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 predicted reading and vocabulary in both languages, phonological awareness played such a role 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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Overview

The present research examines 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). The main purposes are two: (1) We are interested in whether alphabeticity, which is absent in the L1 but present in the L2, would have an effect on the relative roles of speech perception, phonological and morphological awareness in reading and vocabulary. (2) We are 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 a fine-grained phonological system using the phoneme as the representational unit. Children with a sensitivity to phonemes can distinguish and thus learn more lexical items than those who process speech in larger units, such as the syllable. This view therefore 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 focuses on the number of distinctive features within a phoneme rather than the size of the representational unit, and maintains that a poor-quality phonological representation contains fewer distinctive features than a good-quality one; that is, the former is underspecified (Elbro, 1996).

Chiappe, Chiappe, and Gottardo (2004) argue that while expressive and receptive vocabulary place similar demands on children's sensitivity to phonemes, the former requires greater phonological specification in terms of distinctive features than the latter. Therefore if the phonological representation of poor readers is less phonemic than that of good readers as the lexical restructuring hypothesis claims, reading and phonological awareness should correlate similarly with both vocabulary types. But if variability in phonological representation has more to do with the number of distinctive features (i.e., degree of specification), then reading and phonological awareness should correlate more with expressive than receptive vocabulary. Chiappe et al. (2004) reported that reading and phonological awareness turned out to be more closely related to expressive than receptive vocabulary, 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 ages. 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 Cantonese. 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 task, such as syllable and phoneme deletion, to a similar group of Cantonese 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 Cantonese 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 Cantonese ESL children's Cantonese 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.

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.

The Present Study

The present research addresses these two issues using Hong Kong ESL children residing in a non-English 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. In addition to reading, vocabulary is also examined as an outcome variable because it has been shown to rely as much on phonological representation (Metsala & Walley, 1998; Gathercole & Baddeley, 1993). Hence, the pattern of interrelations among speech perception, phonological awareness, and reading across the L1 and L2 may also emerge with vocabulary.

Beside phonological awareness, the present study also examines the effect of morphological awareness on reading and vocabulary. Morphological awareness is the recognition of morphemes as basic meaning units and an ability to combine and re-combine them to form new lexical items. Morphological awareness is therefore a more semantically than phonologically based ability. Some recent research has shown that morphological awareness is clearly associated with reading and vocabulary over and above phonological awareness (McBride-Chang, Cho, Liu, Wagner, Shu, Zhou, Cheuk, & Muse, 2005; McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003). Hence the inclusion of morphological awareness in our design enables us to control for meaning-level effects while looking at phonological effects, and vice versa.

We use speech 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; Joanisse et al., 2000; Manis, McBride-Chang, Seidenberg, Keating, Doi, Munson, & Petersen, 1997; McBride-Chang, 1996). In the present study we ask the following questions:

(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) and English (L2)?

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

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

(4) What are the developmental trends like in speech perception?

Method

Participants

We recruited 141 Cantonese-speaking, Chinese-reading children residing in Hong Kong. They comprised three groups of 50 participants coming from three respective grade levels, thus 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 elementary 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.

Design, Materials and Procedures

Before testing, parents’ or guardians' informed consents for children participation were obtained. 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 and used them in subsequent analyses. 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 standardized 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 three-syllable real words and 14 three-syllable pseudo-words. 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 test, 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. Syllable and phoneme deletion were used to measure English phonological awareness. Syllable deletion required the child to drop one syllable from a three-syllable phrase. For example, the item "one teapot" was presented and the child was required to omit "one" and produce "teapot". Sixteen trials were used for syllable deletion; half of the items were real words or phrases and half of them were pseudo-words. Of the 16 items, 4 required deletion of the first syllable, 4 required deletion of the last syllable, and 8 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 morphemes were recognized and legally re-combined. "Crymer” was less satisfactory and worth 1 point, because it was based on re-combining syllables rather than morphemes. 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/[1] (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,

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

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 Joannisse, Manis, Keating, and Seidenberg (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.

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 prime, 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 prime scores were calculated using the same method as in Cantonese syllable discrimination to indicate discrimination sensitivity.

Insert Table 1 about here

Results

Averaged Performances

Averaged performances are 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 participant 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 (*n* = 150), controlling for age, nonverbal intelligence, and forward digit span. Reading and vocabulary in the L1 and L2 are intercorrelated. In either language, phonological and morphological awareness correlate with reading and vocabulary. Speech perception appears to be more closely associated with reading, vocabulary, and the two metalinguistic awareness in the L1 than L2. Metalinguistic awareness predicts reading and vocabulary cross-linguistically. While L1 speech perception appears to be generally related to L2 reading and vocabulary, L2 speech perception correlates with neither L1 reading nor vocabulary.

