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U.S. and Korean Children's Comprehension of Fraction Names: A Reexamination of Cross-National Differences

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Two experiments tested the claim that the transparency of Korean fraction names promotes fraction concepts (Miura, Okamoto, Vlahovic-Stetic, Kim, & Han, 1999). In Experiment 1, U.S. and Korean first and second graders made similar errors on a fraction-identification task, by treating fractions as whole numbers. Contrary to previous findings, Korean children performed at chance when a whole-number representation was included. Nonetheless, Korean children outperformed their U.S. peers overall. In Experiment 2, U.S. children's performance improved when fraction names were used that explicitly referred to part–whole relations like Korean fraction names. U.S. children's scores actually exceeded those of Korean children. Thus, although the differences in fraction names may influence children's performance, this may not account for the reported cross-national differences.

Even after years of formal instruction, children have difficulty understanding fractions (Kouba et al., 1988). They commonly make procedural errors, such as adding numerators and denominators (e.g., $3/8+2/4=5/12$). Even when children apply procedures correctly, they often fail to grasp the reasoning behind them (Behr, Lesh, Post, & Silver, 1983; Behr, Wachsmuth, & Post, 1985; Behr, Wachsmuth, Post, & Lesh, 1984; Kerslake, 1986; Kouba et al., 1988). For example, 12- to 14-year-olds who correctly solve fraction calculation problems, such as $1/4+2/3$, still cannot explain why a common denominator is needed. Apparently, students simply carry out the procedure they have been taught in school without understanding it.

Although several explanations for these difficulties have been advanced (see Mix, Levine, & Huttenlocher, 1999, for a review), the current study focused on one idea in particular—that poor performance on fraction tasks is caused by confusion about the conventional symbols and terms for fractions. Specifically, it has been proposed that the mapping between English fraction names and their conceptual referents is not as direct as the mapping in other languages, such as Korean (Miura, Okamoto, Vlahovic-Stetic, Kim, & Han, 1999). This lack of transparency is thought to hinder U.S. children's performance on conventional fraction tasks. The present study investigated this claim.

The idea that language differences lead to conceptual lags is not unique to fraction concepts. It underlies several cross-cultural studies showing that U.S. children trail behind their Asian peers on a variety of mathematical tasks (e.g., Miller & Stigler, 1987; Miura, Kim, Chang, & Okamoto, 1988; Miura, Okamoto, Kim, Steere, & Fayol, 1993; Miura et al., 1999; Song & Ginsburg, 1987; Stevenson, Lee, & Stigler, 1986). For example, Miller and Stigler (1987) compared Chinese and U.S. children's ability to count. Whereas the English counting system has irregularly formed decade names (e.g., twenty, thirty, and forty) and "teen" structures (e.g., eleven, twelve, and thirteen), the Chinese counting system is much more regular (e.g., 11 is literally translated "ten-one", 12 is translated "ten-two", etc.). Miller and Stigler found that 4-, 5-, and 6-year-old Chinese children counted substantially higher and made fewer number-word errors than did U.S. children. From this, Miller and Stigler concluded that systematically organized number names facilitate Chinese children's understanding of counting.

Language effects also have been found for children's understanding of place value (i.e., the meaning of the individual digits in a multidigit numeral). Miura et al. (1993) found that Chinese, Japanese, and Korean-speaking first graders used canonical base-10 constructions to represent numbers using blocks more often than did English-, French-, and Swedish-speaking children. For example, whereas English-speaking children used 42

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single-unit blocks to represent the number 42, Asian children used 4 tens blocks and 2 single-unit blocks. Miura et al. attributed this difference to the transparent base-10 structure of Asian counting systems.

Fraction-naming systems also differ between East Asian languages and English. In Korean, Chinese, and Japanese, the notion of fractional parts is explicitly embedded in fraction names. For example, the Korean name for *one fourth* is roughly translated *of four parts, one* (Miura et al., 1999). Recent cross-cultural research suggests that the transparency of part–whole relations in these fraction names helps East Asian children understand fractions (Miura et al., 1999). Children in Croatia, Korea, and the United States were given a fraction-identification task. Only first and second graders were included to avoid prior school instruction on fractions. On each trial, children saw a written fraction and heard it read aloud in their native language. Then they were asked to circle the picture that showed the same fraction from among four choices. The main finding was that Korean children performed significantly better than either Croatian or U.S. children. By the end of first grade, Korean children performed significantly above chance, correctly answering an average of 3 of 8 problems (chance = 2). By the beginning of second grade, Korean children obtained nearly perfect scores ($M = 7.73$). Miura et al. concluded that the transparency of Korean fraction names facilitated children's understanding of fraction concepts.

