Western Undergraduate Psychology Journal

Volume 3 | Issue 1 Article 11

2015

Why Asian Preschool Children Mathematically Outperform Preschool Children from Other Countries

Priscilla R. Gerofsky
Western University

Why Asian Preschool Children Mathematically Outperform Preschool Children from Other Countries

Priscilla R. Gerofsky*

This paper examines why Asian children mathematically outperform children from other countries prior to the start of formal education. A review of the literature, comparing preschoolers from Asian and Western cultures, revealed two important factors: linguistic and parental influences. Studies show that Asian languages use Chinese number words, which simply and consistently represent numbers, providing Asian children with a head start in basic math skills. Furthermore, the Chinese language tends to use number words more frequently, providing more exposure to numerical concepts. Studies also show that Asian parents, compared to parents from Western cultures, tend to promote the development of strong basic math skills. Although it is evident that both linguistic and parental influences provide Asian preschoolers with a stronger mathematical foundation, it is difficult to determine the relative contribution of each factor. Future studies are required to disentangle and isolate the effects of language and parental influences on preschoolers' math performance.

Children in Asian countries such as China, Korea, and Japan consistently outperform children from other countries on international tests of math achievement (OECD, 2013). There are various factors that contribute to this exceptional performance, but most explanations have concentrated on educational factors (Siegler & Mu, 2008), such as teachers allocating more class time to math, deeper explanations of math procedures, and earlier learning of complex topics (Perry, 2000). However, Asian children tend to outperform children from other countries prior to the start of formal education (Paik, van Gelderen, Gonzales, de Jong & Hayes, 2011). It is necessary to understand the cultural factors that affect this performance difference, because this may suggest ways to help preschool children from non-Asian countries develop a stronger math foundation (Paik et al., 2011). Accordingly, the present paper addresses the factors that contribute to the enhanced mathematical skills of Asian preschoolers. A review of the literature points to two important factors that explain why this advantage occurs at such a young age: linguistic and parental influences (Paik et al., 2011). First, linguistic influences will be discussed, followed by a discussion of parental influences.

Linguistic Influences

The influence of Asian languages on math performance has received a great amount of research attention, and it has been suggested that it is one of the important influences on the exceptional math performance of these children (Dowker, Bala, & Lloyd, 2008). There are several advantages that Asian languages, which use Chinese number words, confer upon early number learning.

Base-Ten Number Words: Effects on Counting and Understanding Place Value

Important advantages result from the use of Chinese number words which clearly and consistently represent the base-ten number system. The base-ten number system, based on Arabic numerals (e.g., 1, 2, 3), is the predominant written number system used today (Ng & Rao, 2010). In contrast, the cardinal

*Initially submitted for Psychology 3433G at Western University. For inquiries regarding the article, please e-mail the author at mpgerofsky@rogers.com.

number word names for the Arabic symbols differ across languages. In all languages, the numbers up to 10 involve memorizing unpredictable names; however, unlike most other languages, Chinese number words past 10 consistently and clearly represent the base-ten number system (Miller, Smith, Zhu, & Zhang, 1995). As an example, the number word for 11 is analogous to "ten-one" in English, and the word for 25 is analogous to "two-tens-five." It is argued that the clear, repeated base-ten pattern makes it very easy for children to learn numbers past 10 (Ng & Rao, 2010). In contrast, English teen numbers do not follow the base-ten pattern resulting in children requiring more time to learn to count teen numbers.

To compare counting skills, Miller et al. (1995) had Chinese and American preschoolers count as high as they could. As predicted, the American preschoolers had difficulty counting teen numbers, as well as counting numbers above 20. To illustrate this point, they might count "twenty-ten, twenty-eleven," showing that they did not comprehend the base-10 counting system associated with number names past 20. The Chinese preschoolers demonstrated better counting skills past 10, apparently because of the base-ten clarity of the Chinese number words.