Insert Table 3 about here

Regressions

Hierarchical multiple regressions were performed to examine the hypotheses more closely. In these regressions, age and nonverbal intelligence were entered at the first step, and forward digit span was entered at the second, so that their contributions were removed before the critical predictors were examined. There were 4 regressions in set 1, using Chinese reading as the dependent variable and each of the following as the last entered independent variable, respectively: Chinese morphological and phonological awareness, and Chinese categorical perception and syllable discrimination. 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, categorical perception, 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.

Regression sets 5 and 6 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 6.

Insert Table 6 about here

Finally, 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 7.

Insert Table 7 about here

Discussion

In the present study, Chinese ESL children from three grade levels were tested on metalinguistic awareness (phonological and morphological), speech perception (syllable discrimination and categorical perception), word reading, and vocabulary in both Chinese and English. We examine whether similar patterns of intercorrelations can be established in the two languages, and whether Chinese (L1) metalinguistic awareness and speech perception predict English (L2) reading and vocabulary. We are also interested in examining the development of speech perception in these bilingual children. Overall speaking, our findings showed that there are both similarities and differences between the L1 and L2 in how the variables correlate with one another, as well as how speech perception develops across age. L1-to-L2 influence (i.e., transfer) is demonstrable for word reading but not vocabulary.

Development of Speech Perception

With regard to the research question about developmental trends in bilingual speech perception, what we found indicates 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.

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 the L1 and L2 after controlling for phonological awareness; (2) phonological awareness is associated with reading and vocabulary in both the L1 and L2 before controlling for morphological awareness, as shown in the partial correlations; (3) phonological awareness predicts reading and vocabulary only in the L2 after controlling for morphological awareness. Hence, morphological awareness is important in reading and vocabulary in both Chinese and English, whereas phonological awareness appears to be more critical in English than Chinese reading and vocabulary. 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 morphology, which has to do with the construction of word-level meaning, appears to be universally important in reading and vocabulary, because the derivation of meaning is a common focus of these activities regardless of language and script.

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 this 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 the 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.

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-Chinese 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, Chiappe, and Gottardo (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.

Speech Perception and Phonological Awareness

Finally, there are indications 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).

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.

Conclusion

To conclude, we establish some development trends in speech perception across three age cohorts of Chinese-English bilingual children. Speech perception is involved in the development of phonological awareness in either language; it is also involved in reading and vocabulary development in the L1 but not the L2. While morphological awareness predicts reading and vocabulary in both languages, phonological awareness is predictive of them only in the alphabetic L2. L1-to-L2 transfer occurs with speech perception and metalinguistic awareness in L2 reading but not vocabulary. Cross-language differences in the relationships among speech perception, metalinguistic awareness, reading, and vocabulary are attributable to variations in learning context and script nature between the two languages.

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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.

Averaged performance

	A kindergartners (*n* = 43-50)	B 2nd graders (*n* = 46-48)	C 4th graders (*n* = 42-43)	F- value	Post hoc by Tukey
age in month	69.1 (3.9)	99.2 (10.3)	118.6 (7.0)	515.5***	A< B < C
forward digit span	4.4 (1.5)	5.1 (1.5)	6.6 (1.2)	29.1***	A < B < C
nonverbal intelligence	22.5 (5.7) [out of 36]	32.1 (7.8) [out of 60]	43.2 (6.4) [out of 60]	/	/
Chinese variables					
word reading (max=184)	42.3 (32.5)	124.8 (20.4)	163.6 (11.6)	322.1***	A < B < C
vocabulary (max= 106)	18.1 (6.2)	32.7 (8.8)	54.3 (11.3)	191.8***	A < B < C
morphological awareness (max= 27)	10.5 (4.5)	17.1 (5.6)	25.9 (1.5)	146.6***	A < B < C
phonological awareness (max= 67)	20.1 (7.3)	32.7 (7.9)	44.5 (7.3)	122.6***	A < B < C
syllable discrimination: d'	-1.3 (1.8)	0.1 (1.6)	1.3 (0.6)	33.9***	A < B < C
categorical perception: slope	0.99 (0.02)	0.98 (0.03)	0.94 (0.04)	37.4***	A = B < C
English variables					
word reading (max=80)	10.5 (14. 6)	37.1 (18.9)	68.9 (7.6)	183.7 ***	A < B < C
vocabulary (max=204)	23.8 (10.9)	36.9 (10.8)	48.4 (9.8)	59.2***	A < B < C
morphological awareness (max=27)	7.8 (3.2)	12.1 (4.4)	19.1 (2.6)	119.1***	A < B < C

phonological awareness (max=45)	14.1 (8.1)	25.7 (8.9)	36.1 (5.1)	97.4***	A < B < C
syllable discrimination: d’	-0.8 (1.8)	0.3 (1.2)	0.5 (1.1)	10.5***	A < B = C
categorical perception: slope	1.00 (0.02)	0.99 (0.03)	0.96 (0.03)	32.6***	A = B < C

