Brief Report

Visual spatial skill: A consequence of learning to read?

Catherine McBride-Chang\textsuperscript{a,*}, Yanling Zhou\textsuperscript{a}, Jeung-Ryeul Cho\textsuperscript{b}, Dorit Aram\textsuperscript{c}, Iris Levin\textsuperscript{c}, Liliana Tolchinsky\textsuperscript{d}

\textsuperscript{a} Department of Psychology, Chinese University of Hong Kong, Shatin, N.T., Hong Kong SAR, People’s Republic of China
\textsuperscript{b} Department of Psychology, Kyungnam University, Masan 631-701, South Korea
\textsuperscript{c} School of Education, Tel Aviv University, Tel Aviv 69978, Israel
\textsuperscript{d} Department of Linguistics, University of Barcelona, Barcelona 08007, Spain

\textbf{Abstract}

Does learning to read influence one’s visual skill? In Study 1, kindergartners from Hong Kong, Korea, Israel, and Spain were tested on word reading and a task of visual spatial skill. Chinese and Korean kindergartners significantly outperformed Israeli and Spanish readers on the visual task. Moreover, in all cultures except Korea, good readers scored significantly higher on the visual task than did less good readers. In Study 2, we followed 215 Hong Kong Chinese kindergartners across 1 year, with word reading and visual skills tested twice. In this study, word reading at Time 1 by itself predicted 13% of unique variance in visual skill at Time 2. Together, these results underscore the potential importance of the process of learning to read for shaping one’s visual spatial skill development.

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\textbf{Introduction}

Research on visual skill in relation to reading has a long history (e.g., Orton, 1925) but remains fairly modest. The majority of such research focuses on how visual skill might enhance reading skill, and these results are quite mixed across orthographies. There is general agreement that pure visual skill is not likely a core cause of reading across orthographies (e.g., Goswami, 2004; Vellutino, Steger, Moyer, Harding, & Niles, 1977).

Others (e.g., Chan & Vernon, 1988; Dehaene, 2009; Hoosain, 1991) have suggested that the process of learning to read itself may influence visual skill, although explicit evidence for this association is relatively limited. For example, in a cross-cultural comparison of 8- to 14-year-olds, Demetriou and
colleagues (2005) found that the Chinese consistently outperformed the Greeks on tests of visual spatial reasoning across ages. Differences between the groups in other areas of reasoning were smaller or nonexistent. Interestingly, Chinese children differed most strongly from Greek children in visual spatial reasoning at the youngest ages in that study, implying that such differences are strongest in early readers. Mann (1985) similarly showed that Japanese second graders outperformed American second graders in their memories for abstract visual stimuli, arguing that reading of Kanji (equivalent to Chinese characters in Japanese) likely promotes visual skill in children. Within an alphabetic orthography, Kolinsky, Morais, and Content (1987) also demonstrated some difficulties in both preschoolers and unschooled adults, relative to primary school children, in detecting some visual parts within abstract figures, suggesting that schooling may focus individuals on certain aspects of visual processing. Learning to read might be one such schooling effect. Collectively, this work suggests that learning to read may indeed hone one’s visual skill. Importantly, previous work on visual skill and word reading has been restricted almost exclusively to older children and adults. In the current studies, we focused on children who were just learning to read.

If learning to read influences one’s visual skill, it should do so in two ways. First, beginning readers of visually more complex orthographies should demonstrate more advanced visual skill than those of visually simpler orthographies because they are forced at the onset to make more two-dimensional fine-grained visual discriminations in order to distinguish print. For example, in Chinese, an orthography well known for its visual complexity (e.g., Cole & Pickering, 2010), visual information toward the top, bottom, left, and right of given characters must be equally attended to in order to distinguish across them—日 (sun), 芒 (section), 考 (think), 植 (stay), 果 (plum), and 呆 (dull), and so forth. Second, good readers should outperform poor readers in visual skill because good readers have more experience with print (e.g., Stanovich, 1986), further facilitating their visual skill. Indeed, even before they can read, American preschoolers tend to excel over Chinese children at distinguishing letter reversals within words (e.g., pin vs. nip); Chinese children are better at distinguishing Chinese character reversals. Such results are presumably attributable to the elementary experience with native print in each group (Miller, 2002). Beginning higher achieving early readers might show similar advantages over less high-achieving early readers within a culture as well.

