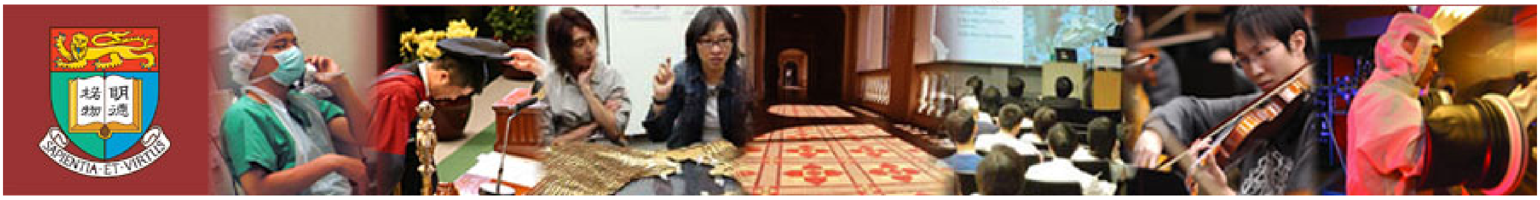

Title	Cross-linguistic perception of pitch of Chinese dyslexic children
Author(s)	Fung, King-yiu; 馮景耀
Citation	Fung, K. [馮景耀]. (2013). Cross-linguistic perception of pitch of Chinese dyslexic children. (Thesis). University of Hong Kong, Pokfulam, Hong Kong SAR.
Issued Date	2013
URL	http://hdl.handle.net/10722/238531
Rights	This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.; The author retains all proprietary rights, (such as patent rights) and the right to use in future works.

Cross-linguistic perception of pitch of Chinese dyslexic children

Fung King Yiu

A dissertation submitted in partial fulfillment of the requirements for the Bachelor of Sciences (Speech and Hearing Sciences), The University of Hong Kong, June 30, 2013.

Abstract

This study examined the relationship between perception of basic auditory processing measures, detection of suprasegmental features and bilingual literacy among Hong Kong children with and without reading difficulties. Sixty native Cantonese speakers with the average age of 7; 11 participated in the study. Forty-four children were age-matched controls and 16 of them were diagnosed to have dyslexia. A series of tasks assessing auditory processing ability, detection of suprasegmental features of both Chinese and English and literacy were given all participants. Tone detection was the strongest predictor to all the scores of Chinese literacy task. There was no significant difference in sensitivity to English prosody task between groups. For auditory processing measures, significant differences between groups were only found in 1 rise and intensity task. Regression analysis showed that auditory threshold of rise time discrimination predicted 20% unique variance of sensitivity to tone detection. We concluded that detection of lexical tone in Chinese was an important linguistic marker that may help diagnose children with reading difficulties in Chinese. Normal children made use of intensity cues to detect rise time. Suggestions were also made to improve the validity of English prosody sensitivity task.

Keywords: Dyslexia, auditory processing, suprasegmental features

Cross-linguistic perception of pitch of Chinese dyslexic children

Lyon, Shaywitz, and Shaywitz (2003) defined dyslexia as "a specific language-based disorder of constitutional origin characterized by difficulties in single word decoding, usually reflecting insufficient phonological processing" (p.2). The range of dyslexia for school-age children is from 1% to 11%, depending on the writing system adopted by the community (Chan, Ho, Tsang, Lee, & Chung, 2007). In Hong Kong, the prevalence rate of dyslexia in Hong Kong children was 9.7% (Chan et al., 2007). There are converging evidences for the negative consequence of dyslexia on low self-esteem (e.g., Ingesson, 2007). Given the prevalence and negative consequences of dyslexia, it is important to understand the linguistic profile of the dyslexic children, and develop a better intervention program to help children overcome the difficulties in word reading.