Another finding was that children from all three nations tended to make the same error. They frequently chose the picture that represented the number of parts for the numerator and denominator as if they were addends. For example, when the target fraction was 2/3, children erred most frequently by selecting the fraction 2/5, which contained two shaded portions and three unshaded portions (see Figure 1, Option 3). The numerator + denominator (henceforth, N+D) foil accounted for more than 75% of the errors in Miura et al.'s (1999) study. Taken together with the evidence of cross-national differences, Miura et al. concluded that, although children from all language backgrounds made this error, Korean children made it less frequently because of their transparent fraction names.

Miura et al.'s (1999) findings raise three questions. First, the fact that all children, regardless of nationality, made the same systematic error suggests that children's poor performance may be due to one particular misconception. What would happen if this misconception were no longer an option? In other words, would U.S. children answer correctly if the N+D foil were not available? If so, it would suggest that Korean children perform better in this task because they can overlook this interpretation. On the other hand, if U.S. children still perform at chance, it would indicate a general failure to grasp fraction names. In this case, the N+D foil would simply be the preferred default.

Second, do Korean children perform better on the fraction-identification task because of their language background? In cross-national comparisons, other cultural differences are usually confounded with linguistic differences. For example, Korean and U.S. attitudes toward mathematics education may vary greatly. After-school courses, educational television programs, and other mathematics-related activities are well implemented in Korea. Song and Ginsburg (1987, 1988) argued that the amount of time Korean parents and educators spend on mathematics education is greater than for U.S. parents and educators. These achievement differences seem to result in stronger motivation in mathematics (Stevenson et al., 1986; Stigler, Lee, Lucker, & Stevenson, 1982). Such cultural differences, rather than linguistic differences per se, could account for Korean children's superior performance on Miura et al.'s (1999) fraction-identification task.

Last, if Korean fraction names are helpful, how specifically do they help? There are at least two differences between Korean and English fraction names that might affect children's learning. One difference is the degree to which the idea of equal parts is made explicit. Fraction names are only meaningful in reference to pieces that are the same size. This idea may be more obvious in Korean, where there is direct reference to the idea of parts (e.g., of four *parts,* one). Another dimension that

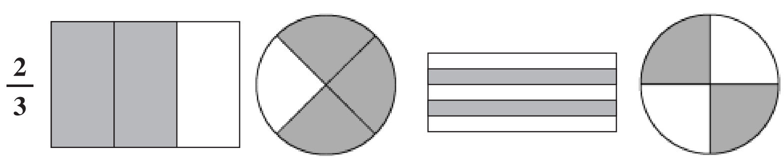

Figure 1. A sample test item—adapted from a figure used by Miura, Okamoto, Vlahovic-Stetic, Kim, and Han (1999).

might matter is the order of the numerator and denominator. In the Korean terms for fractions, the denominator comes first (e.g., *of four parts*, one). English uses the reverse order (e.g., one *fourth*). Children might interpret fraction terms more easily if they are oriented toward the overall number of parts before attending to a specific subset of parts.

The present study addressed these three questions. In Experiment 1, we tested whether children's performance on the fraction-identification task improved when the N+D foil was removed. In Experiment 2, we eliminated nonlinguistic cultural differences by testing whether English translations of Korean fraction names improve U.S. children's performance on the fraction-identification task. We also used several wording variations to determine what specific aspect of the Korean fraction names improved performance. Our findings suggest that the relation between language and concepts in this situation is more complex than it might at first seem.

Experiment 1

Method

Participants. In Experiment 1, 102 children participated. The Korean sample included 28 first graders (age: $M = 7{,}0$; *range* = 6,9–7,4) and 25 second graders (age: $M = 7{,}9$; *range* = 7,2–8,4). Four of the classroom teachers refused to provide birth dates for the children in their classrooms (32% of the sample), so the mean ages reported here are estimates based on the birth dates provided for the remaining children. The U.S. sample included 25 first graders (age: $M = 7{,}2$; *range* = 6,7–8,0) and 24 second graders (age: $M = 8{,}1$; *range* = 6,9–8,11). These mean ages are based on birth dates provided for the entire sample. Each group included approximately the same number of boys and girls.

U.S. children were drawn from four local elementary schools that served a predominantly White, middle-class population. All children spoke English as their primary language. Korean children were drawn from a middle-class population attending two public schools in Seoul, Korea. Both grade levels were tested at each of the participating schools. Although the Korean math textbook for second graders and some of the U.S. textbooks contained an introduction to basic fraction concepts, such as equal parts of a whole and some fraction names (e.g., one half, one third, and one fourth), a questionnaire given to the teachers of the participating schools confirmed that fractions had not been formally introduced in these classrooms.

