LINGUISTIC RELATIVITY AND NUMBER

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Linguistic relativity, the idea that language affects the way that people think, and that people who speak different languages think differently, has implications for mathematics education because people use different languages to teach, learn and practice mathematics. This paper reviews research on linguistic relativity and number, looking at languages with very few number words, languages with extensive and regular number systems and the order of composition of numbers. Linguistic relativity appears to involve memory more than perception. Linguistic relativity effects involving number need to be taken into account in designing mathematics education research.

INTRODUCTION

In the science fiction novel *Nineteen Eighty-Four* (Orwell, 1954), the state-imposed language Newspeak is designed to constrain and control the thoughts of the speakers. Another science fiction novel, *Babel-17* (Delany, 1966), focuses on a language which simultaneously enhances speakers' analytic abilities and turns them into political saboteurs. Both these novels explore *linguistic relativity*, the idea that language affects the way that people think, and that people who speak different languages think differently.

The term linguistic relativity was coined by the American linguist Benjamin Whorf (1956) and the idea is also widely known as the Whorfian Hypothesis. The premise is that since different languages have different structures and categorise the world differently, they promote different conceptual developments and practices. Language shapes the way that we see the world.

The linguistic relativity hypothesis exists in two forms. The strong form, that language *determines* and *constrains* the thoughts of speakers, is explored in the above-mentioned science fiction novels. Such "linguistic determinism" has been discredited to the extent that the linguistic relativity hypothesis was out of scientific favour for some time (Brysbaert, Fias & Noël, 1998) and remains contentious today (e.g. Pixner, Moeller, Hermanova, Nuerk & Kaufmann, 2011).

The weak form, as Whorf (1956) himself put it, is that "people act about situations in ways which are like the ways they talk about them" (p. 148). How a language expresses things and what it must express thorough the imperatives of grammar, as opposed to what it may express, has an impact on what the individual is likely to think and to do.

This means that the effects of linguistic relativity apply *to habitual thought* rather than *potential thought* (Lucy 1992). It is not that people cannot understand concepts that are not commonly expressed in their language. Rather, language affects what we pay

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attention to in the world, how we remember it and how we conceive it. Hunt and Agnoli (1991) expressed this in terms of perception and memory:

> although perception may be relatively immune to language, memory is not. Memory can be based on two different records, a direct record of the sensory information at the time that we perceive an event and an indirect, linguistically based record of our description of the event to ourselves. The latter effects, because they are coded by language, are subject to any biases built into the memorizer's language." (p. 381)

Rather than being a true hypothesis, Hill and Mannheim (1992) contend that linguistic relativity is in fact an axiom which "can only be judged on the basis of the extent to which it leads to productive questions about talk and social action, not by canons of falsifiability" (p. 386). Linguistic relativity is significant for mathematics education because it points to possible impacts of the language of students on their mathematical thinking. There is thus a need to look deeply into languages for how they might affect speakers' mathematical thinking.

LINGUISTIC RELATIVITY EFFECTS

Linguistic relativity effects reviewed here consider the impact of speaking languages that have very few number words, of speaking languages with extensive and regular number systems, the order of composition of numbers and grammatical number. In most cases the educational implications of these effects have not yet been described or are somewhat speculative. This review hopes to stimulate such considerations.

Few number words: Australia and Brazil

Some investigations into linguistic relativity effects regarding number have focused on languages which have very few number words. This includes various indigenous Australian languages. Traditionally, Wik Mungan had only a single unique number name: a word for exactly 'one'; the words for 'two', 'three' and 'five' ('hand') had approximate values and fingers and toes could be used to indicate larger number, but without number names (Sayers, 1983). Warlpiri has number names only for very small numbers such as 'one' and 'two' (Hale, 1975). Some other Australian languages traditionally used elements of a base-5 system such as in Yolngu (Cooke, 1990) and Anindilyakwa (Stokes, 1982). However, the larger numbers – numbers above three – were traditionally used in few contexts, such as the division of foods such as turtle eggs (Cooke, 1990; Stokes, 1982). In these cultures, quantification was traditionally not very important outside those restricted contexts (Rudder, 1983).