Hong Kong children in primary school age exhibit several characteristics of reading and writing acquisition. The medium of instruction of Hong Kong primary education is Cantonese, a Chinese language that is spoken in south China. English is taught as a second language since primary education (Information Services Department, 2012). The diagnostic criterion of dyslexia in Hong Kong primarily relies on the children's performance on Hong Kong test of specific learning difficulties in reading and writing (HKT-SpLD) (Ho, Chan, Tsang, & Lee, 2000). A school-age student is diagnosed with dyslexia if he/ she fulfills the following criteria: (i) IQ is above 85 (as assessed by Hong Kong – Wechsler Intelligence Scale for Children or equivalent), (ii) scores on the literacy test domain (i.e., Chinese word reading, one-minute reading and Chinese word dictation) and (iii) on one or more of the cognitive test domains (i.e., naming speed, phonological awareness, phonological memory and orthographic knowledge) are within or less than 3 standard deviations. Although the focus of current diagnostic criteria puts on Chinese reading and its related skills only, Hong Kong dyslexic children also showed high concomitance rate of reading difficulties in English

(Ho & Fong, 2005). Past studies on reading problems among Chinese dyslexic children mainly took account of merely segmental phonological awareness (e.g., Shu, Peng, & McBride-Chang, 2008), phonological awareness and amplitude envelope perception (e.g., Goswami, Wang, et al., 2010; Wang, Huss, Hämäläinen, & Goswami, 2012), or phonological awareness and sensitivity of suprasegmental features (Cheung et al., 2009; Meng et al., 2005). There were few studies to date examining the association between the sensitivity of suprasegmental features and amplitude envelope perception in English speaking population (Goswami, Gerson, & Astruc, 2009) but none of them examined children with Chinese as first language and English as second language. In the present study, we address this issue.

Suprasegmental features include lexical stress and intonation. They are represented in acoustic cues such as intensity, duration, fundamental frequency and spectral quality (Meng et al., 2009). Chinese and English have different representations of suprasegmental features. Chinese is a tone language. Lexical tone is created by changing the fundamental frequency pattern of a given Chinese syllable (Francis, Ciocca, Ma, & Fenn, 2008). There are six leveled contour tones and three entering tones. Tone marks the meaning of spoken words with a given sequence of vowels and consonants. For example, /fu/ with high-level tone means ‘skin’, with medium-rising tone means ‘tiger’, with medium level tone means ‘shorts’, with low-falling tone means ‘symbol’, with low-rising tone means ‘woman’ and with low-level tone means ‘father’. In contrast, English is a stressed-time language which means the duration among stressed syllables is approximately the same (Goswami et al., 2010). A rhythmic unit, called metrical feet, is composed of a stressed syllable. Feet comprised of a stressed then unstressed syllable is called the trochaic pattern, while feet comprised of unstressed then stressed syllable is called iambic pattern (Hayes, 2011).

There are evidences showing dyslexic children’s low sensitivity to suprasegmental features of languages. Corriveau, Pasquini, and Goswami (2007) pointed out that early insensitivity to suprasegmental features such as speech rhythm and stress could have profound effects on the development of the language system. Goswami et al. (2009) found that English dyslexic children had impaired sensitivity to phrase level prosodic cues such as metrical structure. Such impairment affected child word reading and spelling. Similar causal effect between low sensitivity of suprasegmental features and poor reading ability was noted in Chinese language. Cheung et al. (2009) found that dyslexic children perceived Cantonese tone less categorically and accurately than age-matched controls, and speech perception in terms of categorical perception of Cantonese tonal contrast affected word reading through its association with phonological processing skills in Chinese children. Another study conducted by Meng et al. (2005) compared dyslexic and normal developing Chinese children in auditory processing (i.e, tone frequency discrimination and composite tone pattern discrimination), speech processing (i.e., tone temporal order judgment and temporal interval discrimination) and reading development found that these auditory and speech processing tasks are highly correlated with Chinese children’s linguistic ability including vocabulary, reading fluency and phonological awareness which contributes to children’s word reading development. However, there is so far no literature discussing the association between sensitivity to prosodic cues in English and English reading ability among Hong Kong dyslexic children. It is worthwhile to study whether dyslexic children in Hong Kong have impairment perception of English lexical stress. If yes, will such impairment affect their English reading skills?