Materials and Procedure

Children completed an identification task for which they circled the correct pictorial representation of a target fraction from among four choices. For example, given the target fraction 2/3, the correct choice was a rectangle divided into three portions with two portions shaded (see Figure 1, Option 1). Children marked their answers on a test sheet with eight test items targeting seven fractions (1/3, 2/3, 2/4, 3/4, 2/5, 3/5, and 4/5). As in Miura et al.'s study, the fraction 2/4, appeared twice.

Children from each grade were randomly assigned to one of two conditions. Children in the with N+D condition received eight trials with the N+D foil included. Recall that this foil had the same number of shaded portions as the target numerator and the same number of unshaded portions as the target denominator (see Figure 1, Option 3). These materials were the same as those used by Miura et al. (1999). Children in the without N+D condition had the same materials except that the N+D foil was replaced with another foil. Children were tested in small groups of 5 to 10. This allowed the experimenter to monitor whether children understood the task and followed the directions, and it ensured that each child worked independently.

Each child was given a test sheet. On the top of the test sheet there were four numeric fractions along with the fraction names written in the child's native language (e.g., 1/2 = one half, 1/3 = one third, 1/4 = one fourth, 1/5 = one fifth). Following Miura et al.'s (1999) procedure, the experimenter pointed to these sample fractions and explained that these numbers were called fractions. Then, the experimenter read the fraction names aloud, one at a time, while pointing to the appropriate fraction symbols. There were no drawings included with these samples. Below the samples were the eight test items. In the test phase, the experimenter explained that she would read the fraction at the left of the page. Children were told: "Look and listen carefully to how I read the fraction. Try to find a picture that goes with the fraction and draw a circle around the picture." The test phase began when children acknowledged that they understood the procedure. No further prompts or feedback were given. The experiment took approximately 10 to 15 min. A bilingual experimenter tested both the Korean and

U.S. children. This ensured that the testing procedures were consistent across groups.

Results and Discussion

Every child completed the entire task. Figure 2 shows the mean percentage correct for children in each condition. A three-way ANOVA was performed on these scores, with nationality (Korean and U.S.), grade (first and second grade), and condition (with N+D and without N+D) as between-subjects factors. There was a main effect of nationality, $F(1, 94) = 5.72$, $p < .02$. There also was a significant main effect of condition, $F(1, 94) = 29.94$, $p < .001$, which reflected better performance on the without N+D condition ($M = 5.66$, $SD = 2.10$) than on the with N+D condition ($M = 2.77$, $SD = 3.17$). As in previous research, Korean children obtained higher scores than did U.S. children across grade level and condition (with N+D condition: Korean first graders: $M = 3.33$, $SD = 3.64$; Korean second graders: $M = 2.92$, $SD = 3.37$; U.S. first graders: $M = 2.54$, $SD = 3.15$; U.S. second graders: $M = 2.17$, $SD = 2.59$; without N+D condition: Korean first graders: $M = 6.54$, $SD = 1.85$; Korean second graders: $M = 6.46$, $SD = 1.81$; U.S. first graders: $M = 5.58$, $SD = 1.51$; U.S. second graders: $M = 3.92$, $SD = 2.23$).

Two-tailed t tests revealed that U.S. first and second graders' performance on the without N+D condition was significantly above chance (first graders: $M = 5.58$, $SD = 1.51$; second graders: $M = 3.92$, $SD = 2.23$), first graders: $t(11) = 6.45$, $p < .01$; second graders: $t(11) = 2.10$, $p < .05$. Korean first and second graders also performed significantly above chance when the N+D foil was omitted, first graders: $t(12) = 6.38$, $p < .01$; second graders: $t(12) = 6.29$, $p < .05$. However, both Korean and U.S. children performed at chance when the N+D foil was included (Korean children: first graders: $M = 3.33$, $SD = 3.64$; second graders: $M = 2.92$, $SD = 3.37$; U.S. children: first graders: $M = 2.54$, $SD = 3.20$; second graders: $M = 2.17$, $SD = 2.59$). No other significant main effects or interactions were found. Because scores on this task are proportional (X of 8), we conducted a parallel ANOVA using arcsin transformations of children's scores. This analysis yielded the same patterns of significance as before.

An examination of children's individual performance revealed the same patterns as the group results. In Table 1, we present the percentage of children whose scores reached a criterion of at least 5 of 8 correct ($p < .05$). More children reached this criterion in the without N+D condition. This was true for both the U.S. and Korean samples. In fact, the patterns of above-chance performance were strikingly parallel between the two nations. The main difference was that more Korean children reached ceiling, a difference that can account for the higher scores by Korean children overall.

