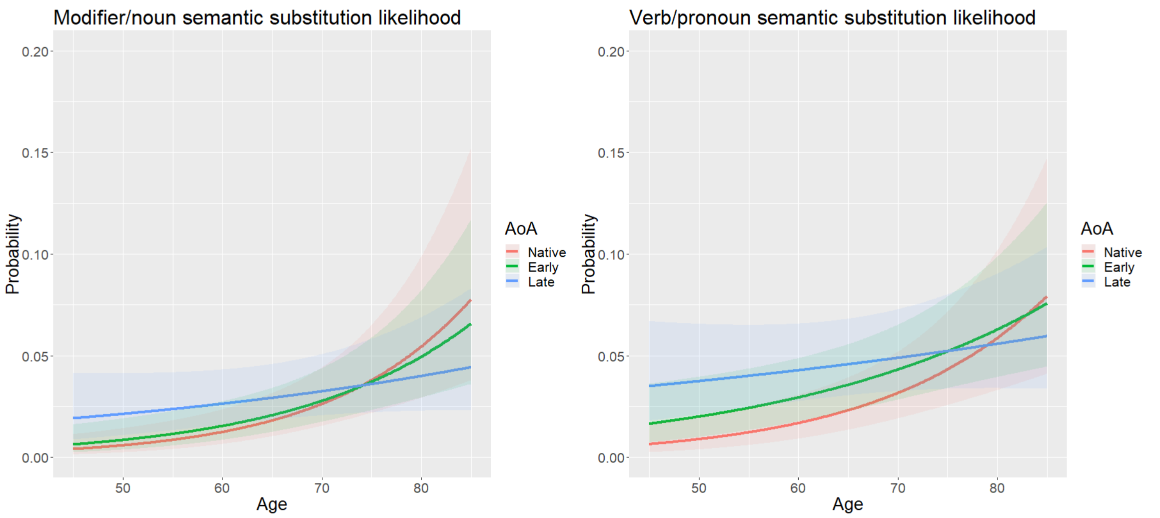

FIGURE 4.3 Probability of word omissions as a function of age and AoA. Left panel, omission of nouns and modifiers; right panel, omissions of verbs and pronouns. Predicted values from model 2, with a 95% prediction interval.

In contrast, consider the repetition of the 85-year-old native signer who produced I DRIVE++ #FIVE HOURS ARRIVE EXHAUSTED. Here, the participant fingerspells #F-I-V-E and signs HOUR, rather than producing the intended numeral-incorporated form of FIVE-HOURS, but correctly includes the first-person pronoun, and the verbs DRIVE and ARRIVE. In contrast to the late learner, despite the minor error (i.e., the fingerspelled #F-I-V-E HOURS, rather than verbatim morphologically complex FIVE-HOURS), the native signer preserves the overall gist of the sentence. This pattern of behavior accords with previous studies of sentence repetition where late learners' renditions resulted in misinterpretation of intended semantic content, perhaps driven by a bottom-up failure to appreciate important differences in the surface form of the signs or making use of this information during the reconstructive recall process. In contrast, for native signers, processing efficiencies afford greater repetition accuracy guided by the successful semantic-conceptual encoding of the message. This efficiency may permit greater top-down control of message reconstitution during the verbatim repetition.

Errors involving pronouns were very common and both omissions and substitutions of pronoun forms were observed. Consider the target sentence INDEX-j NOT LIKE INDEX-i ("He does not like her"). This mono-clausal sentence consists of four separate signs. In the native signers, we find only 4/33 (12.1%) omissions of the subject pronoun. However, 9/40 of the early signers, approximately 23%, failed to mention the initial subject pronoun, while three participants failed to repeat the object pronoun. For late signers, we find 12/34 (35.3%) incorrect repetitions with six omissions and six substitutions. In the substitutions, we observe the replacement of the third-person pronoun either with first- or second-person pronouns. We also note one instance of a spatial reversal of the subject and object pronouns.

Consider again the target sentence I DRIVE+ FIVE-HOURS ARRIVE EXHAUSTED with the initial first-person pronoun. Here, we observe the omission of the first-person subject pronoun "I". While only 4/33 (12.2%) native signers omitted this pronoun, early and late signers show more frequent omissions: 7/40 (17.5%) and 12/34 (35.3%), respectively. In this sentence, it was not unusual to see the incorrect substitution of the personal possessive pronoun MY for the first-person subject pronoun in the early and late learners. This type of pronoun substitution was not observed in the native signers.