Besides sensitivity of suprasegmental features, Goswami et al. (2010) found that rise time sensitivity was a consistent predictor of reading development to Chinese and English. Dyslexic children had higher threshold to rise time in Chinese and English than chronological age peers. However, this study mainly focused on the association between rise time sensitivity and segmental phonological processing in either word or phonemic levels.

Another study carried out by Goswami et al. (2009) investigated the association between rise time threshold and sensitivity to English phrase level prosodic features. They found that rise time threshold (i.e., 1 rise and rise duration rove measure) predicted up to 14% of unique variance in prosodic sensitivity. Even so, whether rise time threshold was a significant predictor to sensitivity of Chinese lexical tone and Chinese literacy still remains unsolved. As evidence above showed that deficits in lexical tone perception affect reading development in Chinese, it is also important to study whether rise time is a predictor to sensitivity to lexical tone of Chinese.

In the present study, two hypothesis will be addressed. First, on the basis of the previous studies, it seems plausible that besides poor lexical tone perception of Chinese, Hong Kong dyslexic children may also have deficits in detection of prosodic patterns of English, which in turn affects the reading competence. Second, higher rise time threshold may result in poorer lexical tone perception of Chinese dyslexic children, thus affecting reading performance of dyslexic children. We test these two hypotheses in Hong Kong Chinese children who learn to read Chinese and English two scripts.

Method

Participants

Sixty local children aged from to 6 to 10 participated in the study. Forty-four of them were normal children (age *M* : 7;11) without any history of reading and writing difficulties. Among 44 normal children, 31 of them were recruited from a local primary school in Tuen Mun, 1 of them was recruited from a community centre and the remaining 12 children were recruited from author's friends or relatives. Sixteen of them were diagnosed as dyslexic (age *M* : 7;10) by the educational psychologist from their schools according to above-mentioned diagnostic criteria with reference to the performance of HKT-SpLD. All of the dyslexic children were referred from the Speech Therapy Unit of the Hong Kong Polytechnic

University through voluntary means. None of the participants had any other neurological disorders. All of participants study in local primary schools with Cantonese as their medium of instruction. They are all bilingual having Cantonese as their first language and English as their second language. Table 1 displays the demographic information of the participants. To examine whether there are differences in chronological age and socioeconomic status of two groups of participants, we conducted two independent t-tests on age and average income of two groups. The result of *t*-tests indicated that two groups were comparable in terms of age and socioeconomic status.

Table1
Demographic information of the participants

	Normal (*N*=44)	Dyslexic (*N*=16)	*F* (58)
Age (Age; month)	7;11 (0;09)	7;10 (1;01)	4.776 (D=N)
Family income	20238.1	23076.92	.002 (D=N)
Education level of parents (%)			
Primary Graduate	6.82	6.25	
Junior Secondary Graduate	29.55	25	
Senior Secondary Graduate	29.55	37.5	
Undergraduate education (or equivalent)	11.36	12.5	
Holder of Bachelor degree (or equivalent)	11.36	9.38	
Postgraduate Education	3.41	3.13	

Tasks

Non-verbal intelligence

Raven’s Standard Progressive Matrices (Raven, 1960) were administered on all participants to assess their non-verbal IQ scores and confirm their eligibility of participation.

Children were asked to select a plate from six choices to complete a visual matrix. All of the eligible participants must have normal intelligence, i.e., did not fall below 5th percentile in the age-equivalent normative score.

Chinese and English literacy measures

Literacy of Chinese and English was examined by components of HKT-SpLD (Ho et al., 2000), Woodcock Reading Mastery Test revised form G (Word identification and word attack) (Woodcock, 1998) and English word reading test replicated from Tong and McBride-Chang (2010) respectively.

Chinese literacy measures. Three tests from HKT-SpLD consisted of Chinese word dictation, Chinese word reading and one-minute reading test were administered. Chinese word dictation contained 48 two-character vocabularies. In each trial, the test administrator read aloud a two-word vocabulary. The participants were asked to write down the word on a specified answer sheet. One mark was given for any correct word. The test was terminated when they failed to write down the target vocabulary for eight consecutive trials. Chinese word reading test contained 150 two-character Chinese vocabularies with ascending difficulties. Participants were asked to read aloud the vocabularies until they failed to read aloud fifteen consecutive vocabularies correctly. One mark was given if the participant was able to read both characters in a vocabulary correctly. One-minute reading test contained 90 two-character vocabularies. The participants were given one minute to read aloud the vocabularies one by one as fast as possible. The number of correctly produced vocabularies within one minute was recorded.