The orthographies selected for the current studies each represented major writing systems classified today: alphabetic (Spanish), abjad (Hebrew), logography based (Chinese), and syllabary (Korean) (e.g., Daniels & Bright, 1996). Both Spanish and Hebrew are similar in the relatively small “set” of visual stimuli used to read. Spanish is written using the 26-letter Roman alphabet, whereas Hebrew is made up of 27 distinct letters. The abjad writing system of Hebrew fully represents consonants, but in abjad writing systems vowel representations are partial or optional. Chinese contains up to 40,000 characters, with approximately 2500 characters needed to read a newspaper (Dehaene, 2009). Korean is an alphasyllabary, featuring approximately 2000 syllables (Taylor & Taylor, 1995). These Korean syllables serve as functional units in Hangul word recognition (Simpson & Kang, 2004), and Korean CV (consonant–vowel) syllables are actually learned as units earlier than are Korean letters of the alphabet (Cho, 2009). Visual processing is, therefore, important for young Korean children because Hangul letters are easy to confuse visually; they consist mostly of horizontal and vertical lines. For example, 모래 (sand), 모래 (day after tomorrow), 헛 (impoliteness), and 하늘 (as many as) are easily visually confusable to a novice. Thus, although adult Hangul readers view Hangul as easy to recognize primarily because of its phonological regularity, children as novices must rely on extensive visual discrimination to distinguish the written syllables.

In the current studies, we tested the hypothesis that learning to read promotes visual skill within and across writing systems. In Study 1, we hypothesized that beginning readers of either Spanish or Hebrew would show less well-developed visual skill than would those of Korean or Chinese because the former orthographies are less visually demanding than the latter. Spanish and Hebrew are minimally visually confusing because the basic configurations of these writing systems are simply strings of the same limited number of letters (e.g., Treiman, Levin, & Kessler, 2007). In contrast, for both Korean and Chinese novice readers, there are at least 2000 possible different graphic patterns to be learned, and visual information is holistic (i.e., from left to right as well as up and down).

There are at least two aspects of visual demandingness that contrast Korean and Chinese with Hebrew and Spanish. The first is the visual information to be kept in mind for each grapheme
encountered. The second is the number of objects or graphemes to keep in mind. Both are critical for visual memory (Alvarez & Cavanagh, 2004). The amount of visual information in Chinese characters is perceived by novices according to the number of strokes or components within each Chinese character (Yeh, Li, Takeuchi, Sun, & Liu, 2003). Similarly, the visual complexity of the Hangul syllable block affects perceptual identification (Lee & Zoh, 1968), discrimination (Taylor, 1980), and lexical decision making (Cho & Jin, 1991), with more features or strokes requiring more effortful processing. Chinese characters are comparatively less efficient to process visually as compared with Hebrew or Roman letters (Pelli, Burns, Farell, & Moore-Page, 2006). Thus, both Chinese and Korean Hangul are likely to be relatively effortfully processed by children because of the relatively large number of components or strokes comprising them as well as the spatial representations (i.e., nonlinearity) of these components (Hoosain, 1991; Taylor & Taylor, 1995). The larger set size of items for Chinese and Korean Hangul readers as compared with Hebrew and Spanish readers might also affect visual processing given that individuals can memorize only a few novel graphemes at a time (e.g., Alvarez & Cavanagh, 2004).

We also expected to find that, within each writing system sample, better readers would show better visual skill than would poorer readers. For many of these kindergartners, letter knowledge was not yet complete even as they began to recognize words. This is clearest in Korea, where letter knowledge is not explicitly taught until first grade (e.g., Cho, McBride-Chang, & Park, 2008). However, in both Israel and Spain, kindergartners’ letter name knowledge is also typically only partial, as was the case in the current studies. Children with better reading skill were expected to be those who could discriminate specific visual features in letters and words in order to distinguish them. We reasoned that children who could distinguish more graphemes and words in print would, as a consequence, develop more general visual spatial skill such as understanding of mirror image or a focus on the top versus the bottom of letters or characters.

In Study 2, we further tested the extent to which initial word reading skill would predict visual skill 1 year later in a longitudinal study of Chinese readers. Although we anticipated that visual skill would also predict reading skill 1 year later as found in previous studies of young children (e.g., Ho & Bryant, 1999; McBride-Chang, Chow, Zhong, Burgess, & Hayward, 2005), we hypothesized that the unique contribution of reading to subsequent visual skill would be stronger than the association of visual skill to later word reading.

