Speech perception, metalinguistic awareness, reading, and vocabulary in Chinese-English bilingual children

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Abstract

This study examines the intercorrelations among speech perception, metalinguistic (i.e., phonological and morphological) awareness, word reading, and vocabulary in a first (L1) and a second language (L2). Results from three age groups of Chinese-English bilingual children showed that speech perception was more predictive of reading and vocabulary in the L1 than L2. While morphological awareness uniquely predicted reading and vocabulary in both languages, phonological awareness played such a role after controlling for morphological awareness only in the L2, which was alphabetic. L1 speech perception and metalinguistic awareness predicted L2 word reading but not vocabulary, after controlling for the corresponding L2 variables. Hence, there are both similarities and differences between the two languages in how the constructs are related. The differences are attributable to variations in language properties and learning contexts. Implications of the present results for an effective L2 learning program are discussed.

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In the present research we examine the predictive effects of speech perception and metalinguistic (i.e., phonological and morphological) awareness on reading and vocabulary in a non-alphabetic first language (L1) and an alphabetic second language (L2). We are also interested in examining how L1 speech perception and metalinguistic awareness would cross-linguistically predict L2 reading and vocabulary. Because reading and vocabulary are the central capabilities of concern in language education, outcome of this research has important implications for the development of a successful language program, especially one for L2 learning that takes L1 properties into consideration. The parameters of such a program are discussed.

The Role of Phonological Representation

Much research over the past three decades has shown that phonological awareness, which refers to the explicit analysis of speech into small phonological units, predicts children's reading over and above general intelligence and other linguistic variables (Adams, 1990; Comeau, Cormier, Grandmaison, & Lacroix, 1999; Cunningham & Stanovich, 1997; de Jong & van der Leij, 1999; Elbro, Borstrom, & Petersen, 1998; Lundberg, Olofsson, & Wall, 1980; Manis & Freedman, 2001; Muter, Hulme, Snowling, & Taylor, 1998; Sprenger-Charolles, Siegel, & Bechennec, 1998; Wagner & Torgesen, 1987; Wagner, Torgesen, & Rashotte, 1994; Wagner, Torgesen, Rashotte, Hecht, Barker, Burgess, et al., 1997; Wimmer, 1993). A similar relation has also been found in languages using non-alphabetic orthographies in which phonemes are not coded in writing (e.g., Cho & McBride-Chang, 2005; McBride-Chang & Kail, 2002). To explain the relationship, it is important to identify the aspect of phonological awareness, as measured by standard tasks such as sound deletion, blending, and rhyming, that is most akin to the processes underlying reading. A popular interpretation holds that phonological awareness reflects the quality of phonological representation, which is also required in reading and listening to speech (Brady, 1997; Goswami, 2000; Metsala & Walley, 1998; Snowling, 2001). One would thus predict an association between phonological awareness and reading, as mentioned, and also speech perception (McBride-Chang, 1995; Metsala, 1997), because these capacities all necessitate phonological representation to a significant degree.

Hence, individual differences in the quality of phonological representation may manifest themselves as variabilities in phonological awareness, speech perception, and reading performance. The exact nature of such individual differences is open to debate. According to the lexical restructuring hypothesis (Metsala & Walley, 1998), children's growth in lexical knowledge requires support from an increasingly fine-grained phonological system ultimately using the phoneme as the representational unit. Children with a sensitivity to phonemes can distinguish and learn more lexical items than those who process speech in larger units, such as the syllable. According to this view, vocabulary correlates with speech processing because vocabulary growth pressures the speech system to continue to re-represent speech by finer units over time so that learned lexical items remain phonologically distinguishable. Developmentally, this re-representation process is thought to start from whole lexical items to syllables, onsets and rimes, and finally down to phonemes. Representing speech by increasingly fine phonological units as a result of vocabulary growth produces two further results: enhanced phonological awareness ultimately reaching the phoneme level, and improved reading because of better mastery of the alphabetic code in which letters correspond to phonemes, not the bigger units. The lexical restructuring hypothesis thus postulates that poor reading originates from a coarse-grained phonological representation, the processing unit of which is bigger than the phoneme.

On the other hand, the distinctiveness hypothesis assumes that all speakers are able to represent the phonemes in speech; individuals differ only in terms of the number of distinctive features that are specified for each phoneme. Development is characterized by an increasing number of features specified within phonemes that are already in place, rather than progress from coarse- to fine-grained phonological representation (from whole words to phonemes) as assumed by the lexical restructuring hypothesis. Given that each phoneme is describable by a fixed set of features, a phonemic representation comprising many specified features is a high-fidelity representation whereas a poor-quality representation contains a smaller number of specified features (Elbro, 1996). According to the distinctiveness hypothesis, poor reading is associated with low-quality phonemic representations that are underspecified for distinctive features. Elbro, Nielsen, and Petersen (1994) showed that dyslexic adults performed especially poorly on a vocabulary task in which they chose the correct meaning of target words from foils that were phonologically close, but not on a parallel task containing semantically close foils. The dyslexic participants' poor discrimination of targets from similar-sounding distracters was attributed to their rough phonemic representations underspecified for features, which was assumed to underlie their reading deficit.

Chiappe, Chiappe, and Gottardo (2004) reason that while receptive vocabulary only requires the child to point to the target picture among distracters upon hearing the test item, expressive vocabulary places a much heavier demand on the child's phonological ability by requiring her to orally produce the target word, which necessitates the retrieval of phonemic representations that are fully specified for distinctive features. Therefore, if the distinctiveness hypothesis is correct in assuming that reading is associated with phonological processing because both depend on the degree of feature specification within phonemes, then they should correlate more with expressive than receptive vocabulary, because the former taps more into the child's knowledge of phonological details. On the other hand, the lexical restructuring hypothesis stipulates that lexical learning promotes segmentation in speech. Given that receptive and expressive vocabulary tap lexical learning equally well, they thus should correlate similarly with speech processing. Chiappe et al. (2004) reported that reading and phonological awareness turned out to be more closely related to expressive than receptive vocabulary, therefore supporting the distinctiveness view.

Native versus Non-native Languages

If the quality of children's phonological representation is responsible for their phonological awareness, reading, speech perception, and consequently the interrelations among these abilities in an L1, would the same be found in an L2? One reason that the answer to this question is not necessarily positive has to do with the variety of L2 learning contexts, compared to L1 acquisition. Whereas L1s are typically acquired through everyday verbal-social interaction right from birth, L2s could be learned in natural social interaction in bilingual communities, in a formal classroom situation that is more biased toward print than speech, in immersion programs, from domain-specific contact (e.g., trading) between speech groups that do not share a common language, and so on. Also, one can start learning an L2 at any age. Given this variety of learning contexts, would phonological representation still play a central role in reading and listening to speech? Another issue is how the L1 and L2 phonological systems may interact, giving rise to cross-language transfer effects.

Chiappe and Siegel (1999) examined the learning of English as a second language (ESL) by Punjabi-speaking Canadian children, and compared their performance to native English-speaking children. Variables such as word reading, phonological awareness, and syntactic awareness were measured. It was found that the two language groups performed differently only on syntactic awareness. Splitting the language groups into reading level sub-groups, the authors further reported that reading and phonological awareness helped discriminate poor from good readers in a similar fashion across the language groups. Chiappe, Glaeser, and Ferko (2007) compared the English performance of a group of Korean ESL children to that of English-speaking children, and demonstrated that phonological awareness and speech perception were similarly predictive of reading for both groups of children. Because the relationship was independent of oral language skills, it should reflect the specific involvement of the phonological system as opposed to general language encoding.