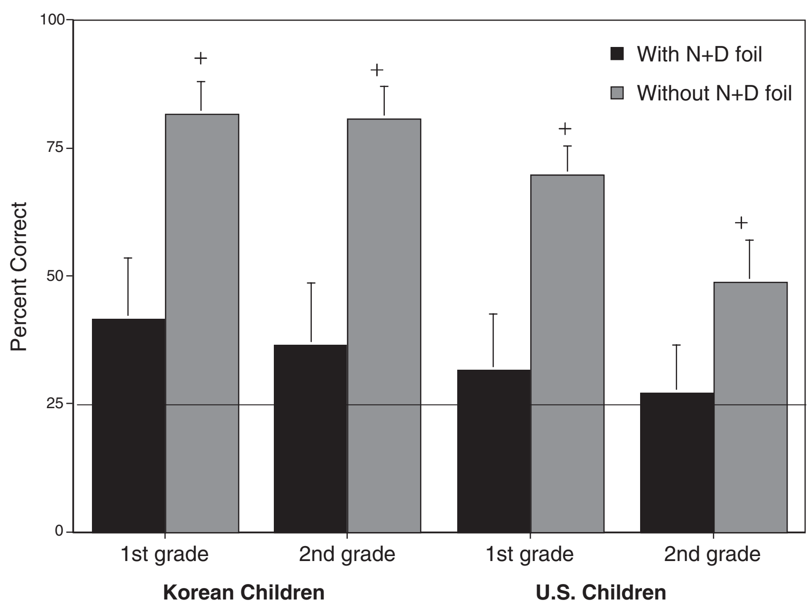

Figure 2. Korean and U.S. children's mean scores in the with N+D and without N+D conditions in Experiment 1.

It is not surprising that the worse performance in the with N+D condition was caused by children choosing the N+D foil. Indeed, this accounted for 77% of the errors made by Korean children and 78% of the errors made by U.S. children. An ANOVA with nationality and grade as between-subjects factors confirmed that this difference was highly significant, $F(1, 88) = 224.75$, $p < .001$. Children from both countries chose the N+D foil much more frequently than the other foil choices when given the option. This suggests that U.S. children's difficulty with this task is not due to a general failure to comprehend fractions, but rather to a specific misconception that is tapped by the N+D foil. Our results also suggest that this misconception has a significant impact on children from both cultures and is not easily overcome by children learning Korean fraction names.

Why is the N+D choice misleading? One reason may be that it invites a whole-number interpretation of the fraction terms, based on children's knowledge of counting and whole-number algorithms, such as addition. In this foil, the numerator and denominator are represented as unrelated quantities within the same whole. It is akin to counting up the number of boys and girls in a classroom without considering the proportion of each group relative to the total. Thus, the N+D foil would be preferred if children were using a counting strategy that did not take part–whole relations into account. This explanation is consistent with the argument made previously that children have an intuitive grasp of fractions but perform poorly on conventional tasks because of interference from the conventional counting system (Mix et al., 1999; Nunes & Bryant, 1996). On this interpretation, it was not surprising that children from both cultures made the same error because they are both familiar with conventional counting and calculation.

However, it was surprising that Korean children performed at chance when the N+D foil was included. Using the same procedure and identical materials, which included the N+D foil, Miura et al. (1999) found that by the end of first grade, Korean children performed significantly above chance. Korean second graders in that study obtained nearly perfect scores. In the present experiment, children from neither country performed above chance when the N+D foil was included. Moreover, even when the N+D foil was omitted, the scores of Korean children did not approach ceiling.

One possible explanation is that the difference was due to sampling bias. Perhaps the Korean children who participated in the present study were somehow disadvantaged compared with those tested by Miura et al. (1999). However, this seems unlikely given that both samples were drawn from middle-class populations. Furthermore, because the Korean educational system is highly standardized, children from different communities have very similar school experiences. For example, the same textbooks are used at each grade level throughout Korea. Thus, children in the two samples should have had similar educational backgrounds generally speaking (i.e., in addition to the fact that none of the children were taught about fractions in school). Although there is no guarantee that both samples represented the same population, there is no obvious reason to suspect that they did not.

Another possibility is that the discrepancy was due to minor but potentially important procedural differences. One difference was that, in Miura et al.'s

Table 1
The Percentage of Scores Exceeding Chance in Experiment 1

Korean children			
First grade		Second grade	
Without N+D	With N+D	Without N+D	With N+D
85 (55)	40 (83)	77 (70)	33 (50)
U.S. children			
First grade		Second grade	
Without N+D	With N+D	Without N+D	With N+D
83 (10)	31 (50)	83 (0)	17 (50)

Note. The criterion used was 63% (5 of 8) correct ($p < .05$). The numbers in parentheses represent the percentage of children within this group whose scores also reached ceiling.