Experiments in Australia have shown that monolingual Warlpiri- and Anindilyakwa-speaking children were able to match small collections of objects in one-to-one correspondence with an accuracy comparable to urban English-speaking Indigenous Australian children (Butterworth, Reeve, Reynolds & Lloyd, 2008). Butterworth and colleagues claimed that these Indigenous children "with very restricted number vocabularies possess the same numerical concepts" (p. 13179) as the comparison group. However, a similar ability to match small collections of objects in one-to-one correspondence does not necessarily mean that the two groups have the same numerical concepts. Success with small quantities compared to larger ones could be related to having number words for small quantities, or it could because of the use of subitisation, that is, the instant recognition of the size of a small collection without counting. In fact, the Australian language-speaking children used a very different strategy to the English-speaking children. The Warlpiri and Anindilyakwa children were successful with a spatial strategy, reproducing the way the objects were arrayed in the stimulus, rather than using enumeration (Butterworth, Reeve & Reynolds, 2011).

Similar experiments have been conducted in Brazil. The Amazonian Pirahã people speak a language that has number words only for 'one', 'two' and 'many' (Gordon, 2004; Everett, 2005). The Munduruku, also from the Amazon, have number words up to five (Pica, Lemer, Izard & Dehaene, 2004). Studies into their number abilities show that both the Munduruku and Pirahã are able to match small collections of objects in one-to-one correspondence (Gordon, 2004; Pica et al., 2004). The Munduruku are also able to make evaluations of larger collections in an approximate manner, such as telling which collection is larger than another (Pica et al., 2004). Gordon identifies the Pirahã strategy with small quantities as subitisation, which he calls parallel individuation. Although Pirahã speakers performed well on some number matching tasks, language was a factor in reduced performance on numerical tasks involving memory (Frank, Everett, Fedorenko, & Gibson, 2008).

This research demonstrated that people without number words have abilities and strategies for dealing with numerosities. However, different strategies and reduced performance in memory tasks suggest that these people have different numerical concepts from people who count with words.

Regular and extensive number words

There is also the contention that the language features of some counting systems facilitate the performance of certain numerical and arithmetic tasks. Some East Asian languages such as Chinese, Korean and Vietnamese have regular, transparent base-10 counting systems. The spoken number in these languages explicitly corresponds to the base-10 composition of the number, so for example, 14 is said *ten-four*, and 44 as *four-ten(s)-four* (Miura, Kim, Chang & Okamoto, 1988). The regularity and transparency is also reflected in the written symbols used for the numbers. These languages have a minimum of arbitrary number names and complete regularity in the rules generating numbers above ten. This contrasts with languages such as English where the tens numbers in particular show irregularities, and although a number name such as twenty contains roots meaning two-ten(s), the roots are not immediately obvious to most learners. The regularity of the number system in the East Asian languages makes learning to count easier (Miller & Stigler, 1987; Song & Ginsburg, 1988). The short word length of the East Asian number names allows larger numbers to be held in short-term memory, which is another factor that contributes to arithmetic success in speakers of these languages (Geary, Bow-Thomas, Fan & Siegler, 1993; Nguyen & Grégoire, 2011; Wong, Taha & Veloo, 2001). There are many other factors that influence arithmetic success among these East Asian cultures or Confucian cultures including personal, familial and cultural motivation (Leung, 2006; Song & Ginsburg, 1988). It is difficult to separate linguistic effects from effects of these other cultural factors in experiments (Saxton & Towse, 1998). As mentioned above, the linguistic relativity impact of number systems on counting and arithmetic performance is due to differences in memory use in these mathematical activities.

Alternatively, a complex multi-base counting system may facilitate arithmetic computation in quite a different way. The Yoruba counting system of Nigeria uses a primary base of twenty with subsidiary bases of ten and twenty. Yoruba uses subtraction as well as multiplication in numeral composition, thus a number such as 36 is said as *minus-four-plus-(twenty-times-two)* (Verran, 2001). While this system is awkward to write, Verran claims that the multiple bases and multiple ways of composing and decomposing larger numbers assist mental calculation in Yoruba.

Order of composition of numbers

Some studies have attempted to investigate how the order of composition of base-10 numbers may affect cognitive processing, specifically whether the tens proceed or follow the units. Brysbaert, Fias and Noël (1998) found differences in the verbal processing of numbers between Dutch numbers, which are said units first and then tens, and French numbers which are said tens first and then units. This difference disappeared when participants wrote their numbers. The authors fail to give significance to the fact that in writing their numbers, Dutch speakers use the same tens and then units structure as the French. A comparative study of German, Czech and Italian found a small Whorfian effect regarding the compatibility between the written and spoken form, that is, whether the spoken and written forms agreed or not in the order of composition (Pixner et al., 2011). This effect was not taken into account in Brysbaert et al. (1998).