Several studies have also shown that the base-ten transparency of Chinese number words reinforces the concept of place value (Ng & Rao, 2010). Place value is an important concept because the value of a digit is based on its position (e.g., units, tens, hundreds). A study by Miura, Okamoto, Kim and Chang (1994) compared children in the early part of grade one from East Asian countries (China, Japan, and Korea) to children from western countries (France, Sweden, and the United States) regarding how they represented numbers up to 42 using base-ten blocks. The non-Asian children usually represented numbers using unit blocks, whereas the Asian children tended to use a combination of ten and unit blocks. Furthermore, the Asian children were more frequently able to represent the same number using blocks in different ways. For example, if they were asked to show 35 other than using three 10 blocks and five unit blocks, they might show two 10 blocks and 15 unit blocks. Since these children did not have previous experience with these blocks, the authors suggested that the base-ten regularity of Asian number words contributed to a better understanding of place value and numerical representation.

The findings of a study involving Welsh children further support the view that a language with a consistent, base-ten counting system gives children a better comprehension of place value (Dowker et al., 2008). In Wales, Welsh, which uses a consistent counting system similar to Asian languages, and English are spoken. Three groups of six-year old and three groups of eight-year old Welsh children were given a comparison test where they had to choose the larger number from a pair of two-digit numbers. One group spoke Welsh at home and school, another group spoke Welsh at home and not at school, and a third group spoke only English at home and school. Within both age categories, the group that spoke Welsh exclusively performed the best, while the group who spoke English exclusively performed the worst. These results suggest that the Welsh language assisted the children in understanding place value, enabling more accurate number comparisons of two-digit numbers. Similar to the Asian preschoolers, the Welsh-speaking children appeared to have a superior grasp of place value.

Simplicity and Consistency of Ordinal Numbers

Another advantage of the Chinese numbering system is that ordinal number names are also simple and consistent (Ng & Rao, 2010). Ordinal numbers are numbers representing sequential ordering or ranking (e.g., first). Chinese ordinal number words are easy to

learn because a prefix is simply added to the cardinal number names (Ng & Rao, 2010). To illustrate the complexity of English ordinal numbers, 'first' and 'second' sound nothing like 'one' and' two' (Ng & Rao, 2010). In addition, although most ordinal numbers past three have the suffix 'th,' this is not consistent (Ng & Rao, 2010). A study by Miller, Major, Shu, and Zhang (2000) compared Chinese and American children (preschoolers, grades two and four) and found that American children made more errors in ordinal number names. Results showed the differences began in preschool, but continued into grade four. Like the inconsistency of cardinal numbers, the inconsistency of ordinal numbers in English results in children requiring more time and effort to learn ordinal numbers.

Shorter One-Syllable Number Words Facilitate Faster Addition

The short, one-syllable Chinese number words provide yet another advantage, because short words enable children to keep numbers in working memory more easily (Ng & Rao, 2010). Working memory is a limited-capacity, short-term memory storage system that temporarily manipulates information (Imbo & LeFevre, 2009). Support for the idea that Chinese number words are less taxing on working memory came from a study which demonstrated that Chinese preschoolers completed addition problems three times faster than American preschoolers (Geary, Bow-Thomas, Fan and Siegler, 1993). Enhanced speed was partially due to faster retrieval of memorized facts, but when they could not retrieve the answer, Chinese preschoolers favored verbal counting, whereas American preschoolers favored finger counting. The authors suggested the differences in their approach were due to the longer number words in English. The longer number words took more time to pronounce and were more taxing to working memory, not only slowing down counting, but often requiring the use of fingers to keep track of numbers.

Frequency of Numeric Language Heard and Used in Chinese

An additional advantage of Chinese is that number words are frequently used due to inherent properties of the language, which promotes the learning of math concepts (Ng & Rao, 2010). One property is the lack of plural words, which necessitates the use of number words to describe plurality (Chang, Sandhofer, Adelchanow, & Rottman, 2011). For example, since you cannot say "dogs," the number of dogs is used along with dog (two dog). There are other examples of number being utilized more in everyday speech (Ng & Rao, 2010). When referring to weekdays or months, numbers are used, such as referring to a day as Weekday Number One (Ng & Rao, 2010). Similarly, family members are referred to by birth order, such as Sister Number One (Ng & Rao, 2010). It is evident that Chinese preschoolers are frequently exposed to number words, reinforcing number concepts.

The evidence presented so far supports the position that these important linguistic advantages contribute to the enhanced math performance of Asian preschoolers. Nevertheless, cultural factors, including parental attitudes and behaviors, are also important.