Note: *** p <.001

Table 3.

Partial correlations controlling for age, nonverbal intelligence, and forward digit span

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Chinese variables												
1. word reading	--											
2. vocabulary	.42***	--										
3. morphological awareness	.41***	.46***	--									
4. phonological awareness	.27**	.24**	.43***	--								
5. syllable discrimination	.34***	.29**	.25**	.19*	--							
6. categorical perception	-.18*	-.29**	-.20*	-.27**	-.26**	--						
English variables												
7. word reading	.56***	.49***	.49***	.46***	.30**	-.27**	--					
8. vocabulary	.26**	.26**	.32***	.38***	.23*	-.00	.62***	--				
9. morphological awareness	.34***	.50***	.54***	.43***	.26**	-.18*	.61***	.40***	--			
10. phonological awareness	.31**	.35***	.44***	.58***	.30**	-.19*	.49***	.44***	.46***	--		
11. syllable discrimination	.13	.01	.09	.13	.43***	-.09	.12	.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

Set 1: predicting Chinese word reading

step	cumulative R^2	R^2 change
1. age, intelligence	.76	.76***
2. forward digit span	.76	-
3. Chi. syl. discrimination	.79	.03***
4. Chi. categorical percept.	.79	-
5. Chi. phono. awareness	.80	.01*
6. Chi. morpho. awareness	.82	.02***
1. age, intelligence	.76	.76***
2. forward digit span	.76	-
3. Chi. morpho. awareness	.80	.04***
4. Chi. syl. discrimination	.81	.01**
5. Chi. categorical percept.	.81	-
6. Chi. phono. awareness	.82	-
1. age, intelligence	.76	.76***
2. forward digit span	.76	-
3. Chi. morpho. awareness	.80	.04***
4. Chi. phono. awareness	.80	-
5. Chi. syl. discrimination	.81	.01**
6. Chi. categorical percept.	.82	-
1. age, intelligence	.76	.76***
2. forward digit span	.76	-
3. Chi. morpho. awareness	.80	.04***
4. Chi. phono. awareness	.80	-
5. Chi. categorical percept.	.81	-
6. Chi. syl. discrimination	.82	.01*

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

Set 2: predicting English word reading

step	cumulative R^2	R^2 change
1. age, intelligence	.59	.59***
2. forward digit span	.59	-
3. Eng. syl. discrimination	.60	-
4. Eng. categorical percept.	.60	-
5. Eng. phono. awareness	.69	.09***
6. Eng. morpho. awareness	.77	.08***
1. age, intelligence	.59	.59***
2. forward digit span	.59	-
3. Eng. morpho. awareness	.74	.15***
4. Eng. syl. discrimination	.74	-
5. Eng. categorical percept.	.74	-
6. Eng. phono. awareness	.77	.03***
1. age, intelligence	.59	.59***
2. forward digit span	.59	-
3. Eng. morpho. awareness	.74	.15***
4. Eng. phono. awareness	.77	.03**
5. Eng. syl. discrimination	.77	-
6. Eng. categorical percept.	.77	-
1. age, intelligence	.59	.59***
2. forward digit span	.59	-
3. Eng. morpho. awareness	.74	.15***
4. Eng. phono. awareness	.77	.03**
5. Eng. categorical percept.	.77	-
6. Eng. syl. discrimination	.77	-

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

Table 5.