The above findings point to similar involvement of phonological representation in phonological awareness, reading, and speech perception in native and non-native languages. It should however be noted that the ESL children recruited in the above studies learned their L2 in an English environment. This contrasts with the samples used by McBride-Chang and Ho (2005), and McBride-Chang and Treiman (2003), whose ESL children learned their English solely in a traditional classroom environment with only minimal out-of-classroom language support from the wider community, which was monolingual Chinese. The relation between phonological awareness and reading in these studies is less clear, because English reading was shown to correlate with letter naming and letter knowledge only, which may not be regarded as measures of phonological awareness. Bialystok, McBride-Chang, and Luk (2005) administered standard English phonological awareness tasks, such as syllable and phoneme deletion, to a similar group of Chinese ESL children, yet a correlation between phonological awareness and English reading was not reported. Using Korean ESL children residing in Korea, Cho and McBride-Chang (2005) did report a relation between L2 phonological awareness and reading. Nevertheless, this relation was based on phoneme-level awareness, which was different from the corresponding L1 relation, which involved syllable-level awareness. Finally, Cheung (1995, 1999) found correlations between English phonological awareness and reading in Chinese ESL adolescents residing in Hong Kong. But these participants were significantly older than those typically used in phonological awareness studies involving native speakers, and therefore the finding may not indicate the same underlying mechanism.

Cross-language Transfer

The issue of cross-language interaction, or transfer, in reading and phonological processing has attracted a fair amount of attention recently. In the tradition of applied linguistics, "transfer" refers to L2 behavior bearing clear characteristics that are traceable to the L1, constituting an interlanguage (Odlin, 1989). In psychological research, the term tends to mean a statistical correlation between an L1 and an L2 ability, taken to indicate some communication between the two languages (e.g., Wang, Park, & Lee, 2006; Wang, Perfetti, & Liu, 2005). Findings on transfer can be considered under the linguistic interdependence model and the phonological core model. Linguistic interdependence (Cummins, 1979) postulates a high level of communication between L1 and L2, in that L1 skills are fully utilized from the start of L2 learning and thus provide a foundation for further learning and usage. Therefore, linguistic interdependence emphasizes the similarities between languages and full transfer. For example, Chiappe and Siegel (1999) reported similar patterns of phonological ability predicting reading in English across native and non-native speakers, hence arguing for the involvement of L1 phonological skills in the latter group, because otherwise their relatively weak English phonological representation would have produced a pattern departing from that of the native speakers. Wang et al. (2005, 2006) demonstrated in Chinese and Korean ESL learners that L1 phonological skills predicted L2 (English) reading on top of the corresponding L2 skills. Even lexical tone processing, which is non-existent in English, predicted English reading.

On the other hand, the phonological core view focuses on the role of a language-specific phonological core ability in reading (Geva & Wang, 2001). Applied to L2 reading, that would mean an emphasis on the L2, rather than the L1, phonological system. The model therefore predicts cross-language differences in how phonological representation is related to reading and other phonologically based language activities. For example, Cho and McBride-Chang (2005) reported that in Korean ESL children, Korean and English word recognition were best predicted by syllable versus phoneme awareness, respectively. A comparable pattern of differential effects of phonological awareness at different levels was reported by McBride-Chang, Cheung, Chow, Chow, and Choi (2006), who showed that Chinese ESL children's Chinese and English vocabulary were predicted by syllable- and phoneme-level awareness, respectively. In these studies, the L1s have their syllables most prominently represented in the respective orthographies, and therefore syllable-level awareness turned out to be important. This contrasts with the L2 (English), in which phonemes, not syllables, are most prominently represented in writing.

Morphological Awareness

Morphological awareness is the recognition of and ability to manipulate the meaning structure of language (Carlisle, 1995). In English research, the notion usually includes three smaller constructs. Inflectional morphological knowledge is the child's recognition of the variation in the form of words for grammatical purposes. Such variation does not impact on the grammatical category of the word in question. In English this can take the form of adding grammatical suffixes, such as the plural "-s" added to nouns and the regular past tense "-ed" added to verbs. It can also involve complete phonological change of the base item, such as the conversion of "be" into "am", "is", and "are" depending on the grammatical subject. Derivational morphological knowledge refers to the recognition of processes having the effect of creating new words by adding affixes, such as the derivation of "emptiness" from "empty". This often changes the grammatical category of the word in question. Compounding morphological knowledge has to do with the child's knowledge about putting morphemes together to form novel units of meaning. For instance, if the word "blackbird" is explained to the child as meaning a bird black in color, then with some compounding morphological awareness she probably would come up with the word "whitebird" when required to label a bird white in color.

Compared with phonological awareness, morphological awareness has two unique characteristics. First, it is more semantically than phonologically based, and thus on top of reading aloud it may also predict vocabulary and reading comprehension, both of which rely heavily on meaning representation and integration. Second, while the world's languages can be analyzed into more or less the same phonological units (e.g., phoneme and syllable), they are highly variable in terms of morphological structure. For instance, whereas English verbs are governed by relatively stable inflectional rules, Chinese verbs are uninflected. Rather, Chinese relies more heavily on compounding than English in word construction. Therefore, the exact operationalization of morphological awareness varies across languages, and, consequently, morphological awareness may not be as readily transferable as phonological awareness from one language to another in bilinguals.

Research findings are generally consistent with the above analysis. Morphological awareness has been shown to correlate uniquely with reading aloud in languages such as English, Chinese, and Dutch (Chow, McBride-Chang, Cheung, & Chow, 2008; Kirby, Desrochers, Roth, & Lai, 2008; Ku & Anderson, 2003; McBride-Chang, Cho, Liu, Wagner, Shu, Zhou, Cheuk, & Muse, 2005; McBride-Chang, Shu, Zhou, Wat, & Wager, 2003; Rispens, McBride-Chang, & Reitsma, 2008). This correlation extends to children diagnosed with dyslexia (Chung, McBride-Chang, Wong, Cheung, Penney, & Ho, 2008; McBride-Chang, Lam , Lam, Doo, Wong, & Chow, 2008). In addition to reading aloud, morphological awareness is also involved in the more meaning-based domains of vocabulary and reading comprehension (Chung & Hu, 2007; Kieffer & Lesaux, 2008; Kuo & Anderson, 2006; McBride-Chang, Tardif, Cho, Shu, Fletcher, Stokes, Wong, & Leung, 2008; McCutchen, Green, & Abbott, 2008). Inflectional, derivational, and compounding morphological knowledge appear to have different developmental timetables, and their exact patterns of development depend on the morphology of the language (Ku & Anderson, 2003; Kuo & Anderson, 2006; McCutchen et al., 2008). Finally, compared with phonological awareness, morphological awareness is overall less transferable between the two languages of the bilingual (Saiegh-Haddad & Geva, 2008). Nevertheless, significant transfer effects can be demonstrated if the exact morphological transformation in question operates similarly transparently in the two languages (Wang, Cheng, & Chen, 2006).