English literacy measures. Word identification test contained 46 English words with ascending difficulty. Participants were asked to read aloud the words printed on a prompt book until they failed in 4 consecutive trials. Participant was awarded one mark for each correctly pronounced word. Word attack test contained 26 English non-words. Each correctly pronounced word scored one mark. Participants were asked to read aloud the words until they scored 0 mark in four consecutive trials. Two practice trials were given to them before actual test started. Feedback was provided on these trials. English word reading test consisted of 60 words chosen from Hong Kong Chinese children's English textbooks. The words were arranged in a list in ascending order of grade levels from third grade of kindergarten to fifth grade in primary schools. There were 10 words in each grade. The participants were asked to read the words one by one from the beginning of the list. One mark was given for a correctly pronounced word. The test terminated when the client failed to read the words in 15 consecutive trials.

Auditory processing tasks

Auditory processing ability (including rise time and intensity threshold) of the participants was assessed using a child-friendly 'Dinosaur' Program (created by Dorothy Bishop, Oxford University, 2001). The stimuli were presented in a forced choice paradigm. Participants were asked to choose a target stimulus from a set of choices. Two types of paradigms were used: two-interval forced-choice paradigm (2IFC) and AXB paradigm. In 2IFC paradigm, two sounds were presented consecutively as the sounds made by two distinctive cartoon dinosaurs (500 ms inter-stimulus interval). This paradigm can effectively assess the participant's ability in detecting changes of target behavior and reduce the memory loading of the participants (Kuppen, Huss, Fosker, Fegan, & Goswami, 2011). In the AXB paradigm, three sounds were presented consecutively as the sound made by three distinct cartoon characters (500 ms IOI). The middle stimulus was the standard stimulus and either the first (A) or the last (B) stimulus was different from the standard (Kuppen et al., 2011). The purpose of the use of AXB paradigm was to allow participant to make comparison of the test stimuli (A or B) with the standard tone (X) (Gerrits, 2001). Five practice trials were given before the start of each task. Visual feedback was provided upon every correct choice.

An adaptive staircase procedure (Levitt, 1971) was used to place stimuli as close to the participant's threshold level as possible. After 2 reversals, the 2-up 1-down staircase procedure changed into 3-up 1-down. The step size halved after the forth and sixth reversal. A test run terminated after eight response reversals or alternatively after the maximum possible 40 trials. One amplitude rise time task in AXB paradigm (1 rise task), one amplitude rise time task with intensity roving in 2 IFC paradigm (rise rove) and intensity discrimination task in 2 IFC paradigm (Intensity ABABA) were carried out. The test procedure replicated Kuppen et al. (2011). A detail of the test procedure was listed in appendix A. To ensure the participants understood the operation of the computer tasks, practice trials were provided before presentation of the experimental tasks. Participants were required to answer four of five practice trials correctly.

Linguistic pitch and suprasegmental processing Tasks

Chinese tone detection task. In tone detection task, two CV syllables (/ji/ and /fu/) with 6 different tones were chosen as test stimuli, creating a total of 12 different meaningful words. These words were represented in separated pictures. The pictures and the corresponding pronunciation of these words were presented before the start of the test. The participant was then asked to name all these pictures again to ensure that they knew which word the picture referred to. There were 3 test trials and 48 actual trials. In the actual test, the administrator first presented 2 pictures (out of the 12 pictures introduced before) to the participant. The pictures were presented in minimal pairs with only tonal contrast (e.g., /ji1/衣 and /ji3/意). Then the administrator played the sound track containing a target word of the pair to the participant. The participant was asked to point to the picture corresponded to the target word. Each correct item scored 1 point.

