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CANADIAN LANGUAGE & LITERACY RESEARCH NETWORK
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The Influences of Different Number Languages on Numeracy Learning

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Introduction

Number naming systems connect number words to quantities. For example, in English, the word *eleven* is used for the quantity that is also represented as *11* in Arabic digits. Number naming systems include words for both small (e.g., *one*, *three*) and large quantities (e.g., *hundred*, *thousand*), plus rules for combining them (e.g., 346 is *three hundred and forty-six*). Because each language has its own number naming system, studying these systems allows us to examine how language and culture affect numerical thinking. Examining how number languages influence number learning is important because mathematical competencies vary across cultures that have different languages. For example, children who speak Asian languages that have regular number naming systems (e.g., Chinese, Japanese) appear to acquire counting and place-value knowledge earlier than children who speak languages like English and French, which have irregular number naming systems (see more on irregular versus regular number naming systems below; Aunio, Aubrey, Godfrey, Pan, & Liu, 2008; Dehaene, 1997; Fuson & Kwon, 1992; Geary, Bow-Thomas, Liu, & Siegler, 1996; Miller, Smith, Zhu, & Zhang, 1995). In this article, we explain how number languages may influence children and adults' numeracy performance.

Research Questions

(1) What are the differences among number languages that may influence children's numeracy knowledge acquisition?
(2) Do more regular number naming systems support children's numeracy learning?
(3) What are the long-term effects of number languages on numerical thinking?

Recent Research Results

What are the differences among number languages that may influence children's numeracy knowledge acquisition?

Counting up to 10 in many languages requires mastering an arbitrary but ordered set of names (e.g., *one, two, three … ten* in English; *yi, er, san … shi* in Chinese). After 10, some languages' number naming systems are regular; they use consistent rules to combine the ten basic number words to indicate quantities. Other languages' number naming systems are irregular; they have rules, but with exceptions. For example, in Chinese, 13 (*shi-san)* translates to *ten-three* and 34 to *three-ten four;* thus, counting beyond 10 in Chinese involves learning rules to combine the the words from one to ten to create larger number words. In contrast, many other languages, including English and French, have special words between 11 and 19. English has rules for producing number words from 20 on, but these are not as predictable as in Asian languages (compare thirty and three-ten, for example). Some other languages, such as French, use some base-20 rules (e.g., 80 is *quatre-vingt* or *four-twenty*). It seems plausible that learning to count in more regular languages should be easier for children than learning to count in less regular languages.

Beyond the number 10, place-value knowledge helps one know the value of each digit in a multi-digit number. The visual Arabic number system is completely regular because it combines a limited set of symbols (0 to 9). Furthermore, this system assigns each number symbol a value depending on the relative position of the digits to indicate quantities. In comparison to the Arabic digit system, many spoken languages have more symbols (i.e., words) and more complex rules for combining the number words to reflect quantities. Thus, in different number naming systems, the place value assigned to each number word may not be consistent with the spoken position of the numbers. For example, in languages such as Dutch and German, ones digits and tens digits are reversed such that 45 is named as *five-and-forty* rather than *forty-five*. In English, 16 is named as *six-teen* whereas in Chinese it is *ten-six*. Furthermore, the structure of complex numerals may involve multiplication (e.g., *two hundred*) and/or addition (e.g., *twenty-three*; Lonin & Matushansky, 2006). Thus, mastering place value is difficult, at least for English-speaking North American children (Fuson & Briars, 1990). It seems reasonable that children will find it easier to learn number naming systems where there is a consistent rule for mapping number words to quantities. Furthermore, because children ultimately need to make connections among the various symbolic and non-symbolic number codes (number words, digits and quantities), the lack of consistency between the spoken and written number words and the visual Arabic digits may make the ongoing translations among these codes more complex. As a result, performance differences may exist across languages (Pixner et al., 2011a).

Do more regular number naming systems support children's numeracy learning?

Children whose languages have regular number naming systems may more easily learn to (a) count (LeFevre, Clarke, & Stringer, 2002; Miller et al., 1995), (b) learn about place value (Ho & Fuson, 1998; Miura, Kim, Chang, & Okamoto, 1988), and (c) acquire number system knowledge (Pixner et al., 2011b; Siegler & Mu, 2008), as compared to children whose number languages are less predictable. In irregular languages, such as English and French, children may have difficulty learning the teen and decade names due to the complex number structure that does not reflect the base-10 system directly. For instance, 3- to 5-year-old English-speaking children from the U.S. could not count as high as Chinese-speaking children, even though children's performance did not differ in counting small sets of objects or solving problems (Miller et al., 1995). Similarly, LeFevre et al. (2002) found that 3- to 6-year-old French-speaking children could not count as high as their English-speaking peers. The differences between children's performance were partially attributed to the structure differences in number languages. However, French children also performed more poorly in object counting and number recognition tasks compared to English-speaking children. In this study, English-speaking parents reported more frequent teaching of early numeracy skills than French-speaking parents. Therefore, when evaluating children's early numeracy knowledge, experiential factors should also be considered.

Children whose languages have regular rules use place value knowledge earlier and more consistently than children who speak less regular languages (Ho & Fuson, 1998; Miura, Okamoto, Kim, Steere, & Fayol, 1993). For example, Miura and colleagues (1993) found that Asian born-and-educated children (Chinese, Japanese, and Korean) illustrated numbers such as 23 as collections of blocks and units (e.g., 2 blocks of 10 plus three units), whereas non-Asians (French, English, and Swedish) used a collection of 23 single units and did not use blocks of 10. These differences in children's representation of numbers were attributed to the transparency of number languages and their correspondence with the base-10 Arabic system.