Summary

In summary, the correlation between phonological awareness and language activities such as reading, vocabulary, and listening to speech has been explained in terms of the quality of phonological representation, which varies across children. Children having a more efficient representation could process phonological information more segmentally, or use fuller sets of distinctive features to represent lexical items. In bilingual children two issues emerge. First, in an L2, phonological awareness and the other language activities may or may not be as closely interrelated as in an L1. Similar interrelations have been found in English (L2) with language minorities residing in English-speaking communities, but the pattern is much less established in places where English is not generally spoken. Second, the L1 and L2 phonological systems may interact to different degrees, producing observable transfer effects of different magnitudes. Whereas linguistic interdependence postulates immediate and almost complete application of L1 phonological processing in L2, phonological core models emphasize the involvement of a core L2 phonological ability. Morphological awareness, a more meaning-based capacity, has also been shown to correlate with reading and vocabulary. In a bilingual context, its transferability depends on how similar the morphologies of the two languages are.

The Present Study

The following questions are asked in the present study:

(1) Are reading and vocabulary associated with speech perception (i.e., syllable discrimination and categorical perception) and metalinguistic awareness (i.e., phonological and morphological awareness) in similar ways in Cantonese-Chinese (L1)[1] and English (L2)?

(2) What is the relation between speech perception and phonological awareness in either language?

(3) Do L1 speech perception and metalinguistic awareness predict L2 reading and vocabulary?

We use syllable discrimination and categorical perception of minimal pairs to indicate speech perception. These two indices have been used in many previous studies which examine speech processes in relation to phonological awareness and reading (Adlard & Hazan, 1998; Joannisse, Manis, Keating, and Seidenberg., 2000; Manis, McBride-Chang, Seidenberg, Keating, Doi, Munson, & Petersen, 1997; McBride-Chang, 1996). The present participants are ESL children residing in Hong Kong, a non-English-speaking environment. English is taught in formal classroom settings primarily by non-native speakers. This form of bilingual education is received by substantial populations across the globe and is therefore worth some attention.

Method

Participants

We recruited 141 Cantonese-speaking, Chinese-reading children residing in Hong Kong. They were at three grade levels, representing three age cohorts. The groups were two school years apart from one another. The youngest group (34 boys, 16 girls; mean age = 69.1 months; *sd* = 3.9 months) included children in their third (last) kindergarten year. These kindergartners had learned rudimentary oral and written English for about two years in school at the time of testing. The two elder groups consisted of 2nd (10 boys, 38 girls; mean age = 99.2 months; *sd* = 10.3 months) and 4th graders (18 boys, 25 girls; mean age = 118.6 months; *sd* = 7.1 months), respectively. In Hong Kong, English is a compulsory school subject starting from the first grade. Rudimentary English, however, is typically taught in kindergartens starting from the very first year. Nevertheless, Hong Kong remains a monolingual community in that very little English is spoken outside of the classroom. Therefore, children's oral English experience is restricted to a formal classroom environment, although contact with written English is much more likely than spoken English in the wider community.

Since testing was done in the schools, not all the children managed to finish all the tests within the times allocated by the school administrations. The degrees of freedom reported for some of the analyses thus vary a little across the tests.

Design, Materials and Procedures

Parents’ or guardians' informed consent for participation was obtained before testing. All tests were conducted in Cantonese in the respective schools by trained experimenters. We first administered the nonverbal intelligence test in groups; then the participants were tested individually on the subsequent tasks, which assessed verbal short-term memory, reading, vocabulary, phonological awareness, morphological awareness, and speech perception. The tasks are described below.

Nonverbal intelligence. Raven's Colored Progressive Matrices (RCPM; Raven, Court, & Raven, 1995) and Raven's Standard Progressive Matrices (RSPM; Raven, Court, & Raven, 1996) were used to measure nonverbal intelligence in the kindergartners and school children, respectively. These tests required the child to select one patch from six to eight alternatives that fits best into in a geometric design. The RCPM consisted of 36 colored items while the RSPM consisted of 60 black-and-white items. Although local norms were established for RSPM by the former Hong Kong Education Department in 1986, no norms were available for RCPM. Hence, instead of deriving IQs we reported the raw test scores. The maximum scores for RCPM and RSPM were 36 and 60, respectively.

Verbal short-term memory. Verbal short-term memory was assessed by the Cantonese version of the Forward Digit Span test (Wechsler, 1974). The test began with 4-item sequences of random digits; sequence length increased as the task progressed, until the child failed in two trials at a certain sequence length. Digit span scores were calculated using the standard method provided in the test manual.

Chinese word reading. Chinese word reading was assessed with Ho and Bryant's (1997) reading test comprising 34 two-character words arranged in increasing difficulty. The children were required to read aloud the items one by one in a left-to-right direction and go onto the next line after finishing a line. Testing stopped if the child failed to read aloud 10 consecutive items. Children who successfully finished the task were further tested with the Chinese Word Reading subtest of the Hong Kong Test of Specific Learning Difficulties in Reading and Writing (HKT-SpLD) (Ho, Chan, Tsang, & Lee, 2000). This test consisted of 150 two-character Chinese words arranged in increasing difficulty. Testing stopped if the child failed to read aloud 15 consecutive items. The maximum possible score for accomplishing both reading tests was 184. The split-half reliability of HKT-SpLD was 0.96, and the internal reliability of the 34-word test was 0.96 (Cronbach's Alpha).

English word reading. There were a total of 80 English words in the test of English word reading. The items were organized into 3 subsets of varying difficulties in accordance with item occurrence frequency in major textbooks designed for the local English curriculum. To better utilize administration time, the child started with the set that was appropriate for her grade level in terms of difficulty. Basal and ceiling rules were applied: If the child erred in more than two-thirds of the items in a set, she did not progress to the next difficulty level (ceiling); if the child erred in fewer than 11 items in a set, she progressed onto the next level (basal). Each word was worth one mark, and the maximum reading score was 80. The internal reliability of this test was .99 (Cronbach's Alpha).

Chinese vocabulary. Chinese vocabulary was assessed with the Chinese Vocabulary Definition subtest of the Hong Kong Wechsler Intelligence Scale for Children (HK-WISC) (Psychological Corporation, 1981), which is the Chinese version of the vocabulary component of the Wechsler Intelligence Scale for Children-Revised (WISC-R) (Wechsler, 1974). It was translated, modified, and standardized with a representative sample of 1,100 Chinese children in Hong Kong between 5 and 15 years of age. The test comprised 53 vocabulary items. The experimenter presented each item orally and the child tried to explain it. Testing stopped if she failed to explain 5 consecutive items. Each response was marked either 0, 1, or 2, following the manual instruction. The maximum score was 106.

English vocabulary. Form IIIA from the Peabody Picture Vocabulary Test – Third Edition (PPVT-III) (Dunn & Dunn, 1997) was used to assess English vocabulary. Each vocabulary item was accompanied by 4 black-and-white illustrations. The items were organized into 17 sets of 12 items, and the sets were of different difficulties. The experimenter read aloud each item and asked the child to point to the illustration, out of the 4, that best represented the meaning of the item. Ceiling Set rule and Basal Set rule were applied according to the manual instruction. A raw score was computed by subtracting the total number of errors made from the Basal to the Ceiling Set, from the number of the Ceiling items. The maximum score was 204.