English prosodic sensitivity (DeeDee) task. Part of the stimuli developed by Goswami et al. (2009) was used. A total of 18 stimuli were selected. All of the test stimuli were recorded in a separated sound track. Each sound track comprised a name of film (e.g., Pokemon) and two synthesized Dee tokens (stressed and unstressed in initial Vs. final position, e.g., Deedee Deedee or dee Deedee Dee). The tokens were presented consecutively with a separation of 2 seconds. The participant was asked to choose the correct pattern verbally. Each correct answer scored 1 mark. Two practice trials were given before the actual task began.

Procedures

All of the tests above were either conducted by the author or the author’s classmates who are well-trained speech and hearing sciences majored students. All test administrators had received at least one-hour training about the test administration before carrying out actual test. The parents of each participant were asked to fill in a questionnaire about the language, social and musical background of the participant and his/ her family before the actual test (see appendix B). For normal children, 12 of them were assessed at home individually. Raven’s Standard Progressive Matrices were first presented. Then Chinese word dictation test was presented. The remaining tests were presented in a random order. Thirty-one of them were assessed in a quiet room within their school during lunch break, or within lessons. One of them was assessed in a quiet room in a local community centre after school. All of these 32 students first received group tests on Chinese word dictation, Deedee task and Chinese tone detection task. Then the remaining tasks (i.e., Raven Standard Progressive matrics, Chinese word reading, one minute reading, word identification, word attack, English word reading test and dinosaur program) were administered individually in a random order. All of the dyslexic children were assessed in their home. Raven’s Standard Progressive Matrices and Chinese word dictation were presented first. Then the remaining tests were presented in a random order. Session lengths varied due to children’s attentiveness and their performance on the tests. On average, a child took 1.5 to 2 hours to complete all the tasks.

Results

Cognitive and Linguistic Profile between Normal and Dyslexic children.

Table 2 shows the mean and standard deviations of the cognitive and linguistic measures of normal and dyslexic children. To compare the cognitive and linguistic ability (in terms of both Chinese and English) of normal and dyslexic children, we conducted multivariate analysis of variance (MANOVA) with group (dyslexics vs. controls) as independent variable and the scores of cognitive and literacy tasks as dependent variables. There was a significant main effect on two groups of participants (Wilks' Lambda = .287, $F(7,52) = 18.410$, $p < .001$, $\eta^2 = .713$). Individual analysis of variance (ANOVA) between groups (dyslexic Vs. Normal) showed that normal group and dyslexic group had comparable scores in Raven's Standard Progressive Matrices (F (1,58) = 1.988, p =.164, η^2 =.000). Also, normal children had significantly higher scores in all the literacy measures.

Comparison of Auditory Processing of Normal Children and Dyslexic Children.

Table 3 below shows the mean and standard deviation of all the auditory processing tasks in normal and dyslexic groups. Normal group had lower mean threshold levels in both 1-rise, rise rove and intensity tasks. To examine the significance of the differences of auditory thresholds, independent analysis of variances (ANOVA) of auditory processing thresholds against group showed that normal children did have significantly lower intensity threshold than the dyslexic group (F (1, 34) = 6.193, p <.05, η2 = .154). One rise threshold also had a marginally significant difference between groups (F(1,34) = 3.783, p=.06, η^2 =.100). Then the number of correct attempts in each category of metric task of each participant was summated as a total score. The average score of metric task in normal children was slightly higher than that of dyslexic children.

Table 2

The mean and the standard deviations on the measures cognitive and linguistic abilities (English and Chinese) of normal and dyslexic children.

Task (Max. Score)	Normal (N=44)	Dyslexic (N=16)	$F(1, 58)$	Partial eta^2
Raven's Standard Progressive Matrices (36)	28.1 (3.8)	28.3 (4.8)	.018	.000
Chinese word dictation (48)	49.1 (18.8)	18.5 (15.3)	33.908***	.369
Chinese word reading (150)	105.8 (18.4)	43.8 (30.3)	92.371***	.614
One minute reading (90)	60.4 (13.1)	30.0 (13.6)	62.144***	.517
English Word Reading Test (60)	26.8 (11.8)	9.44 (7.4)	20.833***	.264
Word Identification (46)	11.8 (3.7)	7.2 (2.7)	14.353***	.198
Word Attack (26)	5.8 (3.7)	1.9 (2.7)	30.217***	.343

* $p < .05$. **$p < .01$ ***$p < .001$

Table 3

Thresholds of auditory processing tasks and mean number of corrected answers in metric task.

