Linguistic Influence on Numerical Development

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Introduction

The idea that language determines the nature of thought has a long history within psychology, being expressed in its most celebrated form via the so-called Sapir-Whorf hypothesis—how people see and speak of the world is immensely determined by their mother language (Whorf, 1956). However, this hypothesis has been criticized for its lack of empirical evidence. Instead, a weaker version of this hypothesis, known as linguistic relativity continues to attract much attention. The linguistic relativity hypothesis states that differences among languages can lead to differences in the thoughts of their speakers.

Concerning language and number concepts, Miura and other mathematics educators and psychologists argued that linguistic differences play an important part in explaining the higher scores of, for example, Korean, Chinese, and Japanese children on number tasks (Fuson & Kwon, 1992; Miura, 1987; Miura, Kim, & Okamoto, 1988; Miura, Okamoto, Kim, Chang, Steere, & Fayol, 1994; Miura, Okamoto, Kim, Steere, & Fayol, 1993; Song & Ginsburg, 1987, 1988). However, recently, Brysbaert, Fias, and Noël (1998) and Saxon and Towse (1997, 1998) argued that the influence of language upon cognitive development is minimal and criticized the methodologies that were previously used.

Korean children routinely score higher on assessments of their numerical knowledge, as well as other concepts in mathematics, than students of the same ages in Western countries (Kantrowitz & Wingert, 1992; TIMSS, 1998). Thus, it is meaningful to review whether there are any benefits to Korean children's learning of numerical concepts. In this paper, I will focus on linguistic influence on the numerical development of children. I reviewed recent papers that dealt with the relationship between number naming systems and numerical concepts of children. I will describe, briefly, these studies and review the controversial issues among these papers.

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The Korean and English Number Naming Systems and Studies Relating Their Influence

Korean and other Asian languages (e.g., Chinese, Japanese, and Thai) have the regular number naming system in which a number word is said and then the value of that number is named (e.g., 5439 is read as "five *thousand* four *hundred* three *ten* nine (*one*)), whereas English and other Western number naming systems lack the elements of tens and ones in their number words (e.g., twelve for 12, in English; six-and-twenty for 26, in German; four-twenty for 80, in French).

Korean children actually must learn two number naming systems, an informal Korean system used for counting objects in the world and a formal system based on Chinese that is used in school and for calculation. However, both systems are structured similarly between ten and twenty: the numbers 11, 12,..., 19 are said as "ten one," "ten two,"..., "ten nine." The formal system explicitly names the tens in the decades in a completely regular fashion (two ten, three ten,..., nine ten for 20, 30,..., 90, respectively). The informal system is more like English in that the decade words share varied amounts of phonetic similarity to the basic words for two, three, and so on, but do not make these links or name ten. Table 1 shows the Korean number naming system.

Song and Ginsburg (1987) reported that Korean kindergartners' scores on informal mathematics skills were lower than those of a comparable group of American children. One explanation they gave was that Korean children's attempts to learn a dual system of counting might affect performance on their measures during the preschool years. However, the formal and informal systems are structurally the same; that is, both systems follow the base ten number naming system. Thus, they argued that mastery of the dual system might contribute further to Korean children's understanding of numbers. Song and Ginsburg (1988) reported that 3- and 4- year-old Korean children could count in both Korean systems about as high as their age-mates in the United States counted in English. By kindergarten, Korean children counted more accurately in their formal system than English-speaking children in the United States. In Miura and his colleagues' 1993 study, Korean first graders performed better than all other groups on the place-value understanding tasks.

By contrast, the English number naming system is missing the elements of tens and ones contained in them. English-speaking children have to memorize them when learning the number sequence of counting numbers. In English, the tens/ones are reversed only in the teen words, for 13...19, so that the 'nine' is first in the teen words—'nineteen' instead of 'teennine' or 'ten nine.' The decades must also be memorized because the number names in English are reversed from their written order so that numbers such as 16 (sixteen) and 60 (sixty) are phonetically similar. In Korean, 16 is read as "ten six," and 60 as "six ten."

Table 1. Korean Formal and Informal Systems of Number Words (Adapted from Fuson & Kwon, 1992)