Chinese phonological awareness. Chinese phonological awareness was assessed by syllable deletion, onset deletion, and rhyme production. In syllable deletion, there were 15 meaningful and 14 meaningless three-syllable items. The experimenters read aloud each item and asked the child to drop either the first, second, or third syllable and say aloud what was left. In onset deletion, 10 real and 12 pseudo one-syllable words were used. The child was to drop the consonantal onset of each item and say aloud what was left. In rhyme production, the child was presented orally with 3 reference syllables sharing the same rhyme and tone, and asked to come up with a legitimate syllable having this same rhyme and tone. There were altogether 16 rhyme production trials. A composite phonological awareness score was calculated by summing the scores from the three tests. The maximum composite score was 67. Practice trials were administered before testing to familiarize the child with the test procedure.

English phonological awareness. English phonological awareness was measured by syllable and phoneme deletion. Syllable deletion was administered in the same way as its Chinese version. There was a total of sixteen items, half of which were real words while the other half were pseudo-words. Of the sixteen items, four required deletion of the first syllable, four required deletion of the last syllable, and eight involved deleting the middle syllable. Each item was worth one mark. Phoneme deletion required the child to omit either the initial or final phoneme of a word and produce what was left. Fifteen initial phoneme deletion items (7 words and 8 pseudo-words) and 14 final phoneme deletion items (7 words and 7 pseudo-words) were used. Each item was worth one mark. The maximum English phonological awareness composite score was 45. Practice trials were administered before actual testing.

Chinese morphological awareness. Chinese morphological awareness was assessed through the morphological construction task administered at graded difficulty levels. Twenty-seven questions were organized into 5 sub-sets of varying difficulties. Two practice questions preceded the test questions. For each question the child was to come up with a novel word not generally used in the language but following the compounding rules to label a novel object or concept described by the experimenter. For example, one description was “Early in the morning the sun comes up, and this is called 'sunrise'. At night, we see the moon come up. What could we call this?” The target response was “moonrise”. The maximum Chinese morphological awareness score was 27.

English morphological awareness. Morphological awareness in English was assessed by an English version of the morphological construction task described above, involving the recognition and manipulation of prefixes and suffixes. Two example and two practice items were given before administering the 21 test items, each of which was accompanied by a colorful picture presented as memory aid. Two scoring methods were used. Sixteen items were scored as either correct (1) or incorrect (0). The rest of the items were scored as incorrect (0), partially correct (1), or correct (2), to differentiate between true understanding of morphemic structures and segmentation of words at a syllable level. For instance, for the item “A person who farms is a 'farmer'; then what do we call a person who cries?” "Cryer” was worth 2 points because this response would suggest that the child did possess the knowledge that "-er" is an English suffix attached to verbs labeling the performing agent of the action. On the other hand, "crymer” was worth only 1 point because it would suggest some flexibility in decomposing words into meaning components and re-combining them to form new meaning, but the target component corresponded with the wrong unit (i.e., a syllable rather than a morpheme). Hence a partial mark was given for an obvious awareness of the existence and flexible re-combination of smaller meaning components within words, but inaccurate mapping of these meaning components onto linguistic units. By allowing a partial mark in-between 0 and 2, we hoped to increase the discriminability of the test. The maximum score for English morphological awareness was 26.

Speech perception. Categorical perception of minimal pairs using the identification paradigm and syllable discrimination were the two indices of speech perception. Sound recording for the construction of speech stimuli was done in a sound-attenuated room using the following equipment: two condenser microphones connected to a Tascam DA-30 MK II DAT tape recorder, feeding sound information into the editing software CoolEdit Pro v.2. Recordings were stored in a 44,100Hz, 16bit format.

The Cantonese identification test measured children's categorical perception of Cantonese syllables varying in voice-onset-time (VOT) associated with the syllable-initial consonant. VOT underlies the aspiration contrast in Cantonese in a way similar to voicing in English. The standard aspirated syllable /kwaa1/[2] (VOT = 110 msec) and its unaspirated counterpart /gwaa1/ (VOT = 0 msec) were produced by a female native speaker using the carrier sentence "I say ____ again (/ngo5 zoi3 gong2 ____ jat1 ci3/)", and subsequently recorded. A continuum consisting of 10 tokens varying in VOT in equal (10-msec) steps was created, via Praat (Boersma & Weenink, 2006), and inserted between the two standards, forming a 12-token continuum. The mean and standard deviation of token durations was 591.3 msec and 33.7 msec, respectively.

On each identification trial, the child judged if an auditorily presented syllable was /kwaa1/ or /gwaa1/, by pressing one of two designated keys on the keyboard. Twelve practice trials were administered before testing to familiarize the child with the procedure. Stimuli were presented via the DMDX software developed K. I. Forster and J. C. Forster, and Logitech premium stereo headsets. Participants' key responses were recorded by Praat (Boersma & Weenink, 2006). Feedback was given for the practice but not the test trials. In testing, each token was presented 5 times randomly, resulting in a total of 60 identification trials.

The variable of interest from the identification task was the slope of the identification curve across the continuum, reflecting categorical perception of speech. We fit logistic curves onto the data via Logistic Curve Fit in SPSS. This method was previously used by Joanisse et al. (2000). Slope coefficients were calculated; large coefficients indicated flat slopes and thus a relative lack of categorical perception.

For English syllable identification, Wright's (1993) task manipulating VOT which represented the absence and presence of /p/ in "slit" versus "split", respectively, was adopted. The task had been shown as a valid measure for assessing children's speech perception elsewhere (McBride-Chang, 1996). A female native speaker said and recorded the word "split", then the /s/ was separated from the rest of syllable. A continuum of tokens was created by inserting different lengths of silence in-between the initial /s/ and the rest of the syllable. Perception typically shifted from "slit" (0 msec of silence after /s/) to "split" (110 msec of silence after /s/). All together 12 tokens were created, including the "slit" and "split" standards. The mean and standard deviation of token durations was 541.2 msec and 38.4 msec, respectively. Syllable lengths were not significantly different across the two languages ($p > .05$). Each token was presented randomly for 5 times, totaling 60 test trials, which were preceded by 12 practice trials. Feedback was given in the practice but not the test trials. Slope coefficients were calculated to represent categorical perception as in Cantonese syllable identification.

Using only one syllable pair in each language in the categorical perception task was based on our past finding that categorical perception performances within an individual were highly similar among multiple syllable pairs. In McBride-Chang (1996) and Cheung, Chung, Wong, McBride-Chang, Penney, and Ho (2009), very similar and stable performances were demonstrated for the three (English) and two (Cantonese) pairs, respectively. Using one pair was thus considered sensitive enough. In the present study a relatively large number of tests were administered in both languages and therefore it was important to avoid redundancies in the tests so that testing time was better managed.

In the Cantonese syllable discrimination task the child was to tell whether two successively presented syllables were same or different, by pressing one of two designated keys on the keyboard. For the "different" pairs, the syllables differed only in their initial consonants, along the articulation manner, place, and aspiration dimensions. Test syllables are shown in Table 1.