Cultural and Parental Influences

In fact, researchers suggest that Asian parental involvement, which is affected by shared Chinese cultural values, has a strong effect on their children's math achievement (Ng & Rao, 2010). Parental influences appear to be particularly important in the preschool years because there is little direct math teaching in preschools; therefore, much of what is learned comes from parent-child interactions (Zhou et al., 2006).

Parental Influences

To examine cultural and parental influences, one study compared second-generation Euro-American, Chinese-American, and Taiwan-Chinese preschool and kindergarten children on mathematical performance. In addition, through parent interviews, they compared parental attitudes and practices (Huntsinger, Jose, Liaw, & Ching, 1997). The Taiwan-Chinese and Chinese-American children performed comparably and outperformed the Euro-American children. Since all attended preschools and kindergartens with comparable philosophies and approaches, the authors felt that the performance differences could be largely attributed to diverse parental attitudes and practices. The authors found that Taiwan-Chinese and Chinese-American parents structured their children's day more, engaged their children in more math activities, used more structured and formal math instruction, and expected to be more involved in helping their children with math in future years.

Cultural Values and Traditions Influence Parents

The findings by Huntsinger et al. (1997) support the view that there are common Chinese cultural values and traditions that influence Chinese and Chinese-American parents' attitudes and actions. First, Chinese culture places great emphasis on the importance of learning math (Ng & Rao, 2010). Second, Chinese culture emphasizes the importance of hard work over ability in order to succeed. Huntsinger and his colleagues (1997) suggested that this attitude is a reflection of Confucian philosophy, which emphasizes that hard work leads to accomplishment. Because Chinese parents emphasize hard work over ability, feedback will tend to be focused on how to improve at math, rather than feedback about their math ability. This may also partially explain why Chinese children tend to work hard. In support of this view, a study by Kamins and Dweck (1999) demonstrated that children who are provided criticism or praise based on their process and effort, rather than based on their ability, show less helplessness and more perseverance when faced with challenges. Third, Chinese parents, when compared to Euro-American parents, have higher expectations (Chen & Stevenson, 1995) and are less satisfied with their children's performance (Crystal & Stevenson, 1991). Therefore, these common values and traditions may contribute to Chinese parents spending more time with their children on structured math activities. In contrast, the Euro-American cultural emphasis on natural ability results in parents spending less time with their children on routine, structured math activities (Huntsinger et al., 1997).

Effects of Greater Time Spent on Math Activities

Since Chinese parents usually spend more time practicing counting and addition problems with their preschool children than American parents (Huntsinger et al., 1997), it is not surprising that studies find Chinese children are superior at basic numerical skills. Siegler and Mu (2008) wanted to know if Chinese preschoolers also had a better conceptual understanding of numbers, and were not simply excelling at previously practiced math skills.

To test conceptual understanding of numbers, Siegler and Mu (2008) asked Chinese and American preschoolers to plot numbers between zero and 100 on an unmarked number line. According to Siegler and Mu, both Chinese and American preschoolers are generally unfamiliar with this number line estimation task. The study was undertaken to determine if the Chinese children's number line estimates best matched a logarithmic or linear function. Demonstration of a linear representation of number estimates is important because this conforms to how actual numerical magnitudes

increase and, therefore, demonstrates a better conceptual understanding of numerical magnitudes. Over development, there is gradual transition from a logarithmic to a linear representation of number estimates (Siegler, Thompson, & Opfer, 2009). Moreover, linear representation of number estimates has been associated with better achievement on other math tasks (Booth & Siegler, 2006). Results of the Siegler and Mu study (2008) showed that the Chinese children had significantly more accurate number estimates and the average estimates most closely matched a linear function. In comparison, the average estimates of the American children most closely matched a logarithmic function. The results for the American preschoolers were consistent with cross-sectional studies of American children which show that kindergarten children's estimates best match a logarithmic function, while second-grade children's estimates best match a linear function (Siegler et al., 2009; Xu, Chen, Pan & Li, 2013). They concluded that the Chinese preschoolers appeared to be about two years ahead with respect to numerical magnitude representation.

