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Morphological awareness longitudinally predicts counting ability in Chinese kindergarteners☆

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ABSTRACT

This longitudinal study examined the extent to which morphological awareness in Chinese uniquely predicted counting ability in a Hong Kong sample. With age, nonverbal intelligence, visual–spatial skills, and phonological awareness being controlled, morphological awareness at the second year of kindergarten (K2) uniquely predicted children's abilities in counting sequence and counting forward at the third year of kindergarten (K3). Phonological awareness and visual–spatial skills at K2 explained unique variance in the ability of counting backward but not in the counting sequence or counting forward at K3. These findings contribute to our understanding of the association between metalinguistic skills and the development of numerical ability.

1. Introduction

One crucial question in studying numerical cognition concerns the extent to which numerical cognition is related to language (e.g. Dehaene, Dehaene-Lambertz, & Cohen, 1998; Jacob & Nieder, 2009; Kadosh, Henik, & Rubinsten, 2008). Before language is learned, infants are able to represent and manipulate numerosities of sets, but the representation is approximate and constrained by a ratio limit. For example, 6-month-old infants are able to discriminate sets differing in a ratio of 1:2 but not in a ratio of 1:1.5 (Dehaene, 1997; Lipton & Spelke, 2004; Starkey, Spelke, & Gelman, 1990; Wood & Spelke, 2005; Wynn, 1992; Xu & Arriaga, 2007; Xu & Spelke, 2000). In contrast to prelinguistic representation, symbolic thinking of math concepts allows people to represent quantities precisely. Language is central to developing symbolic representation of quantities. Gordon (2004) tested an Amazonian indigenous group whose counting system included only "one", "two" and "many." For this group, the exact representation of quantities above three was impaired (e.g., they could not discriminate six objects from seven). Empirical studies consistently suggest that language is crucial to the development of the concept of exact quantity (Carey, 2001; Dehaene, Izard, Spelke, & Pica, 2008; Piazza, Pica, Izard, Spelke, & Dehaene, 2013; Pica, Lemer, Izard, & Dehaene, 2004).

Given the significant role of language in the exact representation of quantities, it is reasonable to assume that the representation of numbers is influenced by linguistic variations. Researchers have reported cross-language differences in counting ability, counting directions, mental representation of the number line, mental spatial-numerical mapping, and neural responses to numbers (e.g.Colomé, Laka, & Sebastián-Gallés, 2010; Göbel, 2015; Hung, Hung, Tzeng, & Wu, 2008; Miller, Smith, Zhu, & Zhang, 1995; Miura, Kim, Chang, & Okamoto, 1988; Nuerk, Weger, & Willmes, 2005; Tang et al., 2006; Zebian, 2005). Counting is one of the earliest symbolic math activities during development. Early counting ability provides an important cognitive foundation for the development of basic arithmetic skills and future mathematics achievement (Sarnecka, 2008; Stock, Desoete, & Roeyers, 2009; Zhang, Koponen, Räsänen, Aunola, Lerkkanen & Nurmi, 2014; Zhang, McBride-Chang, Wong, Tardif, Shu & Zhang, 2014). Therefore, the present study examined the early linguistic predictors of counting ability in kindergarten years.

Given the morpho-syllabic nature of Chinese, which refers to one Chinese character corresponding to one syllable and also one morpheme, morphological awareness, the ability to understand morphological structures and manipulate morphemes (McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003), has been consistently found to be important for Chinese literacy development (e.g. McBride-Chang et al., 2003, 2008). Very interestingly, the Chinese number naming system is straightforwardly morphologically structured (e.g., 12 is literally ten two) (e.g., Miller et al., 1995). It is reasonable to hypothesize that

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morphological awareness is also closely associated with Chinese children's numeracy development. Yet, studies on the relation between morphological awareness and numeracy development in Chinese children are scarce. The present study aimed to address this gap by empirically investigating the role of morphological awareness in the development of counting ability longitudinally. The results would contribute to our understanding of the relation between language and numerical cognition with evidence from a non-alphabetic language (i.e., Chinese).

The learning of counting begins with the acquisition of the number word sequence, that is, to name the number words in a specific order that culture defines. The learning of the number word sequence is crucial for numeracy development because children must learn counting words in the number word sequence and map the acquired counting words onto distinct numerosities to develop an exact representation of numerosities. In general, children can name the first 10 words in the counting list by the age of 3.5 years. Children's counting ability develops rapidly between the ages of 3.5 and 5 years (Wynn, 1990). At the ages of 5–6 years, children are able to count from 20 through 70. Upon entry into primary school, most children can count to 100 and above (Fuson, Richards, & Briars, 1982). In the present study, we investigated how morphological awareness influences the way children learn the number word sequence at the early stage of development.