(1999) study, the classroom teachers collected data from their own students using written instructions. Although the instructions may have been straightforward, it is still possible that there were variations in the way different classroom teachers conducted the experiment. It is also possible that some teachers were more objective than others in assessing their students' ability. For example, just one teacher instructing children and boosting the scores could explain the discrepancy. In the present study, the first author collected data for both Korean and U.S. children. Classroom teachers were not told the details of the procedure before data collection. A second difference was that the entire class was tested as one group in Miura et al.'s study. This may have made it difficult to monitor whether children were working independently. In the present study, the task was administered to small groups of 5 to 10 children, which allowed the experimenter to monitor them closely.

Although there were no significant effects involving grade, an inspection of the means revealed an unexpected pattern—U.S. first graders outperformed second graders in the without N+D condition. Two-tailed t tests confirmed that this difference was significant, $t(22) = 2.14$, $p < .05$. In the Korean sample, the same trend was observed but there was no significant difference between grade levels. Still, it is remarkable that Korean children showed no improvement from first to second grade.

Although performance on most tasks improves with age, reverse age effects have sometimes been reported (Bowerman, 1982; Bybee & Slobin, 1982; Miller & Paredes, 1990). For example, Miller and Paredes (1990) found that children's addition ability seemed to suffer temporarily while they were in the process of learning multiplication. When given blocks of addition and multiplication problems, third graders were faster at solving multiplication problems than addition problems. Also, in a longitudinal study, Miller and Paredes demonstrated that children's performance on the addition problems became slower and less accurate when they were learning to multiply. This suggests that acquiring a new mathematics concept or strategy can interfere with old and related ones.

A similar mechanism could underlie U.S. second graders' lower performance on the fraction-identification task. Second graders have had more exposure to whole-number addition and subtraction than have first graders. Furthermore, they are likely to be more experienced with counting-based strategies for making computations, such as counting-on, that develop during first grade (Ashcraft, 1982; Groen & Parkman, 1972; Siegler, 1987). If second graders were immersed in these counting-based approaches to problem solving, they may have been especially vulnerable to the N+D foil, which represents fractions in terms of two separate numbers without regard for part–whole relations. In contrast, first graders may have approached the fraction task with fewer preconceptions. They may have made fewer errors because they have not had enough input to adopt these whole-number strategies as rigidly.

In summary, Experiment 1 sought to replicate and extend the cross-cultural differences reported previously on this fraction-identification task. Although Korean children performed better than U.S. children overall, they did not perform above chance in the N+D version, as they had in Miura et al.'s (1999) study. Instead, children from both nations performed at chance in this condition, mainly due to their tendency to choose the N+D foil. Children in the U.S. sample did perform above chance when the N+D foil was omitted, lending further support to the idea that their previous difficulties were due to one particular misconception rather than a general inability to grasp fractions. Notably, there was no improvement across grade levels and, in fact, younger children outperformed older children in the U.S. sample.

Experiment 2

Although the evidence for cross-cultural differences in Experiment 1 was not as straightforward as in previous research, Korean children's overall performance on the fraction-identification task was still better than that of their U.S. peers. Thus, there may be support for Miura et al.'s (1999) claim that Korean fraction names promote conceptual understanding. However, evidence of cross-national differences does not necessarily constitute evidence of cross-linguistic effects. As we discussed, there are many cultural differences, such as availability of extracurricular mathematics instruction and parental attitudes toward mathematics, that could account for differential performance between Korean and U.S. children.

Miura et al. (1999) recognized that differences in exposure to fraction names could influence performance on the fraction-identification task, but they concluded such effects would nonetheless depend on language differences. For example, they wrote the following statement about the exposure to fraction terms in the home:

> Out-of-school experiences also might account for differential performance. The extent to which children are exposed to fraction terms and fractional representations or objects is unknown. Certainly, simple unit fractions like one half or one third may be encountered in everyday life. … If children make the connection between one third and its visual counterpart, that understanding may be extended to other fractions and their part–whole representations *when the language (as in the case of Korean) supports the connection* (emphasis needed). Conversely, the absence of such linguistic support in Croatian and English may account for the absence of change across time in the performance of the Croatian and U.S. children. (p. 363)

Thus, the claim seems to be that even if there are cultural differences, the effect of these differences is mediated by differences in language.

To evaluate such claims, it is important to gauge the effects of language independent of other cultural differences. One way to do so is to test children from the same culture under conditions that vary the structure of fraction names in the children's native language. For example, if Korean children's superior performance on fraction tasks is due to the transparency of their fraction names, U.S. children should perform better when fractions are named ''Of X parts, Y'' (the Korean wording) than they do when fractions are named using English conventions. Experiment 2 examined whether this is the case.