Other researchers have argued that the differences that have been attributed to number language could be due to the combined effects of tailored instructions and other cultural differences (Alsawaie, 2004; Dowker, Bala, & Lloyd, 2008; Towse & Saxton, 1997). For instance, Towse and Saxton (1997) demonstrated that experimenters' initial practice demonstration strongly influenced English-speaking children's preference for using only units versus both blocks and units to represent numbers. Zijuan and Chan (2005) found that, although Chinese preschoolers' could provide the right answers to addition and subtraction problems, their computational strategies did not indicate an understanding of the base-10 system or of place value. Instead, they performed well because they were adept at using their fingers to count and produce the answers. Thus, differences in performance between Asian and non-Asian children may be a consequence of differing experiences at home or in school, rather than of differences in number languages (Chen & Uttal, 1988; Göbel, Shaki, & Fischer, 2011; Pan, Gauvain, Liu, & Cheng, 2006; Yang & Cobb, 1995; for review, Ngan Ng & Rao, 2010).

What are the long-term effects of different number languages on numerical thinking?

The structure of number languages may have persistent effects on children and adults' numerical performance. For example, Czech children learn two, equally common, number word systems: One version has an inverted number-word structure (ones digit + decade; *four-and-twenty*) and the other version has a non-inverted number-word structure (decade + ones digit; *twenty-four*). Pixner et al. (2011b) had 7-year-old Czech children write numbers from spoken dictation. When the numbers were spoken using the inverted number-word system, children made many errors in which they incorrectly ordered the digits; no ordering errors were made when numbers were presented using the non-inverted number-word system. Furthermore, Brysbaert, Fias, and Noël (1998) showed that the arithmetic performance of Dutch and French speakers was affected by differences in how numbers were named, at least when answers were produced verbally. In Dutch, multi-digit numbers are inverted, as in *three-and-twenty,* whereas in French, the decade word precedes the ones digit word as in *twenty-three*. Like the Czech children using the inverted system, Dutch speakers were slower to produce the answers to problems like 20 + 3 as compared to 3 + 20. Interestingly, the linguistic differences disappeared when the answers were typed.

Similarly, Colomé, Laka, and Sebastián-Gallés (2010) examined the addition performance of adult Basque speakers and found that they responded to addition problems faster if the problem reflected their language structure. The Basque number language follows a base-20 system, such that 35 is the equivalent of *twenty-fifteen*. Therefore, the addition problems that involved multiples of 20 plus a teen (e.g., 20 + 15 = 35) were easier for the Basque speakers than the ones that did not include multiples of 20 but had the same answer (e.g., 25 + 10 = 35). Such findings suggest that the structure of number languages has long-term implications for processing numbers.

Bilingualism can also affect early numeracy knowledge. For example, when Chinese-English bilingual children counted in English and Chinese, the proficiency in each language determined how high children could count (Rasmussen, Ho, Nicoladis, Leung, & Bisanz, 2006). Children who spoke Chinese more fluently than English counted much higher in Chinese whereas children who spoke English more fluently counted much higher in English. It is possible that children's performance might have been affected by learning to count in two number language systems, as the simultaneous learning may reinforce understanding of the base-10 concept. Furthermore, bilingual children may have more ways of representing numbers than monolinguals (Miura et al., 1993).

Conclusions

Variation in number languages offer a possible explanation for why speakers of Asian languages are better at grasping the counting sequence and acquiring place-value understanding than are speakers of non-Asian number languages. Differences in the structure of number languages also seem to have some long-term implications for how adults use number words in mathematical tasks. However, differences in numeracy skills between, for example, American and Chinese children, have many other potential causes, such as home and school experiences (Huntsinger, Jose, Liaw, & Ching, 1997; Wang & Lin, 2009). Thus, number language differences are only a partial explanation for observed cultural differences.

Future Directions

Much, if not all, of the existing research comparing regular to less-regular number languages is correlational and thus many other sources could be the causes of differences in mathematical performance. An alternative approach is use of interventions to teach children early numeracy skills and examine whether children who speak more regular languages learn faster than children who speak less regular languages. More radically, children could be taught using simplified, regular number languages (e.g., *ten-three* instead of *thirteen*) and their learning progress compared to other children using standard languages. Some number languages have evolved to be simpler. For example, the French spoken in France uses the complex words *soixante-dix*, *quatre-vingt*, and *quatre-vingt-dix* for 70, 80, and 90 (literally, *sixty-ten, four-twenty,* and *four-twenty-ten*), whereas the French spoken in the Walloon part of Belgium uses the words *septante*, *octante*, and *nonante* instead (the equivalent of *seventy*, *eighty*, and *ninety*). Walloon children make fewer errors writing these numbers from spoken dictation than French children (Seron & Fayol, 1994). Thus, research that establishes exactly how the regularity of the spoken number language influences learning has the potential to improve instruction as well as to advance our understanding of numerical thinking.

Date Posted Online: 2012-06-09 14:30:25

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To cite this document:

Cankaya, O., LeFevre, J., & Sowinski, C. (2012). The influences of different number languages on numeracy learning. *Encyclopedia of Language and Literacy Development* (pp. 1-8). London, ON: Western University. Retrieved from http://literacyencyclopedia.ca/pdfs/topic.php?topId=311