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A multivariate twin study of early literacy in Japanese *kana*

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ABSTRACT

This first Japanese twin study of early literacy development investigated the extent to which genetic and environmental factors influence individual differences in prereading skills in 238 pairs of twins at 42 months of age. Twin pairs were individually tested on measures of phonological awareness, *kana* letter name/sound knowledge, receptive vocabulary, visual perception, nonword repetition, and digit span. Results obtained from univariate behavioral-genetic analyses yielded little evidence for genetic influences, but substantial shared-environmental influences, for all measures. Phenotypic confirmatory factor analysis suggested three correlated factors: phonological awareness, letter name/sound knowledge, and general prereading skills. Multivariate behavioral genetic analyses confirmed relatively small genetic and substantial shared environmental influences on the factors. The correlations among the three factors were mostly attributable to shared environment. Thus, shared environmental influences play an important role in the early reading development of Japanese children.

1. Introduction

1.1. Prereading skills and later reading abilities

Prereading skills predict later reading abilities (Scarborough, 2001), although some are stronger predictors than others. According to Scarborough (2001), prereading skills that are closely related to word recognition, especially letter-sound knowledge and phonological awareness, are among the best predictors. Although vocabulary, sentence/story recall, rapid naming, and verbal memory measures such as digit recall and nonword repetition are also reliable predictors (e.g., de Jong & Olson, 2004; Swanson & Siegel, 2001; Wagner et al., 1997), nonverbal abilities, such as visual discrimination and motor skills, are not (Scarborough, 2001).

Correlations among prereading skills and their longitudinal associations with later reading abilities have been also reported in non-alphabetical languages. For example, early literacy skills, including phonological awareness (i.e., mora awareness, described later), vocabulary, visual perceptual skill, and verbal short term memory, are correlated in Japanese children (Inagaki, Hatano, & Otake, 2000; Kakihana, Ando, Koyama, Iitaka, & Sugawara, 2009). Moreover, phonological awareness and rapid number naming are significantly related to word recognition (Cho, McBride-Chang, & Park, 2008), and letter-name knowledge during early literacy development contributes to later word reading in Korean children (Kim & Petscher, 2011). These prereading phonological skills also significantly predict later reading performance in Chinese children (Ho & Bryant, 1997; Tong et al., 2011).

1.2. Genetic and environmental influences on early reading for different orthographies

Several previous studies have assessed genetic and environmental influences on early reading skills, including phonological awareness, verbal memory, vocabulary, and letter knowledge (e.g., Bishop et al., 1999; Dionne, Dale, Boivin, & Plomin, 2003; Hart et al., 2009; Hayiou-Thomas et al., 2006; Hohnen & Stevenson, 1999; Kovas et al., 2005; Petrill, Deater-Deckard, Thompson, DeThorne, & Schatschneider, 2006a,b; Samuelsson et al., 2005, 2007). However, these studies were based on twins who were learning alphabetic languages, mostly English. Thus, relatively little is currently known about genetic and environmental influences on reading development in different orthographies. We are aware of only one behavioral genetic study which focused on a non-alphabetic language. Chow, Ho, Wong, Waye, and Bishop (2011) investigated genetic and environmental influences on reading skills in Chinese-learning children and reported results similar to those found in English acquisition; moderate to substantial genetic influences on word reading, phonological memory, and rapid automatized naming, and moderate to substantial shared environmental

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influences on receptive vocabulary, syllable and rhyme awareness, and orthographic skills. However, their sample included a wide age range (3 to 11 years old) and did not focus on prereading skills. Thus we have very limited knowledge concerning the genetic and environmental etiologies of individual differences in early reading for different orthographies.

In this study, we focused on Japanese, especially on syllabic *kana* letters. To our knowledge this is the first Japanese twin study of genetic and environmental influences on prereading skills. Japanese is a non-alphabetic writing system originally derived from Chinese, but it is very different from Chinese in various aspects. In the next section, we provide a brief description of the Japanese writing systems and syllabic *kana* letters.

1.3. Japanese writing systems and orthographies

The Japanese writing system uses both logographic *kanji* and syllabic *kana*. In standard Japanese orthography, nouns and stems of verbs and adjectives are usually written in *kanji*, and function words and inflectional affixes are written in *kana* in most cases.

Though its roles and usage in the standard orthography are limited, *kana* is a full-fledged phonetic writing system which can represent any item of Japanese vocabulary. In fact, while mastering the enormous numbers of *kanji* characters, children's early literacy solely depends on the *kana*; children's books and text books are first written only in *kana* letters. The rate of *kanji* usage gradually increases as children advance in grade levels. Thus, mastering *kana* literacy is an independent literacy development.

Most Japanese syllables have a consonant-vowel (CV) or a single vowel (V) structure, which has neither a consonant cluster in the onset position nor a coda consonant. In Japanese phonology, just two types of consonants are allowed in the coda position; one is a nasal consonant [N] (e.g., /hoNda/), and the other is a geminate stop consonant [Q] (e.g., /niQpoN/).