Studies of spoken languages have shown that the omission of pronouns may be amplified in cases where processing difficulties interact with language-specific grammatical properties that license pro-drop. For example, Bencini and colleagues (2011) reported that, relative to age-matched controls, omissions of pronouns were common in patients with mild to moderate Alzheimer's disease (AD) in SRT in Italian, a pro-drop language. In addition, these Italian patients were shown to omit pronouns far more frequently than a comparable group of English speakers with AD, suggesting that language-specific grammatical properties interact with processing difficulties. ASL is a pro-drop language, but there are specific restrictions on when pronouns can be omitted (Lillo-Martin, 1991). One wonders whether, in cases of late L1 acquisition, such grammatical rules are less well instantiated, leading to more idiosyncratic omission and substitution of pronouns, even in cases where it is not licensed.

The second type of pronoun omission error suggests a different mechanism: diachronic change in ASL. Two sentences make use of a reflexive pronoun. MY DAUGHTER HERSELF THREE-YEARS-OLD and WOMAN HERSELF +right SKILLED MATH. Across these two sentences, and collapsing across AoA, we observe that a younger cohort of signers (45–64 years) omitted HERSELF 14/55 (25%) times, while over two-thirds of the older respondents (65–85 years) omitted these forms 33/52 times (63.5%).

ASL has been generally assumed to have reflexive pronouns (often glossed as SELF), but more recent work has suggested that these forms have a more common emphatic role than purely reflexive function (Koulidobrova, 2009; Wilkinson, 2013). This form of emphasis marking is common in ASL but, in Wilkinson's (2013) analysis, is more likely to occur in monologues including video blogs (i.e., vlogs) and formal and informal presentations that take place with little or no interaction with the discourse participants in their immediate physical environment. Wilkinson (2013) raises the question of whether there is a diachronic change in the use of SELF in ASL, prompted perhaps in part by the proliferation of vlogs popular with younger signers. In the present data, we see a marked reduction in the repetition of the form SELF in our oldest cohorts which may be a reflection of the diachronic change in the use of sign SELF in the Deaf community.

Finally, in addition to the pronoun and verb errors, chronological age affected the details of sentential semantics. Consider the sentence SUNDAY NEWSPAPER TEND CLC:C (Sunday newspapers tend to be thick). A striking pattern was seen with the sign TEND. Collapsing across AoA, in the younger signers (ages 45–64 years) this sign was omitted only 1/55 (1.8%) times, while in the older cohorts (65–85 years) this sign was omitted 15/52 (29%) times, with 11 instances in the oldest group. The omission of the verb "TEND" in this case results in only a subtle meaning change, equivalent to "Sunday's newspapers are thick." A similar simplification is seen in the sentence MY DOG CONTINUE +REP BARK (My dog continued to bark). Here we see the omission of the adverb CONTINUE in 3/55 (5%) signers in the two younger age groups (ages 45–64 years), but we see 15/52 (29%) omissions in the older age groups (65–85 years). Here again, a subtle semantic distinction is lost in this rendition of the sentence, but it remains grammatical. These omissions, which preserve the semantic meaning of the intended sentence, appear similar to reports of spoken language repetition errors in which older participants retain the gist of sentences despite subtle changes in surface form (Wingfield et al., 1985).

Discussion of omission errors

The analysis of omission errors as a function of word class showed that verbs and pronouns were more likely to be omitted than nouns and modifiers, but this effect did not interact with the effects of CA or AoA. A priori, it was not clear whether the grammatical properties of verbs and pronouns in comparison to nouns and modifiers might serve to increase the saliency of these items and protect them from omission. It is clear from our data that the reverse is true: the relatively greater load on grammatical and syntactic processing may make these signs vulnerable to omission. Limitations in visual–spatial working memory may also contribute to the increased processing load of these forms.

It is curious (and perplexing) to note that, in an early developmental study of ASL, Anderson and Reilly (2002) reported that children acquiring ASL show a higher proportion of verbs to nouns than children learning English. A recent analysis of native signing parents' input to their deaf infants shows a far greater proportion of verbs to nouns (Fieldsteel et al., 2020). Given the prominence of verb forms in early ASL signing, it is surprising to find that verb (and pronoun) forms are most likely to be omitted during sentence repetition in older deaf adults. Further work is required to understand this counter-intuitive finding and whether it reflects a pattern that is unique to signed languages or is common to languages whose acquisition profiles weight the early expression of verbs over nouns, such as Italian (Camaioni & Longobardi, 2001) and Mandarin (Tardif et al., 1997).

