‘Iconic’ Number Signs Do Not Hasten Acquisition of Number Knowledge

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Children’s ability to link linguistic symbols representing quantities (number words) with those quantities follows a protracted developmental trajectory[1,2,3,4]. Much research has attempted to discern the factors contributing to this process in both hearing[5,6,7] and deaf and hard of hearing children[8,9,10,11,12]. One approach examines whether children can make use of the cardinality inherent in number gestures to help them more easily bridge the gap between an arbitrary linguistic symbol and its corresponding referent. Wiese, for instance, maintains that children 2-3 years old can recognize iconicity in number representations[13]. In American Sign Language (ASL), the linguistic symbols for quantities 1-5 have iconic characteristics—that is, the number of extended fingers matches the quantity that sign refers to. If children acquiring ASL are sensitive to this iconicity, they should learn these meanings at younger ages (i.e., earlier in development) than children acquiring spoken English, whose number words lack such iconicity.

Data presented are from 131 children aged 3;2-6;8. Children differed in *what language they acquired* (Modality: ASL vs. English) and *when they were exposed to language* (Timing of Language Exposure: Early vs. Later). The “Early” group were deaf children acquiring ASL from deaf, signing parents and hearing children acquiring spoken English from hearing parents; the “Later” group were deaf children acquiring spoken English via assistive devices received after birth, or deaf children acquiring ASL in an early intervention or school program (Table 1). We assessed each child’s knowledge of the meanings of spoken English or signed ASL numerals 1-5 by asking them to generate a set of toys of a specific quantity (Give-N[14]).

An ordinal logistic regression (Table 2) predicted children’s highest quantity correct on the Give-N task (up to 5) by Language Modality, Age at Test, Timing of Language Exposure, and Socioeconomic Status[15]. Previous work[16] showed that children’s knowledge of number words/signs (measured by their ability to count to 20) uniquely predicted Give-N performance; we therefore included Count List Knowledge as a covariate. To discern whether children learning ASL learned ‘iconic’ number symbols earlier than children learning spoken English, we also included an Age x Modality interaction term.

Children’s understanding of the words/signs for 1-5 was predicted *only by Count List knowledge*. Though age of language exposure affects development in many domains[17,18], Timing of Language Exposure did not independently predict Give-N performance. *For this specific aspect of cognition*, knowing the count list (linguistic symbols) plays a greater role than the age at which a child is exposed to language (which presumably affects how many number words/signs children know). Importantly, we detected no significant Age x Modality interaction, indicating that children learning ASL did not acquire the meanings of the signs 1-5 earlier than children acquiring spoken English. Contrary to Wiese, this indicates that children learning ASL either do not recognize, or cannot make use of, the iconicity in ASL number symbols.

This finding accords with work by Nicoladis and colleagues[19], who trained hearing children (2;0-5;0) to use conventional number gestures (e.g., holding up the index and middle fingers to represent 2) to generate sets of certain sizes (as in our Give-N task). Children did generate accurate sets in this condition; however, they were less likely to generate accurate sets requested using unconventional number gestures (e.g., holding up the index finger of each hand simultaneously to represent 2) than children trained to use their count lists (number words) alone. This suggests that the iconicity in unfamiliar number gestures did not help children generate accurate sets.

Working memory limitations may have hindered children's ability to use the iconicity present in the number gestures. Representing the extended fingers in a number gesture as individual units, and then using one-to-one correspondence to map those units to individual objects in set they were generating, likely exceeds the working memory of 2-5 year-olds. It might require less working memory capacity to 'package' the units in a number gesture into a single symbol (e.g., a number word) that is independently linked to the quantity that symbol refers to.

Accordingly, Spaepen and colleagues[20] found that adult homesigners in Nicaragua treat certain number gestures as a collection of individuals (extended fingers) rather than a summary symbol representing a set. Homesigners made more errors when repeating handshape configurations featuring more extended fingers, consistent with working memory limitations. Indeed, Nicoladis and colleagues also found that children trained on their task with number gestures performed better on smaller vs. larger quantities. *Therefore, iconicity present in the number symbols (of ASL and many other sign languages) and gestures, while quite apparent to and interpretable by adults, does not help children build their understanding of quantities.*

Table 1. Participant Information

	Language Timing	
	Early	Later
ASL (signed)	19	24
English (spoken)	44	44

Table 2. Ordinal Logistic Regression Results

	Dependent variable: Give-N Performance (up to 5)
Language Modality (Spoken English)	1.008 (2.595)
Age (Years)	-0.232 (0.469)
Age x Modality Interaction	-0.105 (0.524)
Timing of Language Exposure (Later)	0.682 (0.474)
Socioeconomic Status	0.024 (0.015)
Count List Knowledge	**0.134** (0.046)**
Observations	131
Akaike Information Criterion	242.408
Note:	$^{*}p<0.05$ $^{**}p<0.01$ $^{***}p<0.001$

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