Strictly speaking, each *kana* letter does not represent a syllable but a mora—a syllable-like phonological unit. The mora is a unit with which Japanese speakers segment speech streams (Otake, Hatano, Cutler, & Mehler, 1993). The mora is a syllable nucleus, preceded by a syllable onset, a syllable coda, or an extended portion of the vowel. When a syllable has a [V] or [CV] structure, the syllable has just one mora. However, when a syllable has a nasal coda [N], a geminate stop [Q], and an extended portion of the vowel, the syllable has two (e.g., CVN) or three morae (e.g., CV:N).

The *kana* writing system represents morae in Japanese. There are 46 basic *kana* letters, consisting of 45 letters representing CV and V morae, and one letter representing a mora of the nasal coda [N]. A mora of geminate stop consonant [Q] and an extended portion of the vowel are also given a letter in words, by using a certain basic letter.

There are 103 distinct morae in the Japanese language[1], though there are 46 basic letters. In addition to the basic letters, there are 2 supplementary notational systems to represent remainders of morae: diacritics and combinations. Twenty syllables with voiced stop and fricative are represented by a letter for its unvoiced counterpart with a *daku-ten* diacritic, the two little strokes on the right shoulder of the letter (e.g., か = ka, が = ga). Five syllables with a /p-/ are represented by /h-/ letter with another diacritic, a small circle (*handaku-ten* diacritic) on the right shoulder of the letter (e.g., は = ha, ぱ = pa). Thirty-three CjVs, which exceptionally have a consonant cluster on their onset (like the /kjo/ sound in /kjoto/), are represented by two-letter combinations. For example, /kja/ is written as "きゃ," which is き (/ki/) with the subscription of や (/ja/). To sum up, *kana* has 46 letters and 2 supplementary notational systems which represent 103 Japanese morae, all of the morae in the Japanese language.

As with children in western countries, Japanese children start their literacy development by memorizing letter names. However, importantly, the roles of letter name knowledge in *kana* literacy development are quite different from those in alphabetic languages. In alphabetic systems, letter names (e.g., /bi/ for B) or "letter sounds" (/bu/ for B) may be quite different from the exact phonetic value (e.g., /b/ for B) of the letters. In contrast, in a syllabic system such as *kana*, each of the letter name/sounds[2] (e.g., /ne/ for ね) are almost equal to the exact phonetic value of the letters. Thus, all that is needed to read a *kana* word is to sound out each letter name/sound in turn. For example, for ねこ(cat), giving each letter nameね(/ne/) andこ(/ko/) produces the word it represents (/neko/). Consequently, once someone has memorized the 46 letter names and understands the usage of the *daku-ten* diacritic, *handaku-ten* diacritic, and the combinations, they can read all Japanese words. Because of these characteristics of *kana*, letter name/sound knowledge is regarded as a direct measure of children's reading ability in *kana* reading research (e.g., National Institute for Japanese Language and Linguistics, 1972).

1.4. Present study

In the present study, we investigated the extent to which genetic and environmental influences contribute to prereading skills and to correlations among them in Japanese-learning twins at 42 months of age. Although the children were younger than those in previous behavioral genetic studies of prereading skills (e.g., 4.5-year-olds, Kovas et al., 2005; Hayiou-Thomas et al., 2006; 5-year-olds, Samuelsson et al., 2005; 6-year-olds, Petrill et al., 2006a,b), choosing 42 months of age was appropriate for studying prereading skills in Japanese *kana* because most Japanese children master reading *kana* before they start primary school education (Shimamura & Mikami, 1994). Also, choosing the younger age was expected to increase our knowledge concerning the etiology of early reading for both non-alphabetic languages and alphabetic languages because reading outcomes may be predicted by different sets of language variables at different ages (Scarborough, 2001; e.g., Siok & Fletcher, 2001). We included measures which were as similar as possible to those used in previous studies of alphabetic languages. In addition, we included a measure of visual perceptual skills, though little evidence has been found concerning the relation between visual perceptual skills and later reading in English learning (Scarborough, 2001). Visual perceptual skills are related to other literacy skills in the early phase of reading development and may be significant predictors of word reading in non-alphabetic languages (Chinese: Ho & Bryant, 1997; Siok & Fletcher, 2001; Tong et al., 2011; Korean: Cho et al., 2008; Japanese: Kakihana et al., 2009;).

2. Method

2.1. Participants

Participants were Japanese twins (mean = 3.57 years, SD = 0.14) tested in the Tokyo Twin Cohort Project (ToTCoP; Ando et al., 2006). ToTCoP is a twin registry based on data from Basic Resident Registrations in the Tokyo area (see Ando et al., 2006). The ToTCoP study was approved by the Ethics Committee at the Faculty of Letters, Keio University. Written informed consent was obtained from twins' parents.

Zygosity was determined using a questionnaire that has 95% accuracy based upon physical similarities of twin siblings at around one

[1] One hundred and three morae consist of 69 CV morae, a nasal coda /N/, and 33 yo-on morae (CjV). Recently, however, at least 33 morae seemed to be added to the Japanese language, most of which came from Western languages (see Tamaoka & Makioka, 2004 for details). Most of these are written in *katakana* as CV letters with the subscription of V (e.g., "ティ (/te/+/i/)" for /ti/), a usage that is analogous to the conventional *yo-on* combination.

[2] There is no conceptual distinction between "letter name" and "letter sound" in Japanese.