Hierarchical regressions predicting vocabulary

Set 3: predicting Chinese vocabulary

step	cumulative R^2	R^2 change
1. age, intelligence	.64	.64***
2. forward digit span	.64	-
3. Chi. syl. discrimination	.68	.04***
4. Chi. categorical percept.	.70	.02*
5. Chi. phono. awareness	.70	-
6. Chi. morpho. awareness	.75	.05***
1. age, intelligence	.64	.64***
2. forward digit span	.64	-
3. Chi. morpho. awareness	.72	.13***
4. Chi. syl. discrimination	.74	.01**
5. Chi. categorical percept.	.75	.01*
6. Chi. phono. awareness	.75	-
1. age, intelligence	.64	.64***
2. forward digit span	.64	-
3. Chi. morpho. awareness	.72	.08***
4. Chi. phono. awareness	.72	-
5. Chi. syl. discrimination	.74	.02**
6. Chi. categorical percept.	.75	.01*
1. age, intelligence	.64	.64***
2. forward digit span	.64	-
3. Chi. morpho. awareness	.72	.08***
4. Chi. phono. awareness	.72	-
5. Chi. categorical percept.	.73	.01*
6. Chi. syl. discrimination	.75	.02*

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

Set 4: predicting English vocabulary

step	cumulative R^2	R^2 change
1. age, intelligence	.47	.47***
2. forward digit span	.48	-
3. Eng. syl. discrimination	.49	-
4. Eng. categorical percept.	.50	-
5. Eng. phono. awareness	.58	.08***
6. Eng. morpho. awareness	.61	.03*
1. age, intelligence	.47	.47***
2. forward digit span	.48	-
3. Eng. morpho. awareness	.56	.08***
4. Eng. syl. discrimination	.57	-
5. Eng. categorical percept.	.57	-
6. Eng. phono. awareness	.61	.04**
1. age, intelligence	.47	.47***
2. forward digit span	.48	-
3. Eng. morpho. awareness	.56	.08***
4. Eng. phono. awareness	.60	.04***
5. Eng. syl. discrimination	.60	-
6. Eng. categorical percept.	.61	-
1. age, intelligence	.47	.47***
2. forward digit span	.48	-
3. Eng. morpho. awareness	.56	.08***
4. Eng. phono. awareness	.60	.04***
5. Eng. categorical percept.	.60	-
6. Eng. syl. discrimination	.61	-

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

Table 6.

L1-to-L2 transfer effects

Set 5: predicting English word reading

step	cumulative R^2	R^2 change
1. age, intelligence	.59	.59***
2. forward digit span	.59	-
3. Eng. awareness and speech percept.	.77	.18***
4. Chi. phono. awareness	.78	.01*
1. age, intelligence	.59	.59***
2. forward digit span	.59	-
3. Eng. awareness and speech percept.	.77	.18***
4. Chi. morpho. awareness	.78	.01**
1. age, intelligence	.58	.58***
2. forward digit span	.58	-
3. Eng. awareness and speech percept.	.76	.18***
4. Chi. syl. discrimination	.77	-
1. age, intelligence	.59	.59***
2. forward digit span	.59	-
3. Eng. awareness and speech percept.	.75	.16***
4. Chi. categorical percept.	.76	.01*

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

Set 6: predicting English vocabulary

step	cumulative R^2	R^2 change
1. age, intelligence	.47	.47***
2. forward digit span	.48	-
3. Eng. awareness and speech percept.	.61	.13***
4. Chi. phono. awareness	.61	-
1. age, intelligence	.47	.47***
2. forward digit span	.48	-
3. Eng. awareness and speech percept.	.61	.13***
4. Chi. morpho. awareness	.61	-
1. age, intelligence	.46	.46***
2. forward digit span	.46	-
3. Eng. awareness and speech percept.	.60	.14***
4. Chi. syl. discrimination	.60	-
1. age, intelligence	.47	.47***
2. forward digit span	.47	-
3. Eng. awareness and speech percept.	.61	.14***
4. Chi. categorical percept.	.62	-

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

Table 7.

Hierarchical regressions predicting Chinese and English phonological awareness

outcome variable	step	cumulative R^2	R^2 change
Chi. phono. awareness	1. age, nonverbal intelligence	.61	.61***
	2. forward digit span	.61	-
	3. Chi. syllable discrimination	.63	.02**
	4. Chi. categorical perception	.65	.02**
Chi. phono. awareness	1. age, nonverbal intelligence	.61	.61***
	2. forward digit span	.61	-
	3. Chi. categorical perception	.64	.03**
	4. Chi. syllable discrimination	.65	.01*
Eng. phono. awareness	1. age, nonverbal intelligence	.56	.56***
	2. forward digit span	.56	-
	3. Eng. syllable discrimination	.57	-
	4. Eng. categorical perception	.60	.03**
Eng. phono. awareness	1. age, nonverbal intelligence	.56	.56***
	2. forward digit span	.56	-
	3. Eng. categorical perception	.59	.03**
	4. Eng. syllable discrimination	.60	-

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