Arabic might be a fruitful language to include in a comparative investigation because its numbers are units-first in both spoken and written form. Alsawaie's (2004) investigation of the linguistic relativity hypothesis and place value with Arabic speaking children did not use natural (in the sense of day-to-day use) Arabic numbers, but instead made the tens more explicit, such that 23, which is usually said *thalathah-wa-ishroon*, (3 and twenty) was said *thalathah-wa-asharatan* (3 and two 10s). The study thus investigated the effect of making explicit the tens in the number rather than the effect of saying the unit first. Interestingly, units first numbers, described by Brysbaert et al. (1998) as "reversed", predated the practice of saying and writing the higher powers first, which began with a reversal of the reading order of numbers adopted from Arabic (Edmonds-Wathen, 2012).

Grammatical number

Grammatical number refers to how and whether a language marks singularity and plurality of objects or actions grammatically. In languages like English, most nouns must be either singular or plural, where plural is any quantity of two or more. In many

Australian languages, there are singular, dual and plural categories. The dual form is used for two objects, and the plural form is used for three or more (Cooke, 1990; Hale, 1975; Sayers, 1983; Stokes, 1982). Hale (1975) speculates that the small number names in Warlpiri are not counting words at all, but are instead grammatical “determiners” or tags, corresponding to the singular, dual and plural the grammatical categories. These Australian languages emphasise the use of small numbers through their dual (and sometimes triple) grammatical categories in addition to the single and plural categories of a language such as English. While English makes a grammatical division between one item (singular) and more than one (plural), these languages must also specify grammatically exactly two and sometimes exactly three items. The cognitive effects of this attention to small quantities have not been investigated.

DISCUSSION AND CONCLUSION

Understandably, the claim of a Whorfian effect seems to generate more controversy when it can be used to suggest a deficiency, as in the case of the Pirahã or Munduruku languages, rather than a superiority, as in the case of Korean or Chinese. The reader may have noted that in most cases English or another European language is used as reference for comparison either directly or indirectly. It is worth considering how linguistic and cognitive norms are constituted within mathematics education as well as in field such as linguistics or psychology. Since when we talk about languages we are also talking about peoples and cultures, we need to be careful that a claim for an increased or decreased ability is not used to reinforce hierarchical ideas about peoples and cultures. The findings of Butterworth et al. (2011) are important because they show different groups of people using different strategies rather than focusing on a lack or deficiency in one group.

The balance of the evidence shows that people who do not have counting words, perhaps because historically they have not felt the need to invent and use them, have different concepts of number than people who have and use counting words. Although speakers of Pirahã, Munduruku, Warlpiri and Anindilyakwa can all subitise small quantities and match concrete collections, their use of memory in tasks involving quantities differs from that of English and French speakers. People with few number words think differently during these tasks than people who have many.

It is difficult to avoid a deficit perspective in a discussion of people not using numbers because Western culture and mathematics education values quantification so highly. Nevertheless, it also does learners a disservice if their prior learning and conceptual development is not taken into account by mathematics educators. This is particularly relevant for remote Indigenous Australian children who enter a compulsory school system that is largely designed and taught by English-speaking non-Indigenous people who learnt their own number words from their parents within their own cultural milieu. Similar contexts exist in many countries and educational systems.

There is extensive scope for further empirical investigations into the effects and implication of linguistic relativity in mathematics education. For example, the studies of the East Asian languages suggest that number naming practices that make the place value structure explicit can be advantageous for learners. The teaching of comparative number systems may also help develop rich and solid conceptual structures of number. Although is it difficult to separate cultural and linguistic factors in learning and practice, investigations that require the use of memory in number processing might better draw out linguistic factors.

At this point it might also be productive to consider the implications for mathematics education and mathematics education research of taking linguistic relativity as an axiom rather than a hypothesis (Hill & Mannheim, 1992) and as a fundamental part of linguistic diversity in mathematics education. There is still the need for carefully designed comparative research. Mathematics education researchers need to avoid making normative and universalist assumptions about language processing in their designs. Linguistic relativity may also offer an explanation of why effects of linguistic diversity cannot be written out of large scale international testing regimes.

The languages that people speak, particularly those they learn as a child, affect their worldview and their thought processes. Mathematics educators and mathematicians need to be thinking about the possibilities created out of these differences between languages. What mathematical practices might be drawn out of the attention to small quantities in Australian languages, from the complexity of multi-base counting systems such as Yoruba or from speaking and writing lower powers before higher powers as in Arabic? People use different languages to teach, learn and practice mathematics, and the differences between these languages matter. Accepting linguistic relativity is part of true acceptance of linguistic diversity.

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