1.1. Morphological awareness in language acquisition

A morpheme is the smallest unit in language that carries semantic information. Various types of morphology have been noted by researchers, e.g., inflectional morphology, derivational morphology, and compounding morphology (Kuo & Anderson, 2006). Inflectional morphology involves grammatical transformations in words (e.g., singular and plural changes (one dog → two dogs) and tense markings (touch → touched)). Derivational morphology involves producing new words by including additional morphemes (e.g., prefixes such as “im” in *im*possible and suffixes such as “er” in teach*er*). Compounding morphology involves combining two or more morphemes to produce a new word (e.g., to combine *cup* with *cake* to produce *cupcake*). In learning alphabetic languages, inflectional morphology and derivational morphology are essential indicators to evaluate morphological awareness and crucial to the development of reading ability (Berko, 1958; Kirby et al., 2012; Tong, Deacon, Kirby, Cain, & Parrila, 2011). By contrast, compounding morphology is a more productive word generation rule in Chinese than in English. In Chinese, compound words are dominant. According to a report by the Institute of Language Teaching and Research of China, 1986, over 70% of words in Chinese involve compound words (cited in Liu & McBride-Chang, 2010). In Chinese, knowledge and manipulation of lexical compounding are thus crucial indicators of morphological awareness.

Compounding morphological awareness has been widely investigated in the field of Chinese reading. The ability to compound two or more morphemes to construct new words is related to and predictive of literacy development in young Chinese children, even after other domain-general abilities and phonological awareness are controlled (e.g. McBride-Chang et al., 2003, 2008; Tong, McBride-Chang, Shu, & Wong, 2009; Wang, Cheng, & Chen, 2006; Zhang, Koponen et al., 2014; Zhang, McBride-Chang et al., 2014). Additionally, Chinese dyslexic children have shown impaired compounding morphological awareness (e.g. Shu, McBride-Chang, Wu, & Liu, 2006; Zhou et al., 2014).

To our knowledge, no previous studies have investigated the role of compounding morphological awareness in learning the number word sequence in Chinese. Morphological awareness facilitates the learning of counting in English-speaking children. The acquisition of inflectional morphology contributes to early number word learning in English-speaking children. For example, the comprehension of the singular–plural distinction in English helps 22- and 24-month-old children master the meaning of *more than one* (Barner, Thalwitz, Wood, Yang, & Carey, 2007; Wood, Kouider, & Carey, 2009). However, this evidence cannot explain how Chinese children learn the number word sequence. With respect to number words, inflectional morphology does not occur in Chinese. For example, in Chinese, 两只狗 (two dogs) is literally “two dog”. Thus, in the present study, we focused on examining the link between compounding morphological awareness and Chinese children's development of counting ability.

1.2. Number naming system and compounding morphology in Chinese

The base-10 structure is not transparent in the English number naming system, particularly for teen quantities (e.g., Cankaya, LeFevre, & Dunbar, 2014). For example, “11” is “eleven,” which does not indicate a clear semantic relation to the prior number words, one to ten, or the base-10 structure. By contrast, the Chinese number naming system is considered more transparent (e.g.Miller, Kelly, & Zhou, 2005; Miller & Stigler, 1987). The base-10 structure is conveyed in the Chinese number naming system in a way that is consistent with the operation of lexical morphemes to generate a new word. Similar to English number words, the Chinese 1–10 are represented by arbitrary number words. For numbers between 11 and 19, in contrast to arbitrary English number words, Chinese number words are counted as ten one (11), ten two (12)… ten eight (18) and ten nine (19). Numerically, 11 is ten plus one. Linguistically, two morphemes (ten and one) are combined to construct a word with a clear numerical meaning (i.e., ten one [11]). Numerical relations are thus explicitly conveyed in linguistic expressions in Chinese through compounding morphology. For 20–99, in contrast to English, which uses modified number words for groups of ten numbers (e.g., thir*ty*), Chinese number words are generated by combining words representing quantities from 1 to 9 that are placed before and after the Chinese word representing the base 10 multiplier. For example, 87 is literally translated as “eight ten seven.” In Chinese, each multidigit number word between 11 and 99 involves combining morphemes to construct a number word (e.g., eight, ten, and seven for 87). Consequently, in Chinese, compounding morphology can be inferred to facilitate the abstraction of numerical meanings from words.

Chinese children's superior counting performance is considered to be related to the language structure in Chinese number naming system (Ng & Rao, 2010). Understanding the base-10 structure in Chinese number naming system requires the apprehension of compounding morphology. The association between compounding morphological awareness and knowledge of number words in Chinese children is indicated in a recent longitudinal study (Zhang & Lin, 2015). It found that compounding morphological awareness at the second year of kindergarten (K2) significantly predicted Chinese children's success in solving verbally presented arithmetic word problems at the third year of kindergarten (K3) (e.g., Ivy has four apples, and her brother gives her two more apples. How many apples does Ivy have now?). This piece of evidence indicated the predictive power of compounding morphological awareness of basic number knowledge in Chinese kindergarten children. However, it was not clear in the study whether compounding morphological awareness contributed to contextual understanding of problems (e.g., the story scenario and the structures of sentences) or understanding of number words per se. The present study aimed to provide direct evidence with regard to the role of compounding morphological awareness in Chinese children's counting ability, which does not involve contextual information.

1.3. The present study

We examined young children's compounding morphological awareness at K2 and their counting ability at K3 one year later. Three important aspects of counting ability were assessed, counting sequence, counting forward, and counting backward. Children's mathematical thinking is largely dependent on their precise representations of the number word sequence. Young children rely mainly on their counting forward and counting backward skills to solve addition and subtraction