Method

In Study 1, participants were 190 kindergartners from Hong Kong (33 boys and 30 girls, mean age = 69.7 months), Korea (30 boys and 20 girls, mean age = 69.6 months), Israel (16 boys and 20 girls, mean age = 68.8 months), and Spain (21 boys and 20 girls, mean age = 68.9 months). These groups did not differ from one another statistically by age. All children were native speakers in their cultures and were tested on the standardized Visual Spatial Relationships task (Gardner, 1996) as well as word reading in their native writing system. Across cultures, the majority of the children’s mothers had attended high school (from 55% in Israel to 84% in Spain); most of those remaining had attended college and/or graduate school. Fully 82% (Spain) or more (e.g., 100% for Korea) of all parents across cultures were married at the time of the study. Literacy training for this age group differs across schools as well as cultures. In Korea, children are initially taught some Hangul at home, typically by parents. Hangul is introduced as whole syllable blocks (rather than as individual letters) through kindergarten (e.g., Cho et al., 2008). In Hong Kong, kindergartens begin teaching some Chinese characters during the first year of kindergarten at around 3.5 years of age. In Spain and Israel, letter names and some sounds are introduced in kindergartens from 4 to 5 years of age. Preliminary word reading and writing also begins in kindergarten.

Participants in Study 2 were from a longitudinal study consisting of 215 Hong Kong kindergartners (95 boys and 120 girls, mean age at Time 1 = 5 years 1 month) and were tested on Chinese word reading and visual spatial relations (Gardner, 1996) at both 5 and 6 years of age. The Visual Spatial Relationships task has demonstrated good internal consistency and test–retest reliability across cultures for this age group (McBride-Chang et al., 2005) and taps spatial orientation, which is cross-culturally associated with early reading skill (e.g., Lee, Stigler, & Stevenson, 1986).
Across both studies, in Chinese, the word reading task at 6 years of age consisted of 211 one- and two-character words from the Hong Kong Test of Specific Learning Difficulties in Reading and Writing (Ho, Chan, Tsang, & Lee, 2000) and elsewhere. At 5 years of age for Study 2 only, the word reading test consisted of 51 words from the kindergarten version of this task (e.g., McBride-Chang et al., 2005). The Korean words were 90 Hangul items composed of two- or three-syllable words. In both Spanish and Hebrew, a total of 10 words were included. All word recognition tasks scored the total number of words read correctly.

**Results**

In Study 1, each group was divided by median split into higher and lower reading groups based on the word reading scores and then compared on visual skill. Although these two groups did not differ in Korea ($t = 0.70, p = .49$), the higher reading groups outperformed the lower reading groups on the visual spatial task in Hong Kong ($t = 2.94, p < .01$, Cohen’s $d = 0.74$), Israel ($t = 2.59, p < .05$, Cohen’s $d = 0.83$), and Spain ($t = 2.43, p < .05$, Cohen’s $d = 0.77$), as shown in Fig. 1.

A 2 × 4 factorial analysis of variance (ANOVA) revealed that Hong Kong and Korean children demonstrated significantly more advanced visual skill than did Israeli and Spanish children. There was a significant main effect of culture group on the Visual Spatial Relationships task, $F(3, 184) = 16.26, p < .001$. Post hoc tests revealed that the Hong Kong children ($M = 11.46, SD = 2.98$) performed significantly better than the Spanish children ($M = 8.73, SD = 4.63, p < .001$, Cohen’s $d = 0.70$) and Israeli children ($M = 7.90, SD = 2.63, p < .001$, Cohen’s $d = 1.27$) on the visual task; the Korean children ($M = 11.86, SD = 3.56$) also outperformed the Spanish children ($p < .001$, Cohen’s $d = 0.76$) and Israeli children ($p < .001$, Cohen’s $d = 1.26$) on this task. However, no significant differences in visual skill were found between the Hong Kong and Korean children or between the Spanish and Israeli children.

![Visual-Spatial Relationships](image)

**Fig. 1.** Visual spatial relationships.
Interestingly, when each group was instead divided into high and low visual skill groups based on a median split of the Visual Spatial Relationships task (Gardner, 1996) and then compared on word recognition, only children in the Hong Kong and Spanish groups differed significantly on word reading skill.

In Study 2, Hong Kong kindergartners’ word reading ability at 5 years of age was significantly correlated with visual skill at the same age ($r = .47$) and 1 year later ($r = .36$). In addition, the Visual Spatial Relationships tasks at Times 1 and 2 were significantly correlated ($r = .58$), as were the word reading tests across time ($r = .84$).

