Language as a source of numerical concepts

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It has been suggested that the acquisition of the meaning of numerals is bootstrapped from the knowledge of grammatical number. Sarnecka et al. (2007) and Li et al. (2003) report on studies which show that the rate of number acqusition differs among children with different linguistic backgrounds. English- and Russian-speaking children were faster in acquiring the number system than Japanese and Chinese children. Both studies suggest that this difference can be attributed to the differece in grammatical number marking in these languages. While both Russian and English use overt morphology on nouns to mark plurality, Chinese and Japanese use no such overt morphosyntax. This has been taken to suggest that at least in the early stages of number acquisition, the interpretation of numbers is bootstrapped from children's understanding of the difference between singular and plural morphology. Children with different language backgrounds therefore do exhibit differences in learning, but at the same time, they eventually all reach the same final stage – they become fully competent counters.

We tested the role of language in the construction of early numerical concepts by investigating the acquisition of Slovenian (in the central Slovenian region), which makes a distinction between singular, dual, and plural number, and which marks this three-way number distinction on nouns, adjectives, verbs, and even on numerals (e.g. Herrity, 2000). Following Carey (2009), who hypothesized that singular-plural marking in English may speed up children's acquisition of the numeral *one* by supplying its meaning, we asked whether Slovenian children were faster to acquire *two* by virtue of learning the dual, since *two* is frequently used with dual morphology. To test this, we used Wynn's Give-a-Number task to compare Slovenian children's comprehension of number words to that of English-speaking children, as reported in previous studies (Le Corre & Carey, 2006; Barner et al., 2009; Sarnecka et al., 2007). We also tested Slovenian children's comprehension of singular, dual, and plural morphology using two tasks: What's-on-this-Card (where children labeled sets presented on cards), and Give-a-Set (where they were asked to give sets using singular, dual, and plural requests).

Children learn how to count fairly quickly, but it takes time before they really know what the list of numbers they recite means (Carey 2004). Children first (approximately between 24 and 30 months) learn the meaning of 'one' and contrast all other numbers with 'one' (as reported in Schaeffer, Eggleston, & Scott 1974; Le Corre & Carey 2007 etc.). They remain 'one-knowers' for six to nine months before they learn what 'two' means. 'Two-knowers' respond with the correct number of items presented to them only for numbers 'one' and 'two', but grab a random-size bunch for any number above that. It takes them around two more months to become 'three-knowers' and several more to fully understand how counting works. Since children are reported to remain at the one-knower stage for a longer period than at the two-knower stage, we should find more one-knowers than two-knowers in a random age-weighted sample of children between ages 2 and 4.

The Give-a-Number task revealed a significantly higher number of two-knowers compared to one-knowers than what would be expected based on how English-speaking children have been reported to behave. Among the children we tested, we found 45% (33/74) two-knowers and only 12% (9/74) one-knowers (Figure 1 shows the distribution of n-knowers across age groups). We also found more Slovenian- than English-speaking children who comprehended *two*, when 2-

year-olds, 3-year-olds, and 4-year-olds were analyzed separately. Among 2-year-olds, 21% (20/96) of English-speaking children were 2-knowers, compared to 42% (11/26) in the Slovenian group (p<.05). Among 3-year-olds, 28% (27/98) of English-speaking children were 2-knowers, compared to 58% (15/26) in the Slovenian group (p<.01). Finally, among 4-year-olds, 7% (1/15) of English-speaking children were 2-knowers, compared to 44% (7/16) in the Slovenian group (p<.05). Further, children's knowledge of *two* was significantly associated with both their adult-like production and comprehension of the dual. On both the What's-on-This-Card task and the Give-a-Set task, 2-knowers were twice as likely to exhibit adult-like knowledge of the dual relative to non-knowers and 1-knowers, although these younger groups were equally competent in their use of the singular and plural forms.

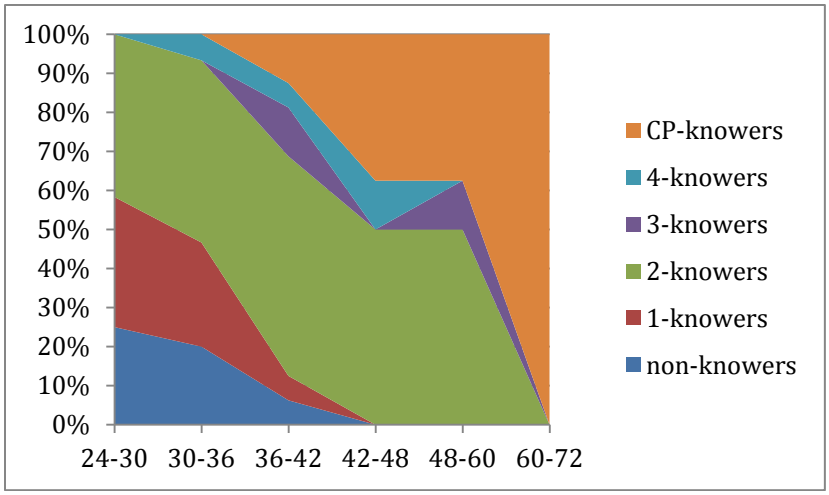

Figure 1: The distribution of n-knowers across age groups.

These results provide strong evidence that linguistic structure can be used to bootstrap number-word learning. Thus, they also demonstrate that the concepts encoded by singular and dual morphology are similar in content to those encoded by children's early number words. We hypothesize that these concepts are therefore not domain-specific mathematical concepts, but may take their origin in the human faculty of language.

We are currently conducting further experiments. Previous research that investigated the relation between number learning and language (Sarnecka et al., 2007; Li et al., 2003) all contrasted acquisition rates in children who differed in their language systems, but who also differed considerably in their cultural backgrounds (e.g. United States and Japan). The next step in the investigation of the relation between linguistic structure and number-word learning is thus to minimize the difference in cultural background. For this, the Slovenian context makes a good candidate, since the realization of dual differs considerably across Slovenian dialects (Jakop 2008). Western and southern Slovenian dialects realize the dual to a much lower extent than the central and eastern dialects. For example, whereas the western and southeren dialects use the plural forms "nas (dveh)" 'us$_{PL.GEN}$ (two)' and "nam (dvem)" 'us$_{PL.DAT}$ (two)' in reference to two people, basically all other Slovenian dialects use the special dual forms of the pronoun, "naju" 'us$_{DU.GEN}$' and "nama" 'us$_{DU.DAT}$' (Jakop 2008). Slovenian thus offers access to children growing up in virtually identical cultural environments but with two relevant linguistic backgrounds: one that fully realizes the dual and one that almost does not realize it at all.