Errors of omission likely reflect moments of processing overload and capacity limitations. The vulnerability of verbs and pronouns relative to nouns and modifiers may reflect differential processing requirements. In spoken language sentence repetition, the syntactic structure serves to integrate and bind forms in working memory for efficient recall (Lombardi & Potter, 1992; Potter & Lombardi, 1990). If delayed exposure to a signed language results in less well-ensconced grammatical knowledge, this may lead to deficiencies in syntactic scaffolding necessary for ASL sentence encoding and recall.

Rönnberg and colleagues (2008) provide a general model to understand language processing capacity limitations. Under optimal conditions, spoken and signed language understanding requires the rapid integration of multiple levels of linguistic structure (phonology, semantics, syntax, and prosody), which are rapidly and automatically bound together at the cognitive level to form a stream of phonological information. As long as optimum conditions prevail, the rapid automatic multimodal binding of phonological information mediates rapid and implicit unlocking of the lexicon by matching input with stored phonological representations in long-term memory (Rönnberg et al., 2010). Under suboptimal conditions, the probability that information will fail to match stored representations increases. In this view, a mismatch may occur because of slow lexical access or less precise phonological representations in long-term memory (Andersson, 2002). When a mismatch occurs, the system will signal a need for explicit processing and storage capacity. This capacity is needed to infer meaning, prospectively as well as retrospectively, on the basis of incomplete information, and the capacity to infer meaning is crucial for compensatory purposes (Rönnberg et al., 2008). In the present data, the simplification of sentence structures, the omission of grammatically rich sign forms, and the presence of formational errors are all suggestive of capacity limitations.

Our data suggest that delayed primary language acquisition may interfere with the rapid automatic encoding of language. The relative poorer performance of early exposed and later exposed signers suggests a compounding of these effects over and above the effects of normal aging.

Lifespan theories of cognitive development (LTCD) provide a framework for interpreting the effects of AoA and CA. The LTCD model proposed by Baltes and colleagues (1998) holds that cognitive development reflects the operation of two intertwined components, one biological and the other cultural (Baltes et al., 1998; Lindenberger & Baltes, 1997). Children's language acquisition is often regarded as a quintessential example of the interplay between these two components, as the ontological unfolding of the biologically governed linguistic capacities is dependent upon culturally specific exposure to one's mother tongue. For many deaf individuals, this expected relationship is disrupted, resulting in the delayed acquisition of an accessible L1 (i.e., a signed language). It is an open question whether such disruptions, with time, can be overcome, or whether the imbalance engenders persistent lifelong effects. The present data strongly suggest the latter – language ability, rather than exhibiting a functional resilience (which over decades of consistent use may normalize), instead is subject to stage-like constraints which establish enduring set-points in linguistic capacities. It is worthwhile to note that the observation of sensitive periods in the development of grammar was a major theme in the work of Helen Neville. Helen and her colleagues provided some of the finest examples of how neural indices of language are impacted by AoA (Pakulak & Neville, 2011; Weber-Fox & Neville, 1996).

In infancy and early childhood, age-related biological changes often yield domain-specific and predisposed processing capabilities (Wellman & Gelman, 1992), whereas age-related biological changes after maturity affect broad processing capabilities (e.g., information processing rate, working memory, and inhibition) that may cut across perceptual, cognitive, and action domains. We speculate that the age-related declines observed across the deaf signing cohorts may be a reflection of changes to domain-general cognitive processes. The question raised, but not answered by the current study, is whether changes (for example in working memory) could lead to differential impacts that vary as a function of a language's modality of expression. Future research aimed at directly comparing rates of sentence repetition ability decline in native ASL-English hearing bilinguals could provide important evidence for this possible state of affairs. The documentation of the vulnerabilities and resilience of modality-specific language systems in the face of aging may allow us to better understand the role of human language in LTCD.

Conclusion

This chapter reports some of the first efforts to explore the effects of aging on language abilities in deaf signers. The study of this population 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. This research calls attention to the need to understand how cognitive and linguistic factors contribute to age-related maintenance and declines in language processing. Our data suggest that early imbalances in the temporal coordination between biological and cultural factors driving language acquisition have persistent and long-lasting effects across the lifespan. This work is a fitting tribute to Helen Neville, whose research legacy and mentorship propelled a new generation of cognitive neuroscientists to carefully consider the interplay between biological and cultural factors in our explorations of the human mind.

Note 1 The responses were rated by two native signers (L.F. and S.P).

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