Language modality doesn't affect number concept development, but timing of language exposure does: Insights from deaf children acquiring signed and spoken language

Children's early numeracy skills are critical for mathematical and academic outcomes.[1] Carey's bootstrapping hypothesis posits that the number words comprising the count list (e.g., *"one", "two", "three"*) serve as placeholders, and that children slowly learn how they refer to exact quantities, from 2-4 years old.[2] In hearing children, variability in language input influences the trajectory of this development.[3]

Deaf and hard-of-hearing children experience much greater variability in language input. Fewer than 10% have full access from birth to American Sign Language (ASL)[4]; the vast majority experience delayed language exposure.[5] Later exposure to language negatively affects both language and cognitive development.[3] Deaf children perform worse on tests of number concepts and mathematics achievement than typically-hearing peers[6,7], but when controlling for number list knowledge, hearing and deaf native language users showed comparable numerical competence.[8] No work has systematically investigated the effects of both language modality and the timing of language exposure on number concept development.

Here we ask how number acquisition is affected by: 1) **modality** of language input; 2) **timing** of language exposure; and 3) knowledge of the **number list**. We tested 39 hearing children who acquired English from birth (English Early) and 61 deaf children in three groups: ASL Early (from birth); ASL Later (delayed ASL exposure); and English Later (delayed spoken English via hearing technology) *(Table 1)*. In their preferred language, we assessed children's ability to count to 20 (Number List, a proxy for number input/experience), and their knowledge of meanings for specific numerals (Give-N)[9]. In Give-N, children provide a requested number of fish; quantities 1-6 were each assessed 3 times, and children who answered 6 correctly were assessed once for quantities 7, 9, 10, 12, and 16. Our dependent measure was highest known quantity.

Three ordinal logistic regressions examined the effects of: 1) *language modality* (signed vs. spoken) and age for participants in the Early language groups; 2) *timing of language exposure*, controlling for modality, SES[10], and age; and 3) *number list knowledge*, controlling for language timing, modality, SES, and age. In the first model, language modality did not predict Give-N performance ($ß$=-0.333, p=0.633), but age did ($ß$=1.643, p<0.001). In the second model, timing significantly predicted Give-N performance: children exposed to ASL or English *early* were 2.62 times more likely to perform better on Give-N than *later*-exposed children ($ß$=0.963, p=0.025). Age also significantly predicted Give-N performance, but language modality ($ß$=0.312, p=0.527) and SES ($ß$=0.017, p=0.185) did not. When added to the model, number list knowledge was the only significant predictor of Give-N ($ß$=0.290, p<0.001); age, language timing, language modality, and SES were no longer predictors.

Neither early sign language experience nor deafness per se hinders number acquisition; rather, the delay results from later exposure to spoken or sign language. Furthermore, number list knowledge predicts Give-N performance to the exclusion of other variables, suggesting that number list knowledge mediates the relationship between language and number concepts. This work highlights the importance of early language access, especially exposure to and practice using a count list, for all children, regardless of language modality.

Word Count: 500

Table 1. *Demographic information.*

Group	Approximate Age of Language Exposure	Hearing Status	N	Mean Age *(SD)*	Mean SES_{10} *(SD)*
English Early	Birth (0 months)	Hearing	39	4.57 *(0.70)*	54.13 *(11.52)*
ASL Early	Birth (0 months)	Deaf/Hard of Hearing	13	5.56 *(1.37)*	44.62 *(17.37)*
English Later	32 months	Deaf/Hard of Hearing	29	5.28 *(0.90)*	46.72 *(17.43)*
ASL Later	42.25 months	Deaf/Hard of Hearing	19	5.46 *(1.06)*	43.29 *(17.94)*

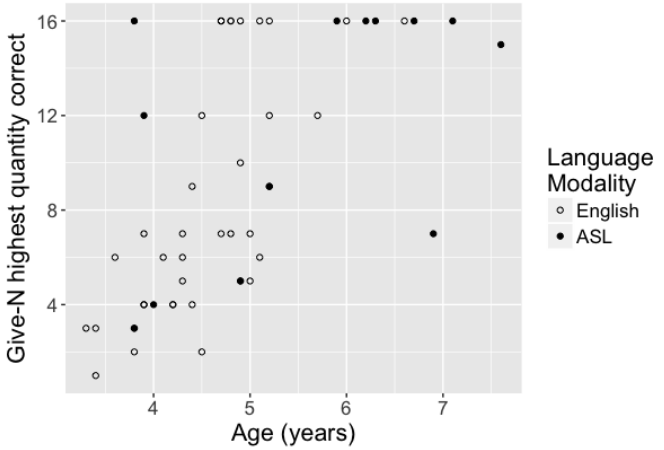

Figure 1: *Deaf children exposed to ASL from birth (ASL Early) do not differ from hearing children exposed to spoken English from birth (English Early) on Give-N.*

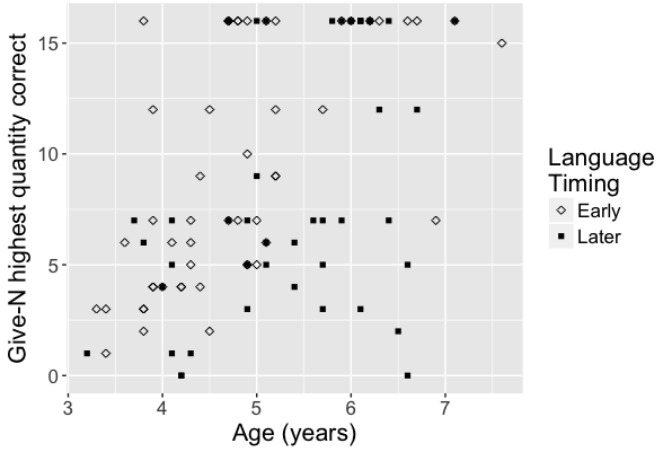

Figure 2: *Children exposed to ASL or English Later perform significantly worse on Give-N than do children exposed from birth. The presence of Later learners (black squares) in the lower-right quadrant shows that even some of those above 5 years of age do not respond correctly on quantities < 8.*

References

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