The tokens were said and recorded by a female native speaker, using the carrier phrase "I say ____ again (/ngo5 zoi3 gong2 ____ jat1 ci3/)". Syllable editing was handled by CoolEdit Pro v.2. The mean and standard deviation of token durations was 427.1 msec and 59.5 msec, respectively. Four actual presentations were created out of each pair of syllables. For example, the ”土 - 賭” pair was arranged into two "same" (”土 - 土” and “賭 - 賭”) and two "different" presentations (”土 - 賭” and “賭 - 土”), so that stimulus order was balanced in actual testing. The inter-stimulus-interval (ISI) was 500 msec. Results from a pilot test showed that the "same" presentations were too easy for the children. We suspected that it was because in the "same" condition the sound recordings were simply repeated, and hence irrelevant acoustic cues could have been used by the child. We therefore produced another set of the "same" syllables and used one token from each set to create the "same" presentations, so that the child was listening to different tokens of the same syllables. A higher false alarm then resulted, which enhanced the discriminatory power of the task.

Children were instructed to press the key labeled with “=” for "same" and that with “≠” for "different" judgments. Stimuli were presented via DMDX and Logitech premium stereo headsets. Twelve practice trials were administered with feedback before testing, which involved 36 test trials. Discrimination was reported as *d'*, which was calculated as the difference between the z score for hits and that for false alarms.

The English syllable discrimination task followed the same procedure as the Cantonese task. The mean and standard deviation of the English syllables was 409 msec and 76.9 msec, respectively. Syllable lengths were not significantly different across the two languages ($p > .05$). The English test syllables are shown in Table 1. *d'* scores were calculated using the same method as in Cantonese syllable discrimination to indicate discrimination sensitivity.

Insert Table 1 about here

Results

Mean Performance

Mean performance is reported separately for the three age groups in Table 2. For each task an omnibus Analysis of Variance (ANOVA) and post hoc contrasts were conducted to pinpoint differences among the groups except for nonverbal intelligence, which was measured by different tests for the different age groups, and therefore no direct group comparisons were made. Overall group differences were significant for all the measures. Post hoc analyses showed that the 4th graders performed at a higher level than the 2nd graders who in turn outperformed the kindergartners in all the tasks except categorical perception in both languages, in which no difference between the kindergartners and the 2nd graders was found. Also, in English syllable discrimination, the 2nd and 4th graders performed at similar levels.

Insert Table 2 about here

Partial Correlations

Table 3 presents partial correlations among the measures from all the children, controlling for age and nonverbal intelligence. Because nonverbal intelligence was measured by two different tests, one of which lacked a local norm and hence no IQs could be derived, we converted the raw scores from each group into standard scores using the respective group mean and standard deviation, having a possible range from -1 to 1 with a mean of zero. These scores were used in the partial correlations and the subsequent regressions. Forward digit span was dropped because it did not contribute significantly in any of the analyses. Results showed that reading and vocabulary in L1 and L2 were intercorrelated. In either language, phonological and morphological awareness correlated with reading and vocabulary. Syllable discrimination appeared to be more closely associated with reading, vocabulary, and the two metalinguistic awareness measures in L1 than L2. Metalinguistic awareness predicted reading and vocabulary cross-linguistically. While L1 speech perception appeared to be generally related to L2 reading (but not vocabulary), L2 speech perception correlated with neither L1 reading nor vocabulary.

Insert Table 3 about here

Regressions

Hierarchical multiple regressions were performed on the combined data from all the three age groups to examine the hypotheses more closely. The groups were combined so that the analyses would reveal how the variables of interest were generally associated with enhanced statistical power. In these regressions, age and nonverbal intelligence were entered at the first and second step, respectively, so that their contributions were removed before the critical predictors were examined. There were two regressions in set 1, both using Chinese reading as the dependent variable. In the first regression Chinese metalinguistic awareness and speech perception were entered at steps 3 and 4, respectively; in the second regression their entry order was reversed. Speech perception and metalinguistic awareness were entered at separate steps so that the unique contribution of either with the other controlled for could be evaluated in a more stringent way at step 4, as they were highly correlated. Set 2 was identical to set 1 except that the corresponding English variables were used instead. Results are presented in Table 4.

Insert Table 4 about here

After controlling for the effects of other metalinguistic awareness and speech variables, morphological awareness and syllable discrimination turned out to be significant predictors of Chinese word reading. For English word reading, both phonological and morphological awareness were significant predictors, but none of the speech variables appeared to be involved.

Regression sets 3 and 4 were identical to sets 1 and 2, respectively, except that vocabulary instead of word reading was used as the dependent variable. Results are shown in Table 5.

Insert Table 5 about here

The reliable predictors of Chinese vocabulary were morphological awareness and syllable discrimination. For English vocabulary, as in word reading, both phonological and morphological awareness were significant predictors; none of the speech variables was involved.

In regression set 5, phonological awareness in the two languages were regressed on the respectively speech variables. The pattern turned out to be slightly different across the languages. In the L1, both categorical perception and syllable discrimination were predictors of phonological awareness, whereas in the L2 only categorical perception predicted phonological awareness. These results are shown in Table 6.

Insert Table 6 about here

Finally, regression sets 6 and 7 examined L1-to-L2 transfer; English word reading and vocabulary were the dependent variables, respectively. In these regressions, English metalinguistic awareness and speech perception were entered at step 3, so that their effects were considered before examining the transfer effects of the Chinese variables. Results showed that Chinese phonological awareness, morphological awareness, and categorical perception were significant predictors of English word reading, whereas no Chinese variables actually predicted English vocabulary. These results are shown in Table 7.

Insert Table 7 about here

Discussion

Overall, our speech perception data indicate that: (1) there is an overall trend of development for both categorical perception and syllable discrimination accuracy in either language, within the age range from 5.7 to 9.9 years; (2) age differences in categorical perception are clear only in the older children, in both languages; (3) age differences in discrimination accuracy are all clear in the L1 but are so only for the younger children in the L2. Hence, development in categorical perception based on syllable identification becomes clearly visible slightly later than syllable discrimination. Development of L2 syllable discrimination is not observable after the 2nd grade. This may have to do with the fact that for the present bilingual sample, L2 speech is available only in the classroom for a limited amount of time, usually delivered by non-native speakers, compared to the continual exposure to native L1 speech in natural social settings. Further progress is therefore slow beyond the 2nd grade. Following this logic, the present lack of progress in L2 syllable discrimination after grade two may not be extended to an environment in which the L2 is naturally spoken, nor may it be found with total immersion learning. This result thus indicates more of the peculiarities of English learning in the Hong Kong Chinese context than how an L2 is generally acquired.

Predicting Reading and Vocabulary

For the question about whether speech perception, metalinguistic awareness, and reading/vocabulary are similarly related in an L1 versus L2, our findings indicate that: (1) morphological awareness correlates with reading and vocabulary in similar ways in both L1 and L2 after controlling for phonological awareness; (2) phonological awareness predicts reading and vocabulary only in the L2 after controlling for morphological awareness. This pattern is consistent with some previous findings contrasting alphabetic with non-alphabetic writing systems (McBride-Chang et al., 2005). In alphabetic writing phonemes are represented in the script and therefore phonological (phonemic) processing is automatic and mandatory in reading-related activities. But in non-alphabetic writing the script may be directly interpreted for meaning without obligatory phonemic processing, because phonemic segments are not coded in writing (McBride-Chang, Bialystok, Chong, & Li, 2004). What we observe is therefore differential involvements of phonological skills in processing alphabetic versus non-alphabetic scripts. On the other hand, a sensitivity to compounding morphology appears to be equally important in reading and vocabulary in both Chinese and English, presumably because compounding works in similar ways in the two languages (Wang et al., 2006).