A multiple regression analysis showed that word reading ability at 5 years of age alone accounted for 13% of the variance in subsequent visual skill, $F(1, 213) = 31.84, p < .001$. When Time 1 visual skill was also included to predict Time 2 visual skill, it contributed 21% unique variance to visual skill at 6 years of age, $F(1, 212) = 68.97, p < .001$, for a total of 34% of variance explained. With both variables included simultaneously to predict Time 2 visual skill, the final beta weight for Time 1 reading skill was .12 ($p < .07$). Time 1 visual skill also predicted 15% of the variance in Time 2 word reading, $F(1, 211) = 36.42, p < .001$. However, Time 1 word reading skill accounted for most of this variance: When Time 1 word reading ability was also included to predict Time 2 word reading skill, it contributed an extra 56% of the variance in word reading at 6 years of age, $F(1, 210) = 408.62, p < .001$, for a total of 71% of the variance explained. With both variables included to predict Time 2 word reading ability, the final beta weight for Time 1 visual skill was $-0.03 (p = .56)$, suggesting that the association between Time 1 visual skill and Time 2 word reading was entirely attributable to the association between visual skill and word reading at Time 1.

**Discussion**

The results highlight the potential importance of both writing system and reading skill for young children’s early visual skill development. The Chinese and Korean writing systems are more visually dense than those of Hebrew and Spanish. The set sizes of graphemes to memorize in Chinese and Korean units are also much larger than those of Hebrew and Spanish. Both set size and visual density are crucial for learning visual stimuli (e.g., Alvarez & Cavanagh, 2004). The visual challenge of these Asian writing systems may force young children to focus more directly on visual features of their orthographies, facilitating their visual skill. In addition, even among these beginning readers, in three of the four cultural groups, good readers had significantly stronger visual skill than did poor readers. Those with more reading experience have had more exposure to print (Stanovich, 1986) and, thus, to greater fine-grained visual analysis. In Study 2, with the autoregressor included, the association between word reading at Time 1 and visual skill at Time 2 was stronger than that between visual skill at Time 1 and word reading at Time 2. Clearly, visual spatial skill and word reading are bidirectionally associated. At the same time, however, the association between word reading and visual skill appears to be particularly robust. Therefore, although most research on children’s literacy development so far has tended to focus on potential causal links between visual skill and word recognition (Ho & Bryant, 1999; McBride-Chang et al., 2005; Willows, Kruk, & Corcos, 1993), how learning to read influences one’s visual analytic skill may be another important association to pursue (e.g., Hoosain, 1991).

These studies have both theoretical and practical implications. Theoretically, they add weight to the argument that literacy experiences themselves may influence visual spatial intelligence (Demetriou et al., 2005). Although there are many senses in which the experience of learning to read may share some “universals” across cultures (e.g., Dehaene, 2009; McBride-Chang, 2004), our preliminary results also suggest that the experience of learning to read different orthographies may differentially shape some aspects of visual spatial processing, an important domain of intelligence (Chan & Vernon, 1988; Demetriou et al., 2005). Given the fundamental importance of visual spatial skills across different conceptualizations of intelligence (e.g., Carroll, 1993; Gardner, 1985), researchers should consider the extent to which reading different orthographies might influence overall variability in intelligence, which is sometimes currently attributed to ethnicity (e.g., Rushton & Jensen, 2005).

Practically, such results illustrate the conundrum of using some tasks that are often judged to be culture free across cultures. The smoothed median reported for the Visual Spatial Relationships task

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normed on American children, among 5-year-olds is approximately 8, which is in line with our obtained results in Study 1 for the children from Spanish- and Hebrew-speaking backgrounds. However, it is clear that the Korean and Chinese children’s performances were above this. Among Chinese children, performance on this task tends to be at approximately ceiling for those age 7 years and above, although this test has actually been normed for American children from 4 to 12 years of age.

Future work could expand and refine these ideas. For example, it would be useful to look at the developmental course of visual skill with age. For older children, more difficult visual tasks would be interesting to include in order to test whether visual skill differences across cultures diminish with age as found by Demetriou and colleagues (2005). In addition, a longer term longitudinal study testing the bidirectional effects of visual skill and word reading on one another across scripts, rather than in Chinese only, would be useful in attempting to further disentangle the associations between the two. Finally, given that children take longer to learn to read in deeper, as compared with shallower, alphabetic orthographies as a backdrop (Seymour, Aro, & Erskine, 2003), it should be noted that many of the Korean and Chinese children were capable of reading many more words in Study 1 than were the Spanish and Hebrew children. This phenomenon implies that the Asian children had more experience in reading than did the non-Asian children in the current studies. Thus, because of either necessity or cultural choice, Asian children’s reading experiences, in addition to the orthographies to which they were exposed, might also have affected the results of Study 1.

Despite these limitations, however, results of this research have extended what is known about the process of learning to read and visual skill. Specifically, we demonstrated that both reading skill and the writing system may influence children’s visual spatial skill development even from the beginning phases of the reading process.

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