Method

Participants. A total of, 99 U.S. children participated including 51 first graders (age: $M=7{,}6$; $range=6{,}7$–$8{,}8$) and 48 second graders (age: $M=7{,}11$; $range=7{,}3$ months–9,4). There were approximately the same number of boys and girls in each age group. Children were drawn from five local elementary schools that served a predominantly White, middle-class population. Both grades were tested at each of the participating schools. All children spoke English as their primary language. A questionnaire completed by the teachers of the participating schools confirmed that fractions had not been formally introduced in their classrooms.

Materials and procedure. The materials and procedure were identical to those used in Experiment 1, except that all children received a test sheet with the N+D foil included.

Different fraction wording conditions. Children were randomly assigned to one of four conditions that tested specific language differences between Korean and English that might promote understanding of fraction symbols (see Table 2). The four wording conditions resulted from crossing two dimensions: (a) explicitness of parts and (b) numerator–denominator order. Thus, in two of the conditions, the notion of fractional parts was explicitly mentioned in the fraction names, but the numerator came first in one condition and the denominator came first in the other condition (e.g., ''of four parts, one'' vs. ''one of four parts''). In another two conditions, the explicit reference to parts was removed, but the difference between numerator–denominator orders was still contrasted (e.g., ''four-one'' vs. ''one-four''). The number of children in the four conditions was roughly equal. Children's scores from the conventional English condition (e.g., ''one fourth'') of Experiment 1 were used for comparison in some analyses.

Results and Discussion

An inspection of Figure 3 indicates that performance was better in both of the ''explicit parts'' conditions. This difference was confirmed with a three-way ANOVA performed on children's total number correct, with grade (first and second), fraction name (part–whole relations explicit,

Table 2
The Five Wording Conditions in Experiment 2 Numerator–denominator order

Ideal of part–whole relations	Denominator→Numerator	Numerator→Denominator
Explicit	of four parts, one	one of four parts
Not explicit	four-one	one-four
Control condition (standard English fraction names)		one fourth

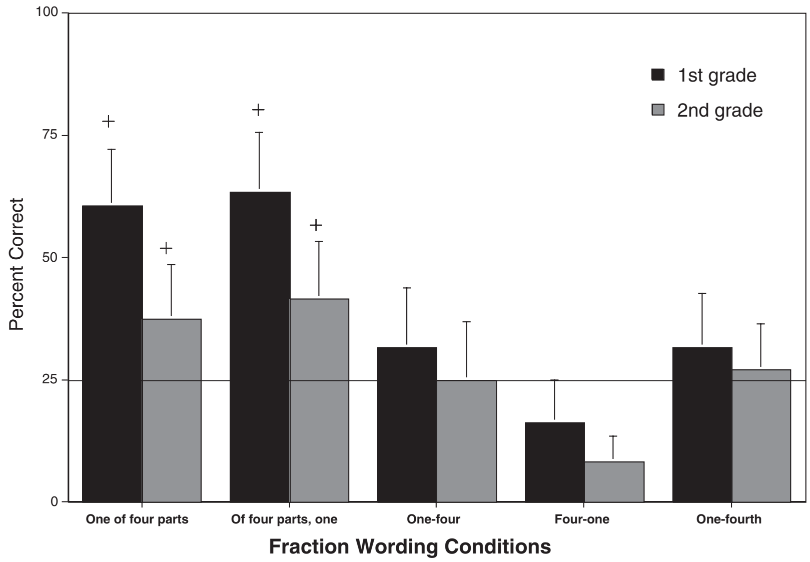

Figure 3. U.S. children's mean scores for the different fraction name conditions in Experiment 2.

Table 3
The Percentage of Scores Exceeded Chance in Experiment 3

		First grade		
One of four parts	Of four parts, one	One-four	Four-one	One fourth (Exp. 1)
57 (75)	67 (50)	25 (67)	15 (50)	31 (50)
		Second grade		
One of four parts	Of four parts, one	One-four	Four-one	One fourth (Exp. 1)
33 (50)	42 (20)	25 (67)	8 (0)	17 (50)

Note. The criterion used was 63% (5 of 8) correct ($p < .05$). The percentages in parentheses represent the number of children within this group whose scores reached ceiling.

part–whole relations not explicit, and standard English fraction name), and order of the numerals (numerator–denominator and denominator–numerator) as between-subjects factors. Children's scores were significantly higher in the explicit parts wording conditions ($M = 4.1$, $SD = 3.3$) than they were in the other nonexplicit parts wording conditions ($M = 1.88$, $SD = 2.88$), $F(2, 114) = 8.75$, $p < .0001$. As in Experiment 1, first graders performed marginally better ($M = 3.28$, $SD = 3.39$) than second graders ($M = 2.23$, $SD = 2.86$) across conditions, $F(1, 114) = 3.21$, $p < .08$, No other significant main effects or interactions were found. Notably, performance did not differ based on numerator–denominator order, $F(1, 114) = 0.73$, $p < .4$.