One explanation to account for the Chinese preschoolers' advanced performance on this previously unpracticed task involves the extra practice that their parents provide with counting and addition which often involves using different sensory modes simultaneously (Siegler & Mu, 2008). To elaborate, early counting often involves counting fingers (or objects) and associating larger numbers with: moving more fingers, seeing more fingers, speaking more number words, and involving more time. Accordingly, multi-modal cues involving movement, vision, audition, and time are utilized (Siegler & Mu, 2008). Research on multi-modal learning suggests that providing children with multiple, simultaneous cues improves learning a variety of skills, including numerical skills (Jordan & Baker, 2011). For example, American preschool children who played linear number board games, which involve multiple sensory modes, subsequently improved in number comparison and number line estimation (Ramani and Siegler, 2011). Thus, there is literature to support the idea that because Chinese parents spend more time with their preschoolers in structured math activities, they develop a conceptually advanced understanding of numerical magnitude.

As an alternative explanation, these mature numerical estimations may be due to the advantages of Chinese number words. It can be argued that the base-ten number system leads to a better understanding of place value, which then improves number line estimation (Laski & Yu, 2014). As a result, the effects of language and parental practices may be difficult to separate.

A study by Paik et al. (2011) further illustrates the challenge of separating linguistic and parental factors. This study was the first to involve preschoolers from four continents. They found that the American, Dutch, and Peruvian preschoolers had comparable mathematical skills, but were significantly outperformed by Taiwanese preschoolers. The authors suggested that the performance gap reflects the fact that the English, Dutch, and Spanish languages have irregular number names, but acknowledged that it may also partially reflect other cultural factors such as different parental practices. Obviously, parental influences on preschoolers are crucial, but it is often difficult to disentangle the effects of language and culture on numerical performance.

Conclusions

This paper examined important factors that contribute to the superior numerical skills of Asian preschool children. A review of the literature pointed to two important contributing groups of factors: linguistic influences and parental influences.

Asian languages use Chinese number words which clearly, consistently, and simply represent the base-ten Arabic number system, providing Asian children with a head start in basic math skills such as counting, understanding place value, learning ordinal numbers and quickly solving addition problems. Furthermore, properties of the Chinese language result in number words being heard more frequently by preschoolers, providing them with more frequent exposure to numerical words and concepts. Thus, the effects of language on math performance begin in the preschool years, providing Asian-speaking children with a strong mathematical foundation.

Although the influences of language are important, parental influences are also extremely important. East Asian parents tend to place more importance on math, emphasize hard work over ability in order to succeed, and have higher expectations and lower satisfaction regarding children's achievement. These factors all contribute to Asian parents investing more time with their preschool children on structured math tasks, which promote the development of strong basic math skills such as counting and addition. Asian preschoolers also demonstrate a linear representation of number estimates, which occurs about two years earlier than American children. The linear representation of number estimates is extremely advantageous because it has been associated with enhanced performance in other math tasks. However, both language and parental factors can be used to explain this mature numerical representation.

Although it is extremely challenging to isolate the effects of language and parental influences, well-designed studies would be helpful in this regard. For example, Paik et al. (2011) suggested that more studies comparing preschoolers who have similar cultures, but who use languages of varying numerical transparency—recall the Welsh study by Dowker et al. (2008)— can help determine the importance of language on numerical development.

Since most cross-cultural studies have focused on East Asian and western cultures, it would also be beneficial for future studies to examine the math performance of preschoolers in a variety of cultures (Paik et al., 2011). Identification of parental practices in countries where preschoolers excel in mathematics, such as the East Asian countries, may illuminate how to help young children around the world develop a strong mathematical foundation. Entering school with a strong foundation is important, because studies show that children who begin their formal education with lower math performance tend to remain behind in later years (Ding & Davidson, 2005). It is hoped that future studies will continue to reveal ways parents and preschool teachers can facilitate children's learning of basic numerical skills. Although languages cannot be suddenly changed, parents and preschool teachers can be made aware of the challenges that English poses, and informed regarding the benefits of formal, structured math activities and proven strategies, such as multi-modal numerical activities (e.g., linear numerical board games).

First Received: 08/04/2014
Final Revision Received: 01/02/2015

References

Booth, J. L., & Siegler, R. S. (2006). Developmental and individual differences in pure numerical estimation. *Developmental Psychology, 42*, 189-201.

Chang, A., Sandhofer, C. M., Adelchanow, L., & Rottman, B. (2011). Parental numeric language input to Mandarin Chinese and English speaking preschool children. *Journal of Child Language, 38*, 341-55.

Chen, C., & Stevenson, H. W. (1995). Motivation and mathematics achievement: A comparative study of Asian-American, Caucasian-American, and East Asian high school students. *Child Development, 66*, 1215-1234.