Number in written marks	Formal Korean system	Informal Korean system	English translation
1	Ill	Hana	One
2	Ee	Dool	Two
3	Sahm	Set	Three
4	Sah	Net	Four
5	Oh	Tasut	Five
6	Youk	Yasut	Six
7	Chil	Ilgop	Seven
8	Pal	Yadul	Eight
9	Coo	Ahop	Nine
10	Ship	Yul	Ten
11	Ship ill	Yul hana	Ten one
12	Ship ee	Yul dool	Ten two
13	Ship sahm	Yul set	Ten three
14	Ship sah	Yul net	Ten four
15	Ship oh	Yul tasut	Ten five
16	Ship youk	Yul yasut	Ten six
17	Ship chil	Yul ilgop	Ten seven
18	Ship pal	Yul yadul	Ten eight
19	Ship coo	Yul ahop	Ten nine
20	Ee ship	Sumul	Two ten
21	Ee ship ill	Sumul hana	Two ten one
29	Ee ship coo	Sumul ahop	Two ten nine
30	Sahm ship	Sulheun	Three ten
31	Sahm ship ill	Sulheun hana	Three ten one
40	Sah ship	Maheun	Four ten
50	Oh ship	Shiheun	Five ten
60	Youk ship	Yesun	Six ten
70	Chil ship	Ilheun	Seven ten
80	Pal ship	Yeadeun	Eight ten
90	Coo ship	Aheun	Nine ten
100	Bak	Bak	Hundred

* In the informal system, 20, 30, ... do not follow the exact rule as the formal system does.

Miura et al. (1988) asked Korean and American first graders and kindergartners to show five given numbers between 11 and 42 with base ten blocks—the tens blocks were ten unit blocks long and were marked off to show the individual units. Korean children were more likely to show such numbers with the tens blocks and ones blocks, whereas United States children predominantly just counted out single blocks, even for the large numbers. Although the Korean kindergartners initially preferred single block collections, when asked to show the numbers another way, every Korean kindergartner across trials showed all five numbers in both ways--as a unitary collection of single blocks and as tens and ones. Only 13% of the United States first graders showed all five numbers in both ways, and half of them never showed tens and ones for any of the numbers. They concluded that the exact form of number names can affect children's cognitive representations of numbers.

Fuson and Kwon (1991) also argued that these Korean number words make the recomposition procedures easier because they explicitly name the tens and the ones. For example, $8 + 7$ is recomposed as $8 + (2 + 5) = (8 + 2) + 5 = 10 + 5 = 15$. Another type of recomposition shown in their study was the method of added numbers between 5 and 10. The Korean children structured each addend as five and the leftover. The fives were then combined to make ten and the two leftovers were combined into the part of the sum over ten. This method may be easier with the Korean number word naming system than with that of English. For example, in $6 + 7$, the leftovers one and two equal the part over ten in the sum, that is, the three in the sum "ten three." This method also seems common in the United States. That is, each addend is put on a separate hand, but this method of reusing fingers by folding and then unfolding or vice versa on each hand enables any single-digit addend to be put on one hand, and then the fives can be combined into a ten.

The subtrahend, the number that is subtracted from another, is decomposed into (a) one part that matches the part of the minuend, the number from which another is subtracted, that exceeds ten and (b) the rest, which is then subtracted from ten to give the answer. Therefore, for 12 - 6, the 6 is decomposed into 2 and 4. The 4 is subtracted from 10: 10 - 4 = 6. In English, one extra step is necessary for all of these methods because children have to change the English "teen" word into a ten and some ones. The English number words do not name the ten and the ones in numbers between 10 and 20. Therefore, this ten is not available in a sum to suggest a ten structured method or to suggest the actual recomposition that is used in the ten structured method. Instead, English number words require that a child learn the decomposition into ten and some ones for each number word between ten and twenty (e.g., twelve is ten plus two) and make this decomposition as an extra step when using the ten-structured methods.

Figure 1 shows several grouping of ten methods found in the first half of the Korean first grade textbook (The Ministry of Education, 1996). In fact, according to Fuson and Kwon's (1992) study two-thirds of the Korean first graders used recomposition methods structured around ten, and addition and subtraction had similar combined percentages for the solution categories.

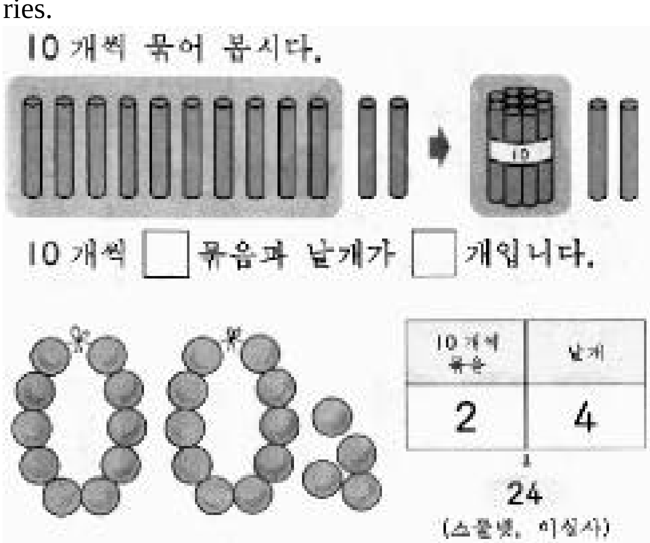
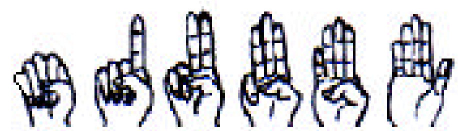