The different involvements of phonological awareness in L1 versus L2 reading is more consistent with the lexical restructuring (Metsala & Walley, 1998) than the distinctiveness view (Chiappe et al., 2004). Because Cantonese and English phonemes are describable by the same set of universal distinctive features which are represented in neither writing systems, phonological awareness should have been equally predictive of reading if what links the two capacities is an underlying representation of distinctive features. In other words, since distinctive features are equally prominent in the sound representations and equally invisible in the writings associated with the two languages, there is no reason to assume differential roles of phonological awareness in reading the two scripts if the representation of distinctive features is what actually links phonological awareness to reading. On the other hand, if the relation is due to an underlying phonemic representation as stipulated by the lexical restructuring hypothesis, then it becomes reasonable to assume a weaker independent link between phonological awareness and reading in Chinese, which depends much less on recognizing phonemes visually because they are not coded in writing.

A further finding is that after controlling for metalinguistic awareness, speech perception predicts reading and vocabulary in the L1 but not the L2. We argue that in the present form of bilingualism in which L2 speech is not generally available, L2 reading and vocabulary development have to rely heavily on print without much help from a weak L2 phonological system, which is deprived of input (i.e., L2 speech). One way to evaluate this speculation is to compare the partial correlations between reading and vocabulary in the two languages. Because reading is obviously based on writing, it should correlate more intimately with vocabulary in the L2 than L1 if L2 vocabulary is indeed heavily dependent on writing rather than speech. The partial correlations between reading and vocabulary in L1 and L2 are .42 and .62, respectively. The difference is significant ($p < .05$). This result, in addition to the weak overall correlation between L2 speech perception and reading/vocabulary, appears to support the claim that in our bilingual sample, L2 language activities are more writing- than speech-based. This observation, together with the finding discussed above that English syllable discrimination did not improve after grade two, is likely to be a characteristic of the present type of bilingualism in which L2 speech input is minimal, compensated by the general availability of L2 print. Orthographic and semantic factors are thus more likely to affect reading and lexical learning than phonological factors. We do not see this part of our results as indicative of processes that are general to all kinds of L2 acquisition contexts, especially those in which L2 speech figures prominently (e.g., total immersion, natural bilingual communities). Therefore, in interpreting results from bilingual studies, it is important to consider exactly what learning condition and socio-linguistic environment are associated with the learning of the target L2s, as the possible variety of these conditions are remarkably larger than what is typically found in L1 acquisition.

Speech Perception and Phonological Awareness

Our data indicate that speech perception is directly involved in the development of phonological awareness in both languages, as categorical perception uniquely predicts phonological awareness in the L2, and both categorical perception and syllable discrimination predict phonological awareness in the L1. These findings are consistent with the results of McBride-Chang (1995) and Metsala (1997).

Transfer Effects

With regard to the question about L1-to-L2 transfer, regression results showed that L1 categorical perception and metalinguistic awareness predict L2 reading but not L2 vocabulary after controlling for L2 speech perception and metalinguistic awareness. This finding is consistent with the transfer data in reading obtained from Korean ESL students by Wang et al. (2005, 2006), in support of the linguistic interdependence model (Cummins, 1979). The model stipulates that L1 language competence is immediately and fully available for L2 language learning and performance, and thus predicts strong transfer effects. This is clearly shown in our finding, that the bilingual child's English word reading is dependent on her categorical perception of Cantonese speech over and above her experience with English speech.

But why are there no transfer effects in L2 vocabulary learning? One possible explanation is that we have used PPVT to measure English vocabulary, which is a receptive test requiring less phonological specification than an expressive test, such as the vocabulary definition test we have adopted to measure Chinese vocabulary. The argument was made by Chiappe et al. (2004), who contrasted children's receptive with expressive vocabulary performance in order to ascertain the role of phonological specification in reading. The assumption that receptive vocabulary does not require much phonological specification is especially applicable to an L2, in which vocabulary is typically small. For instance, our present 4th graders on average scored only around 48 out of a total of 204. With such a small vocabulary only very rough phonological specification is needed to distinguish the vocabulary items. In other words, a "discrimination" strategy demanding only a low level of phonological specification would be adequate with a small L2 vocabulary. Therefore, L2 vocabulary may not benefit from the fine-tuned sensitivity subserving L1 speech perception, and consequently there would be no significant transfer effects.

To test the above speculation, we median-split the participants into a high- and a low-English-vocabulary subgroup and tested the transfer effects of the Chinese speech and metalinguistic variables on English vocabulary, controlling for the corresponding English variables. For the low-vocabulary subgroup there were no transfer effects; but for the high-vocabulary subgroup Chinese categorical perception, morphological awareness, and phonological awareness (marginally) do predict English vocabulary uniquely, explaining 7%, 3%, and 2% of its variance, respectively. These findings support the speculation that the present lack of an overall L1-to-L2 transfer effect for English vocabulary could be due to the generally small vocabulary size, which does not require the fine-tuned sensitivity subserving L1 speech processing.

The differential dependence of L2 reading versus vocabulary on L1 phonological knowledge suggests that the notions of linguistic interdependence (Cummins, 1979) and an L2 phonological core (Geva & Wang, 2001) are applicable to different degrees to the various aspects of an interlanguage (Odlin, 1989). Reading is relatively sound-focused because the ultimate requirement is to utter aloud accurately the speech behind visual symbols. To accomplish this task it is crucial to make use of any phonological resources that may be available (from the L1) for support. In contrast, vocabulary is more meaning-focused as what the learner needs to do is to pinpoint a concept upon hearing or reading a word (receptive), or to utter/write out a word upon receiving a concept (expressive). Accurate phonological analysis and execution are less of a concern than in reading until the vocabulary reaches a certain size at which fine sound discrimination is necessary to support meaning differentiation, as stipulated by the lexical restructuring hypothesis (Metsala & Walley, 1998).

Therefore, if an interlanguage is seen as the result of interaction between an L1 linguistic knowledge base and L2 input, different types of L1 knowledge contribute differentially to the formation of the interlanguage. From an educational point of view, hence, L2 teaching and learning becomes a task of balancing: Rather than constantly insisting on the golden standard achieved by native speakers of the L2 in question, one may consider balancing this standard with L1 knowledge transfer that is useful, achieving an interlanguage that is functional rather than a "perfect" L2. Exactly how such balancing should be implemented depends on the L2 domain in question (e.g., reading versus vocabulary) and what learning environment is available.

Contributions and Limitations

Using English (L2) reading aloud and vocabulary as outcome variables, the present findings suggest that three overarching factors are at work in bilingual learning. First, learning context plays a definite role in how an L2 is acquired. The current finding that L1 syllable discrimination developed continually whereas L2 syllable discrimination stopped improving after grade two may be a result of the general lack of L2 speech input, which is peculiar to the present learning context. Such a lack of L2 speech input may also explain why reading and vocabulary were predicted by L1 but not L2 speech perception. Second, the linguistic properties of the L2 clearly affect its acquisition. After controlling for morphological awareness, phonological awareness predicted reading and vocabulary only in the L2. Such a unique role of phonological awareness in the L2 is attributed to the presence of alphabeticity in the L2 script, in contrast with the absence of it in the L1 script. Third, the L2 learning domain in question has an impact on the transferability of L1 knowledge towards the formation of an interlanguage. Our findings indicated that reading was more subject to L1 phonological transfer than vocabulary learning.

