



Generating a lexicon without a language model: Do words for number count?

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ABSTRACT

Homesigns are communication systems created by deaf individuals without access to conventional linguistic input. To investigate how homesign gestures for number function in short-term memory compared to homesign gestures for objects, actions, or attributes, we conducted memory span tasks with adult homesigners in Nicaragua, and with comparison groups of unschooled hearing Spanish speakers and deaf Nicaraguan Sign Language signers. There was no difference between groups in recall of gestures or words for objects, actions or attributes; homesign gestures therefore can function as word units in short-term memory. However, homesigners showed poorer recall of numbers than the other groups. Unlike the other groups, increasing the numerical value of the to-be-remembered quantities negatively affected recall in homesigners, but not controls. When developed without linguistic input, gestures for number do not seem to function as summaries of the cardinal values of the sets (*four*), but rather as indexes of items within a set (*one-one-one-one*).

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Introduction

Deaf individuals whose hearing losses prevent them from learning the spoken language that surrounds them are sometimes also not exposed to a sign language simply because they do not participate in a deaf community or attend a school where sign language is used. Despite their lack of access to any conventional language, these deaf individuals communicate with the hearing members of their community using gestures, called *homesigns*. Homesigns contain many, although not all, of the properties found in natural language (Goldin-Meadow, 2003). In some cases where access to sign language is the exception rather than the rule, a homesign system may continue to be used

as a primary means of communication into adulthood (Coppola & Newport, 2005).

Studying adult homesign systems allows us to examine the impact that a language model can have on the status of different types of words in short-term memory – an issue that cannot be addressed in typically developing populations, who learn language from conventional language models. Here we ask whether words in a language system developed without conventional linguistic input serve as units in short-term memory, and whether words for numbers work in the same way as words for objects, actions, or attributes.

Homesigners use their gestures to communicate not only about objects, actions, or attributes, but also about number (Spaepen, Coppola, Spelke, Carey, & Goldin-Meadow, 2011). The number gestures produced by adult homesigners, which are based on the gestures hearing individuals use to communicate about number (e.g., holding up 4 fingers to indicate four objects), are fully integrated into their homesign gesture sentences (e.g., four

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fingers held in the air, followed by a gesture for *sheep*, and then a gesture for *go*, form a sentence describing four sheep leaving a pen), just as number words are integrated into spoken sentences and can either modify (e.g., “four sheep go”) or stand in for (“four go”) nouns (Coppola, Spaepen, & Goldin-Meadow, in press). In this sense, homesigners’ number gestures behave like words.

But the gestures homesigners use to represent number do not always behave like words. Homesigners convey the exact number of items in their gestures when describing small sets (e.g., they hold up 2 fingers to represent two items), but they convey an approximate number of items in their gestures when describing sets larger than 4 (e.g., they may hold up either 5, 6, or 7 fingers to represent six items). Homesigners display the same pattern in non-communicative tasks; that is, when asked to match a target set of items, they do so exactly for small target sets (1–4) but only approximately for larger sets (>4). Homesigners thus do not have fully developed gestural or non-communicative representations of large exact number (Spaepen et al., 2011). Although the gestures homesigners use to communicate about large sets are not exactly correct, these gestures could have another property associated with words: they could function as single units in short-term memory, as do both conventional number words and conventional quantifiers that refer to approximate numerical values (like “few” and “many”). We ask here whether homesigners’ number gestures function as words in this sense.

Human short-term memory capacity is limited: we are able to remember a list containing a small number of items better than a list containing a larger number of items (e.g. Cowan, 2001; Miller, 1956). Holding the number of items in a list constant, the capacity of short-term verbal memory depends on phonological, but not semantic, properties of the words: it is harder to remember a list of words with more vs. fewer syllables – *seven* vs. *six* (e.g. Baddeley, Thomson, & Buchanan, 1975) – but not words for bigger vs. smaller numbers – *ten* vs. *six*. In other words, spoken number words are *summary symbols*: symbols that represent the *cardinal value* of an entire set of items (e.g., a set of 8 sticks), and not the individual items within the set (i.e., not *stick–stick–stick–stick–stick–stick–stick–stick*). Remembering the number 8 should therefore be no harder than remembering the number 3, and no harder than remembering any other one-syllable non-number word.

The same pattern holds for sign languages (Bavelier, Newport, Hall, Supalla, & Boutla, 2008; Boutla, Supalla, Newport, & Bavelier, 2004; Hanson, 1982, 1990; Wilson & Emmorey, 2006), with the exception that signers have smaller digit or letter spans than speakers when required to recall items in the exact order in which they were presented, presumably because of the nature of echoic (as opposed to visual) memory. When tested using free recall of a list of words (rather than ordered recall of the list), signers and speakers, both native bilinguals in English and American Sign Language (ASL) and monolinguals of each language, perform comparably (Bavelier et al., 2008; Boutla et al., 2004; Hanson, 1982, 1990). Importantly, holding the number of items in a list constant, the short-term memory capacity for signs depends on form, not meaning

(Wilson & Emmorey, 1998)² – longer signs (i.e., signs that traverse relatively long distances, a form distinction) are harder to recall than shorter signs (i.e., signs that do not change in location), an effect analogous to the length effect found in spoken language (longer words are harder to recall than shorter words). Thus, signers, like speakers, treat their words for numbers as *summaries* for the quantities they represent, making the sign for the number 8 no harder to remember than the sign for the number 3.

The gestures homesigners use to represent number could function as summaries of the cardinal value of sets (summary symbols), but they could also function as representations of individual items within a set: each finger raised could represent another object in the set. In this case, a homesigner’s gesture for “8” sticks would be better described as *stick–stick–stick–stick–stick–stick–stick–stick* and should therefore take up more short-term memory resources during recall than a gesture for “3” sticks (i.e. *stick–stick–stick*). Do homesigners’ number gestures behave as summary symbols for sets, or as representations of individual items within a set in short-term memory?

To address this question, we compare homesigners’ recall of number gestures with their recall of gestures for objects, actions, and attributes, gestures whose forms map as wholes onto their referents (e.g., the gesture for *child*, a one-handed gesture produced with the knuckles of the non-thumb fingers flexed at the second joint, palm facing away from the body, with short repeated downward movements). We therefore gave homesigners two short-term memory tests, one containing gestures referring to numbers (digits), and one containing gestures referring to objects, actions, or attributes (nouns, verbs, adjectives). To control for the impact that the manual modality might have on short-term memory, we also tested five deaf individuals fluent in *Nicaraguan Sign Language* (NSL) on digit span and noun/verb/adjective span tests in NSL. In addition, to control for the impact that schooling might have on short-term memory (the homesigners were all unschooled), we tested nine hearing Spanish speakers in Nicaragua who had not attended school on both tests in Spanish. Although it might have been preferable to control for communication modality and schooling within the same population, it is nearly impossible to find unschooled signers in Nicaragua simply because almost all signers learn NSL at school. We therefore controlled for these factors using separate populations.

If the homesigners’ recall of gestures for objects, actions, and attributes resembles the patterns found for spoken words (in hearing speakers) and signs (in NSL signers), we will have evidence, the first of its kind, that lexical items can develop without linguistic input and can function as units in short-term memory. These findings can then serve as a backdrop against which to evaluate the status of homesigners’ number gestures. Number gestures could map as wholes onto their referents (serving as sum-

² It is not known whether number of selected fingers, an aspect of phonological complexity in sign, affects short-term memory; in contrast to movement length in sign (or number of syllables in speech), this type of complexity does not increase the overall length of a word and thus might not have an impact on short-term recall.

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