Crystal, D. S., & Stevenson, H. W. (1991). Mothers' perceptions of children's problems with mathematics: A cross-national comparison. *Journal of Educational Psychology, 83*, 372-376.

Ding, C. S., & Davidson, M. L. (2005). A longitudinal study of math achievement gains for initially low achieving students. *Contemporary Educational Psychology, 30*, 81-95.

Dowker, A., Bala, S., & Lloyd, D. (2008). Linguistic influences on mathematical development: How important is the transparency of the counting system? *Philosophical Psychology, 21*, 523.

Geary, D. C., Bow-Thomas, C., Fan, L., & Siegler, R. S. (1993). Even before formal instruction, Chinese children outperform American children in mental addition. *Cognitive Development, 8*, 517-529.

Huntsinger, C. S., Jose, P. E., Liaw, F., & Ching, W. (1997). Cultural differences in early mathematics learning: A comparison of Euro-American, Chinese-American, and Taiwan-Chinese families. *International Journal of Behavioral Development, 21*, 371-388.

Imbo, I., & LeFevre, J. (2009). Cultural differences in complex addition: Efficient Chinese versus adaptive Belgians and Canadians. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*, 1465-1476.

Jordan, K. E., & Baker, J. (2011). Multisensory information boosts numerical matching abilities in young children. *Developmental Science, 14*, 205-213.

Kamins, M. L., & Dweck, C. S. (1999). Person versus process praise and criticism: Implications for contingent self-worth and coping. *Developmental Psychology, 35*, 835-847.

Laski, E. V., & Yu, Q. (2014). Number line estimation and mental addition: Examining the potential roles of language and education. *Journal of Experimental Child Psychology, 117*, 29-44.

Miller, K.F, Major, S. M., Shu, H., & Zhang, H. (2000). Ordinal knowledge: Number names and number concepts in Chinese and English. *Canadian Journal of Experimental Psychology, 54*, 129-140.

Miller, K. F., Smith, C. M., Zhu, J., & Zhang, H. (1995). Preschool origins of cross-national differences in mathematical competence: The role of number-naming systems. *Psychological Science, 6*, 56-60.

Miura, I. T., Okamoto, Y., Kim, C. C., & Chang, C. (1994). Comparisons of children's cognitive representation of number: China, France, Japan, Korea, Sweden, and the United States. *International Journal of Behavioral Development, 17*, 401-411.

Ng, S. N., & Rao, N. (2010). Chinese number words, culture, and mathematics

learning. *Review of Educational Research, 80*, 180-206.

Organization for Economic Co-operation and Development (OECD). (2013, March 12). Asian countries top OECD's latest PISA survey on state of global education. Retrieved from http://www.oecd.org/newsroom/asian-countries-top-oecd-s-latest-pisa-survey-on-state-of-global-education.htm

Paik, J. H., van Gelderen, L., Gonzales, M., de Jong, P.,F., & Hayes, M. (2011). Cultural differences in early math skills among U.S., Taiwanese, Dutch, and Peruvian preschoolers. *International Journal of Early Years Education, 19*, 133-143.

Perry, M. (2000). Explanations of mathematical concepts in Japanese, Chinese, and U.S. first- and fifth-grade classrooms. *Cognition and Instruction, 18*, 181-207.

Ramani, G. B., & Siegler, R. S. (2011). Reducing the gap in numerical knowledge between low- and middle-income preschoolers. *Journal of Applied Developmental Psychology, 32*, 146-159.

Siegler, R. S., & Mu, Y. (2008). Chinese children excel on novel mathematics problems even before elementary school. *Psychological Science, 19*, 759-763.

Siegler, R. S., Thompson, C. A., & Opfer, J. E. (2009). The logarithmic-to-linear shift: One learning sequence, many tasks, many time scales. *Mind, Brain, and Education, 3*, 143-150.

Xu, X., Chen, C., Pan, M., & Li, N. (2013). Development of numerical estimation in Chinese preschool children. *Journal of Experimental Child Psychology, 116*, 351-366.

Zhou, X., Huang, J., Wang, Z., Wang, B., Zhao, Z., Yang, L., & Yang, Z. (2006). Parent-child interaction and children's number learning. *Early Child Development and Care, 176*, 763-775.