One main limitation of the present study, however, is that it is based on a cross-sectional design so that no strong claims about development can be made concerning the L2 speech perception data. Another caveat is that because the current design is correlational rather than strictly experimental, one should be cautious about any causal interpretations of the findings. The present study thus represents an important initial attempt to examine the roles of speech perception and metalinguistic awareness in an L1 and a dissimilar L2 that is learned with a lot of print but minimal speech input. It needs to be complemented by future longitudinal studies in which the independent variables of interest, such as L2 learning context and L1-L2 similarity in terms of writing and morphology, are more systematically manipulated.

Educational Implications

We think that the present findings inform us about some parameters to consider in designing an effective L2 learning program. First, the current results highlight the importance of providing an L2 speech environment as emphasized in many immersion programs. We speculate that because of the lack of such an environment, our participants did not progress much in L2 speech perception after the 2nd grade, contrasting with the continuous development in their L1 speech sensitivity. An L2 speech environment also seems to affect how L2 reading and vocabulary are learned, as speech perception uniquely predicted reading and vocabulary in the L1 but not the L2 of the present participants. Hence an L2 speech environment makes speech perception available for supporting the development of reading and vocabulary.

Second, it is important to attend to the differences in how writing represents speech between the L1 and L2. For our participants phonological awareness remained a unique predictor of reading and vocabulary after controlling for morphological awareness only in English. The fact that English but not Chinese writing codes speech at a phonemic level may explain this difference. Therefore, more phonologically based methods can be used in English reading and vocabulary training although they may not be at all effective in learning Chinese.

Third, it makes good sense to evoke certain L1 knowledge to enhance L2 performance, especially in reading, although this may not work equally well in other areas of learning. Therefore it is important to identify learning areas that may benefit from L1-to-L2 transfer and investigate exactly what types of L1 knowledge should be involved. The present results show that L2 reading was more subject to transfer than vocabulary, and that speech perception and metalinguistic awareness were the L1 processes that could impact on L2 reading performance. These are among the dimensions to be included in an effective L2 program making use of knowledge in the L1.

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Footnote

1. "Chinese" is an umbrella term referring to any of the over 200 closely related languages currently spoken in China, of which Cantonese and Mandarin are the better known members. "Chinese" also refers to the one single writing system that is shared by all these languages. Because the present participants were Cantonese speakers, we applied the term "Cantonese" to descriptions of their speech and the speech stimuli that were used on them.

2. Cantonese was transcribed in Jyutping, or Cantonese Romanization, standardized by the Linguistic Society of Hong Kong (1993). Numbers indicate lexical tones.

Table 1.

Stimuli of the Syllable Discrimination Task

Chinese

pair	onset	rhyme	character	onset	rhyme	character
1	/t	ou2/	土	/d	ou2/	賭
2	/g	aa1/	加	/k	aa1/	卡
3	/b	aau1/	包	/p	aau1/	拋
4	/m	iu5/	秒	/n	iu5/	鳥
5	/w	an1/	溫	/j	an1/	因
6	/f	an4/	焚	/h	an4/	痕
7	/d	aai3/	帶	/p	aai3/	派
8	/b	ong1/	幫	/m	ong1/	芒
9	/d	it6/	秩	/l	it6/	列

English

pair	onset	rhyme	spelling	onset	rhyme	spelling
1	/t	u/	two	/d	u/	do
2	/f	æn/	fan	/v	æn/	van
3	/p	eɪ/	pay	/b	eɪ/	bay
4	/s	u/	sue	/ʃ	u/	shoe
5	/w	ɛt/	wet	/j	ɛt/	yet
6	/d	eɪt/	date	/g	eɪt/	gate
7	/n	ɛt/	net	/l	ɛt/	let
8	/b	ɔl/	ball	/m	ɔl/	mall
9	/j	æm/	yam	/r	æm/	ram

Table 2.

Mean Performance (SD) by Grade Level

	A kindergartners *n* = 43-50[a]	B 2nd graders *n* = 46-48	C 4th graders *n* = 42-43	F- value [*dfs*]	Post hoc by Tukey
age in month	69.1 (3.9)	99.2 (10.3)	118.6 (7.0)	515.5*** [2, 138]	A< B < C
forward digit span	4.4 (1.5)	5.1 (1.5)	6.6 (1.2)	29.1*** [2, 138]	A < B < C
nonverbal intelligence	22.5 (5.7) [max=36]	32.1 (7.8) [max=60]	43.2 (6.4) [max=60]	/	/
Chinese variables					
word reading [max=184]	42.3 (32.5)	124.8 (20.4)	163.6 (11.6)	322.1*** [2, 137]	A < B < C
vocabulary [max= 106]	18.1 (6.2)	32.7 (8.8)	54.3 (11.3)	191.8*** [2, 138]	A < B < C
morphological awareness [max= 27]	10.5 (4.5)	17.1 (5.6)	25.9 (1.5)	146.6*** [2, 138]	A < B < C
phonological awareness [max= 67]	20.1 (7.3)	32.7 (7.9)	44.5 (7.3)	122.6*** [2, 138]	A < B < C
syllable discrimination: *d'*	-1.3 (1.8)	0.1 (1.6)	1.3 (0.6)	33.9*** [2, 136]	A < B < C
categorical perception: slope	0.99 (0.02)	0.98 (0.03)	0.94 (0.04)	37.4*** [2, 136]	A = B < C
English variables					
word reading [max=80]	10.5 (14. 6)	37.1 (18.9)	68.9 (7.6)	183.7 *** [2, 138]	A < B < C
vocabulary [max=204]	23.8 (10.9)	36.9 (10.8)	48.4 (9.8)	59.2*** [2, 137]	A < B < C

morphological awareness [max=27]	7.8 (3.2)	12.1 (4.4)	19.1 (2.6)	119.1*** [2, 138]	A < B < C
phonological awareness [max=45]	14.1 (8.1)	25.7 (8.9)	36.1 (5.1)	97.4*** [2, 138]	A < B < C
syllable discrimination: *d'*	-0.8 (1.8)	0.3 (1.2)	0.5 (1.1)	10.5*** [2, 132]	A < B = C
categorical perception: slope	1.00 (0.02)	0.99 (0.03)	0.96 (0.03)	32.6*** [2, 136]	A = B < C

Note: ***$p < .001$; standard deviations are in parentheses.
[a] Range of numbers of participants contributing to the various test means.

Table 3.

Partial Correlations Controlling for Age and Nonverbal Intelligence

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Chinese variables												
1. word reading	--											
2. vocabulary	.42***	--										
3. morphological awareness	.41***	.45***	--									
4. phonological awareness	.28**	.24**	.43***	--								
5. syllable discrimination	.34***	.29**	.26**	.19*	--							
6. categorical perception	-.19*	-.29**	-.21*	-.28**	-.27**	--						
English variables												
7. word reading	.56***	.49***	.49***	.46***	.30**	-.27**	--					
8. vocabulary	.25**	.26**	.31***	.37***	.22*	-.01	.61***	--				
9. morphological awareness	.35***	.49***	.55***	.43***	.27**	-.19*	.61***	.39***	--			
10. phonological awareness	.31**	.35***	.44***	.58***	.31**	-.20*	.49***	.43***	.46***	--		
11. syllable discrimination	.13	.01	.09	.13	.43***	-.09	.11	.17	.17	.17	--	
12. categorical perception	.02	.02	-.12	-.36***	-.15	.25**	-.17	-.19*	-.27**	-.25**	-.16	--

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Table 4.