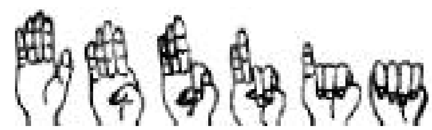
Figure 1. Examples of grouping of ten in Korean first grade textbook

Using fingers while counting is a typical phenomenon among young children (Steffe, Cobb, & von Glasersfeld, 1988). This finger path is supportive of this prerequisite of the ten structured methods. The Korean number naming system is also supportive in the use of the finger path. When the sum is over ten, the counting of the second addend is visually broken into two parts by using up the ten fingers (e.g., for 8 + 6, count "one, two," and the making of the fingers over ten by counting "three, four, five, six"). Repeated use may enable children to use a method in which the finger pattern for the first addend is made, and then the second addend is made by two patterns of fingers, the first of which completes the ten fingers and the next shows the rest of the second addend. The sum is then recognized as "ten four." Either of these methods might be performed with mental visual images instead of real fingers, as suggested by the Korean children who said they did the ten-structured methods using fingers in their heads.



0 1 2 3 4 5

American children's finger pattern



0 1 2 3 4 5

Korean children's finger pattern

Figure 2. Children's finger pattern

As shown in Figure 2, children in the United States commonly show numbers by raising in succession contiguous fingers from the index finger to the little finger and then raising the thumb; I also noticed this finger pattern in the videotapes of Wiegel's (1993) study. However, Korean children tend to count using fingers from all fingers raised and by bending the thumb first.

With small addends of five or less, each addend is shown on a separate hand. For example, to show 4 + 3, four fingers are raised on one hand, three fingers are raised on the other hand, and then all of the fingers are counted. This method of showing addends is very clear for small numbers, but it makes addition and subtraction of sums over ten difficult because it takes two hands to show one addend over five. This difficulty is solved by counting on. The child just begins the final sum count with the first-addend number, and the fingers then may easily be used to show the second addend in order to keep track of the second addend words counted on, up, or down as shown in Figure 3.

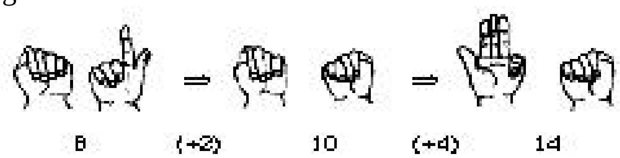


Figure 3. Example of 8 + 6 by a Korean child

Thus, for 8 + 6, the child, if he or she is on and beyond the Initial Number Sequence stage—the third of five counting stages (Steffe et al., 1988)—will just say, "eight, nine, ten, eleven, twelve, thirteen, fourteen" while extending six fingers in correspondence with the second-addend words nine through fourteen. When counting on, neither the fingers nor the irregular English number words for the teens signal that something special is happening at ten, so the child has no special support for inventing ten-structured methods. In contrast, both the Korean number naming words and the Korean folded/unfolded fingers signal that a repetition is occurring at ten, and both of these support the decomposition of the second addend into the part to make ten, and the part over ten is added.

In summary, the Korean language has a regular number naming system, which names the ten values as well as the hundred and thousand values in a regular way. Fuson and Kwon (1992) argued that this helps Korean children construct base ten mental representations for multidigit numbers. This affects the kinds of mathematical skills that can be taught early in the elementary school. These mental representations allow Korean children to add and subtract numbers with sums between 10 and 19 and to add and subtract multidigit numbers earlier, more easily and more accurately and to render multidigit addition and subtraction more meaningful than American children do. English-speaking children construct and use, for a long time, unitary representations of numbers that allow them to make errors in place-value tasks and in multidigit addition and subtraction. Fuson and Kwon argued that, because of the lack of support for understanding tens and ones in English, perceptual or linguistic support for constructing adequate multi-unit representations needs to be provided in the classrooms in the United States.

Rethinking the Previous Findings

Criticizing the methodologies of the previous studies, Towse and Saxton (1997) argue that children can be strongly influenced by subtle shifts in the instructions provided at the outset. They reexamined Miura et al.'s (1994) study from this perspective. That is, they explained that Miura et al. first demonstrated how to represent numbers with the cubes by giving children two examples, in which only 2 and 7 were chosen, both of which require ones cubes only.

Towse and Saxton argue that this demonstration may have cued some children to follow the experimenter's demonstration and use only ones cubes. They tested this possibility with fifty-four 6- and 7- year-old British children by creating a scenario in which each child was supposed to explain the written numbers to Ricky, a visitor from another planet.