Table 3 shows the percentage of children whose scores exceeded chance performance in each condition (i.e., 5 of 8 correct, $p < .05$). More children performed above chance in the explicit wording conditions, ''one of four parts'' and ''of four parts, one.'' This suggests that the results of the group analysis are unlikely due to extreme individual differences.

Pairwise comparisons (Tukey HSD) confirmed that across grade level, children's scores were significantly higher in the explicit wording condition than in the nonexplicit wording condition ($p < .0001$). These scores were also significantly higher than U.S. children's scores in Experiment 1 where the standard English fraction name condition was used ($p < .05$). Moreover, t tests confirmed that first graders performed significantly above chance in the explicit wording conditions, $t(50) = 3.23$, $p < .01$, two-tailed. As reported in Experiment 1, both first and second graders performed at chance when the standard English fraction names were used (first graders: $M = 2.54$, $SD = 3.20$; second graders: $M = 2.17$, $SD = 2.59$). No other significant main effects or interactions were found. As before, an ANOVA using arcsin transformed scores yielded the same pattern.

By testing only U.S. children under different naming conditions, the present study equated cross-cultural factors such as parental attitudes, after-school programs, and so forth, which could have influenced children's performance in Experiment 1 as well as Miura et al.'s (1999) study. Thus, the present findings are particularly important because they demonstrate the effects of fraction-naming language independent of other cross-cultural differences. These results also suggest that it is the explicitness of the part–whole relations in particular that might lead to Korean children's superior performance on the fraction-identification task.

However, if this interpretation is correct, it is surprising that U.S. children exposed to translations of Korean fraction names performed better than Korean children in Experiment 1. U.S. children were exposed to these terms only briefly. Assuming that children from both nations heard these terms for the first time in this experiment, there would be no reason to expect one nation to outperform the other. If there were a significant difference, it should favor the Korean children given that they may have overheard these terms in conversation even if they had not been taught them directly. Until now, it has been assumed that the translation ''Of X parts, Y'' accurately represents how Korean fraction names are heard by Korean children. However, the pattern obtained in this experiment suggests that the translation used here and in previous research may not be quite right. Specifically, the word *parts* used in the translated fraction names may be more transparent for U.S. children than the Korean equivalent is for Korean children.

In English, the word *parts* is in children's everyday vocabulary. By the time children enter grade school, they usually understand the word *parts*, even if they have not mastered the idea of equal parts. In contrast, the Korean word for *parts* that is used in fraction names (i.e., *boon*) is not in children's everyday vocabularies before formal schooling. This word is actually borrowed from Chinese and is not introduced to children until they are taught fractions in school. Until then, children use informal words to refer to *parts* in their daily lives (e.g., *jo-gak*). In fact, this discrepancy is explicitly discussed in the second-grade Korean math textbook. An analogy would be if we called 1/4 ''of four *morceaux* one'' in English. Children might come to learn that *morceaux* meant *parts*, but this would not be immediately apparent from their informal experiences. Thus, it may take some time for Korean children to grasp the meaning of the word, *boon*. Korean children in the present study probably did not have a good understanding of their own fraction names because they had not been formally introduced to the mathematical term for *parts* in school. For this reason, it seems unlikely that the higher scores of Korean children in the present task were due to linguistic differences. Still, as we consider in the General Discussion, exposure to these fraction names may lead to improved performance on more complex tasks, once children can grasp the terms' meaning.

Finally, as in Experiment 1, these results indicated that U.S. first graders tended to outperform second graders in all five wording conditions. Thus, the reverse-age effect in Experiment 1 appears not to be anomalous. As noted previously, second graders may have invented a faulty whole-number strategy based on approaches they have learned for solving other whole-number problems (e.g., counting fingers to solve addition problems). Because of their extra experience, they may be more prone to apply this approach and ignore the information given in the fraction names. In contrast, because first graders have had less practice with whole-number strategies in general, they may attend to the novel fraction names more.

General Discussion

To explain why children have difficulty grasping fractions, some researchers have turned to cross-national comparisons. This work has focused on linguistic differences that may promote fraction understanding in some cultures more than others. Specifically, it has been argued that East Asian languages, such as Korean, promote children's understanding of fractions because part–whole relations are transparent in their fraction names. Although we found support for the general idea that differences in fraction names can influence children's performance on fraction tasks, our results indicate that this may not explain the cross-national differences obtained here and reported previously.