Hierarchical Regressions Predicting Word Reading in the L1 and L2

Set 1: predicting Chinese word reading

Step	Independent variable	Final betas	*df*s	R^2 Δ	*F* Δ
1.	Age	.86***	134	.74	389.56***
2.	Intelligence	.12**	133	.01	7.28**
3.	Chi. phono. awareness	.08	131	.05	15.26***
	Chi. morpho. awareness	.29***			
4.	Chi. syl. discrimination	.13*	129	.01	3.96*
	Chi. categorical percept.	-.02			
1.	Age	.86***	134	.74	389.56***
2.	Intelligence	.12**	133	.02	7.27**
3.	Chi. syl. discrimination	.18***	131	.03	9.20***
	Chi. categorical percept.	-.05			
4.	Chi. phono. awareness	.05	129	.03	9.50***
	Chi. morpho. awareness	.25***			

Set 2: predicting English word reading

Step	Independent variable	Final betas	*df*s	R^2 Δ	*F* Δ
1.	Age	.75***	131	.57	172.45***
2.	Intelligence	.16**	130	.02	8.03**
3.	Eng. phono. awareness	.26**	128	.18	46.69***
	Eng. morpho. awareness	.45***			
4.	Eng. syl. discrimination	.03	126	.00	0.27
	Eng. categorical percept.	-.02			
1.	Age	.75***	131	.57	172.45***
2.	Intelligence	.16**	130	.02	8.03**
3.	Eng. syl. discrimination	.04	128	.01	1.77
	Eng. categorical percept.	-.11			
4.	Eng. phono. awareness	.26**	126	.17	43.49***
	Eng. morpho. awareness	.46***			

Note: **p* < .05, ***p* < .01, ****p* < .001

Table 5.

Hierarchical Regressions Predicting Vocabulary in the L1 and L2

Set 3: predicting Chinese vocabulary

Step	Independent variable	Final betas	*df*s	R^2 Δ	*F* Δ
1.	Age	.79***	135	.62	221.64***
2.	Intelligence	.89**	134	.02	8.56**
3.	Chi. phono. awareness	.04	132	.08	18.04***
	Chi. morpho. awareness	.42***			
4.	Chi. syl. discrimination	.13*	130	.02	5.37**
	Chi. categorical percept.	-.11			
1.	Age	.79***	135	.62	221.64***
2.	Intelligence	.15**	134	.02	8.56**
3.	Chi. syl. discrimination	.20**	132	.06	11.35***
	Chi. categorical percept.	-.14*			
4.	Chi. phono. awareness	.11	130	.04	11.46***
	Chi. morpho. awareness	.18***			

Set 4: predicting English vocabulary

Step	Independent variable	Final betas	*df*s	R^2 Δ	*F* Δ
1.	Age	.65***	124	.42	91.17***
2.	Intelligence	.23**	123	.05	11.70**
3.	Eng. phono. awareness	.34**	121	.03	18.07***
	Eng. morpho. awareness	.26**			
4.	Eng. syl. discrimination	.06	119	.00	0.47
	Eng. categorical percept.	-.03			
1.	Age	.65***	124	.42	91.17***
2.	Intelligence	.23**	123	.05	11.70**
3.	Eng. syl. discrimination	.11	121	.01	3.19*
	Eng. categorical percept.	-.14			
4.	Eng. phono. awareness	.13**	119	.10	14.29***
	Eng. morpho. awareness	.25*			

Note: *$p < .05$, **$p < .01$, ***$p < .001$

Table 6.

Hierarchical Regressions Examining the Association between Speech Perception and Phonological Awareness

Set 5: predicting Chinese and English phonological awareness

Outcome variable	Step	Independent variable	Final betas	*df*s	R^2 Δ	*F* Δ
Chi. phono. awareness	1.	Age	.76***	135	.58	186.64***
	2.	Intelligence	.16**	134	.03	8.89**
	3.	Chi. categorical perception	-.17**	132	.04	7.96**
		Chi. syllable discrimination	.13*			
Eng. phono. awareness	1.	Age	.74***	131	.54	155.11***
	2.	Intelligence	.13*	130	.02	4.99*
	3.	Eng. categorical perception	-.19**	128	.03	5.19**
		Eng. syllable discrimination	.07			

Note: *$p < .05$, **$p < .01$, ***$p < .001$

Table 7.

Hierarchical Regressions Examining L1-to-L2 Transfer

Set 6: predicting English word reading

Step	Independent variable	Final betas	*df*s	R^2 Δ	*F* Δ
1.	Age	.75***	131	.57	172.45***
2.	Intelligence	.16**	130	.02	8.03**
3.	Eng. awareness[a]	.26**/.46***	126	.18	23.21***
	Eng. speech perception[b]	-.02/.03			
4.	Chi. phono. awareness	.20*	125	.01	5.45*
1.	Age	.75***	131	.57	172.45***
2.	Intelligence	.16**	130	.02	8.03**
3.	Eng. awareness	.26**/.46***	126	.17	23.21***
	Eng. speech perception	-.02/.03			
4.	Chi. morpho. awareness	.15*	125	.01	3.38*
1.	Age	.75***	129	.56	163.73***
2.	Intelligence	.15**	128	.02	7.14**
3.	Eng. awareness	.26**/.46***	124	.18	22.64***
	Eng. speech perception	-.02/.03			
4.	Chi. syl. discrimination	.09	123	.00	2.39
1.	Age	.75***	129	.57	169.40***
2.	Intelligence	.16**	128	.02	8.31**
3.	Eng. awareness	.26**/.45***	124	.17	22.79***
	Eng. speech perception	-.02/.03			
4.	Chi. categorical percept.	-.11*	123	.01	4.00*

Set 7: predicting English vocabulary

Step	Independent variable	Final betas	*df*s	R^2 Δ	F Δ
1.	Age	.65***	124	.42	91.17***
2.	Intelligence	.23**	123	.05	11.70**
3.	Eng. awareness	.33**/.24*	119	.13	9.19***
	Eng. speech perception	.06/-.03			
4.	Chi. phono. awareness	.11	118	.00	0.87
1.	Age	.65***	124	.42	91.17***
2.	Intelligence	.23**	123	.05	11.70**
3.	Eng. awareness	.33**/.24*	119	.13	9.19***
	Eng. speech perception	.06/-.03			
4.	Chi. morpho. awareness	.09	118	.00	.64
1.	Age	.64***	122	.41	85.51***
2.	Intelligence	.22**	121	.05	10.85**
3.	Eng. awareness	.33**/.24*	117	.13	9.06***
	Eng. speech perception	.05/-.03			
4.	Chi. syl. discrimination	.05	116	.00	0.30
1.	Age	.65***	122	.42	88.66***
2.	Intelligence	.22**	121	.05	11.36**
3.	Eng. awareness	.33**/.24*	117	.13	9.30***
	Eng. speech perception	.05/-.03			
4.	Chi. categorical percept.	.12	116	.00	2.83

Note: *$p < .05$, **$p < .01$, ***$p < .001$

[a] Eng. awareness includes English phonological (left of slash) and morphological awareness (right of slash).

[b] Eng. speech perception includes English syllable discrimination (left of slash) and categorical perception (right of slash).