Towse and Saxton (1997) also studied English-speaking children to assess whether they are also affected by the experimental cues in a similar situation. They used a scenario for the tests. In the experiment, each child was tested individually in a quiet area and the scenario was introduced as follows:

> I want to play a pretend game with you and with my friend here, Ricky-Ricky the Raccoon [E shows the child a teddy]. What I want to do is pretend that Ricky has come to visit us from another planet and has brought with him all these cubes, and he knows how many there are, and knows all about them [E points to the single and block cubes which are in clear plastic trays]. Now, when Ricky has arrived here, he has found that we have a way of writing down numbers. But poor Ricky doesn't know what these numerals mean, because no one has ever taught him. So Ricky wants you to try and explain to him what these numbers mean. And this is how we can do it. (p. 364)

After this introduction, they showed the number "2" as an example and let the child read the numeral.

The experimenter then took two single cubes from a tray and placed the cubes adjacent to the child to represent the number "2." As shown in the scenario, the children were asked to explain to Ricky two-digit numbers such as 13, 15, 18, 24, 26, and 27 using 1's, 10's and 20's cubes. They concluded that the first demonstration of showing the number "2" using single cubes might cue children to use only single cubes to represent the two digit numbers.

In the second and third experiments, the experimenter demonstrated the number "14" using one ten block cubes and four single cubes after the demonstration of the number "2." In the third experiment, only two digit numbers were used. They concluded that children's representations of numbers can be heavily influenced by experimental conditions.

They also did three similar experiments with 93 English-speaking children and 50 Japanese-speaking children (Saxton & Towse, 1998). In these experiments, they also found that subtle shifts in task instructions produced a marked influence on children's performance. They concluded that the influence of language on the cognitive representation of number is less direct than had previously been suggested.

In another study, Brysbaert, Fias, and Noël (1998) examined the Sapir-Whorf hypothesis and numerical cognition by making use of the fact that, in the Dutch number naming system, the order of tens and units is reversed—24 is read 'four-and-twenty.' In the first experiment, they compared naming latencies of French- and Dutch-speaking individuals when they had to pronounce, as fast as possible, the solution of a simple addition that consisted of a two-digit number and one-digit number (e.g., 20 + 4 = ?, 3 + 45 = ?, 67 + 8 = ?). The order of the operands was manipulated—20 + 4 vs. 4 + 20—as well as the presentation modality—Arabic vs. verbal. The authors concluded that mathematical operations are not completely impervious to language influences.

In the second experiment, they tried to find out whether the language difference is due to processes involved in the addition operation, or rather to output requirements. The study showed that these differences were due to input or output processes rather than differences in the addition operation. That is, the differences between Dutch and French disappeared when subjects were asked to type the answer rather than pronounce it. As a result of the study, Brysbaert et al. are suspicious of whether mathematical operations are based on verbal processes. In summary, instead of showing a Whorfian effect, their study has demonstrated how careful one must be in interpreting a language difference in a numerical task as the result of a difference in the semantic number system.

Discussion

Number word sequences are very important because children construct their higher level thinking (e.g., fraction schemes) through reorganization of their whole number operation based on their abstract number sequences (Olive, 1994; Steffe & Tzur, 1994). As mentioned earlier, Miura and other researchers argued that the Korean regular number naming system facilitates Korean children's numerical development. Many researchers (e.g., Fuson & Kwon, 1992; Miura et al., 1994; Song & Ginsburg, 1988) consent that Korean children have more sophisticated numerical capabilities (e.g., recomposing numbers), and that the Korean number naming system might have some benefits in enhancing children's numerical development. Also, there is a possibility that the Korean number naming system helps children construct the number sequence with ease. However, we cannot say, as the studies above suggest, that language differences would be the biggest factor in making Korean children superior in mathematics.

Methodologically, Saxton and Towse's (1998) study showed that the demonstration condition seems to reflect, in part, the expectations which children have about what they are asked to do and not just what they are capable of doing. That is, there is the possibility that the exact form in which the task is introduced has a considerable impact on the performance of young children. We should also consider Donaldson's (1978) argument that children think something magical happens when experiments are performed by adults or teachers. Thus, researchers and experimenters should be very sensitive when conducting an experiment with young children.

Finally, many previous researchers considered that they minimized the effect of schooling, but they did not take into account many Asian children's real lives.

We have to consider that many Asian children participate in some sort of private nursery schools where they learn number sequences. In other words, they start to learn the number concepts earlier than American children. In addition, there are other factors that seriously affect performance, such as cultural difference in emphasizing mathematics and parent assistance concerning numbers. Even though Fuson and Kwon (1991) recommended that base ten should be used artificially with English-speaking children, it is doubtful that it would be effective for them to learn the number concepts because their daily language and thought are interwoven inseparably. More careful appreciation of the complex factors that contribute to numerical competence is necessary for better understanding of numerical development.

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