As in Miura et al.'s (1999) study, Korean children in the present study outperformed U.S. children on the fraction-identification task. However, in contrast to Miura et al.'s findings, neither Korean nor U.S. children performed above chance when the N+D foil was included. Recall that in this and previous research, choosing the N+D foil was the most common error for children from both nations. Miura et al. argued that Korean children are better able to overcome this error with the support of their fraction-naming system. Our results cast doubt on this claim. Instead, we found that this error leads to random performance regardless of language or other cultural differences. When the N+D foil was not one of the distracters, children from both nations performed above chance. Still, Korean children's scores were significantly higher than those of the U.S. children overall. Thus, it is possible that Korean fraction names are helpful when the N+D foil is not available, but not enough to help children avoid the N+D error. Alternatively, this finding may reflect the influence of nonlinguistic cultural differences discussed previously.

The results of Experiment 2 lend support to the latter interpretation. The main finding was that English translations of Korean fraction names helped U.S. children overcome the N+D error, leading to significantly higher scores compared with children who received conventional English terms. On the surface, this seems to suggest that Korean fraction terms support performance in this task. However, the improvement was so great that U.S. children's scores surpassed those of Korean children. How is it possible that U.S. children exposed to such wording for the first time would outperform Korean children for whom these terms must be at least as familiar and transparent?

We conclude that it must be because these terms are not as transparent to Korean children as previously assumed. As we noted before, the word for *parts* used in Korean fraction names is a formal word that may not be as familiar to Korean children as the word *parts* used in the explicit fraction names is for U.S. children. Thus, although highly transparent fraction names like those used in Experiment 2 may be easier to interpret, this might have little to do with the superior performance of Korean children found in Experiment 1 and in previous research. Instead, these performance differences are likely due, either entirely or in large part, to cultural differences other than language.

Of course, it is possible that an advantage for Korean fraction names emerges later in development on more complex tasks. Once Korean children become more familiar with the word *boon* and formal fraction names become as transparent to them as the English translations were for U.S. children in the present study, they might exhibit greater understanding of fraction concepts. However, this may take several years and, thus, may only be evident on more complicated tasks, such as fraction addition or reduction.

If this interpretation is correct, several new predictions follow. First, if Korean children have difficulty understanding their fraction terms because the formal word for *parts* (i.e., *boon*) is unfamiliar, they should perform better if *boon* were replaced with a more familiar word for *parts*. This would more closely parallel the "of X parts, Y" condition that led to big improvements for U.S. children in Experiment 2. It also would be interesting to see how children from other East Asian countries, such as Japan and China, perform on this fraction-identification task. Both Japanese and Korean fraction names are derived from Chinese. Formal fraction names may be immediately transparent for Chinese children if the word used for *parts* is in their everyday vocabularies. However, this should not be the case for Japanese children, who, like Korean children, would only know this term from formal schooling.

With respect to the main question addressed in this research—namely, why U.S. children have such difficulty understanding fractions—it is ironic that the answer seems to come not from cross-national differences but from a striking cross-national similarity. Across studies, both Korean and U.S. children misinterpreted fraction names the same way—by trying to map the numerator and denominator onto the number of shaded and unshaded portions of the fraction (i.e., the N+D error). The fact that children were misled by the N+D foil suggests that they tried to apply whole-number strategies to this task. The N+D foil allows one to map the fraction name onto a picture with no regard for part–whole relations. When this mapping is not available (i.e., the without N+D condition), children from both language backgrounds chose the correct picture most often. Thus, it seems that both Korean- and English-speaking children have developed some informal understanding of fractions but that, for both groups, whole-number experience interferes with their performance on conventional tasks.

The finding that U.S. first graders outperformed U.S. second graders lends support to this interpretation. By second grade, children have mastered the conventional counting system and whole-number problem-solving strategies for addition and subtraction. Because second graders have had greater exposure to whole-number problems, they may be more committed to whole-number interpretations of any mathematical problem than are first graders.

This would explain why, in Experiment 2, second graders benefited less from the transparent fraction names than did first graders. Perhaps first graders, with fewer preconceptions, can more readily interpret transparent fraction names in terms of part–whole relations and overcome the N+D error.

In conclusion, cross-national comparisons have consistently shown Asian children's superiority over their U.S. peers on mathematical tasks. This superiority is often interpreted in terms of language differences (Miura et al., 1999; Song & Ginsburg, 1987; Stevenson et al., 1986). However, the present study suggests that, at least in the case of fractions, the contrast between U.S. and Korean children is more complex. The present results point out the need to specify both the problems that interfere with learning and the mechanisms by which cultural tools such as language might facilitate it, to make the most of cross-national comparisons.

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