	Normal (N=22)	Dyslexic (N=14)	F value	Partial eta^2
1-rise (ms)	146.7 (85.2)	193.0 (30.0)	$F(1,34) = 3.783^a$	.100
Rise rove (ms)	113.5 (59.4)	149.4 (78.2)	$F(1,34) = 2.443$	.067
Intensity (dB)	10.9 (4.4)	14.5 (4.0)	$F(1,34) = 6.193$*	.154
Metric	13.5 (4.1)	13.9 (2.5)	$F(1,58) = 2.672$	.044

* $p<.05$

[a] $p=.06$

The total score was then compared against children groups using ANOVA and the result showed that there was no significant difference in the total scores of metric task among normal and dyslexic group (F(1, 58)= 2.672 , p=.108, observed power = .362).

Comparison of suprasegmental features tasks against groups

Table 4 below shows the mean and standard deviation of the scores of two suprasegmental feature tasks (Chinese tone detection task and English Deedee task). Normal children had higher mean scores than dyslexic children in both tone detection and Deedee task. Two groups of children performed above chance level in Chinese tone detection task. From the mean score of Deedee task, both normal children and dyslexic children performed nearly at chance level (Normal: 59%; Dyslexic: 54%). The differences of scores of two tasks for normal and dyslexic group were examined separately using one-way analysis of variance (ANOVA) with groups as independent variable and scores of the tone detection task or Deedee task as dependent variable. Significant group difference was only noted in tone detection (F(1,58) =5.994, p<.05, η^2 =,094) but not in Deedee task (F(1,58)=2.258, p=.138, observed power =.315). Normal children had significantly higher scores than dyslexic children only in tone detection but not in Deedee task.

Correlations between auditory processing tasks, suprasegmental feature tasks and literacy tasks

Table 5 shows the correlation between auditory processing tasks, suprasegmental feature tasks and all literacy tasks in normal and dyslexic children. One rise threshold in normal children had significant negative correlation with tone detection (r = -.450, p < .01) and all English literacy scores. It also had a positive correlation with rise rove task (r = .423, p < .01). Intensity discrimination task had significant negative correlation with one minute reading task (r = -.355, p < .05). It also had significant positive correlation with rise rove task (r = .394, p < .05). The scores of tone detection task had significant positive correlation with all the English and Chinese literacy measures. To further investigate the relative contribution of auditory processing thresholds to sensitivity of lexical tone detection and literacy competence, multiple regression analysis was carried out.

Table 4

Mean and standard deviation of the scores of Chinese tone detection and English Deedee task.

Task (Max. score)	Normal (*N*=44)	Dyslexic (*N*=16)	*F* (1, 58)	Partial eta^2
Tone Detection (48)	40.3 (3.3)	37.7 (4.6)	5.994*	.673
Deedee (18)	10.6 (1.7)	9.8 (2.2)	2.258	.037

* $p<.05$

Multiple Regression Analysis

Multiple regression analysis was used to explore the relative contribution made by 1 rise threshold to tone detection and tone detection to literacy competence. With reference to our second hypothesis, if deficits of reading performance among dyslexic children can be explained by deficits of lexical tone perception, the variances of scores of lexical tone perception should predict scores of different literacy measures. And if variance in 1 rise threshold accounts for the variance of scores of tone detection task, we can confirm that deficit of lexical tone detection in dyslexic children is contributed by deficits in auditory processing. A series of three-step fixed entry multiple regression equations were created. The order of independent variables entered was as follows: (1) age, (2) scores of Raven’s Standard Progressive Matrices and (3) auditory threshold of 1 rise task or scores of tone detection task.

Table 5

Partial correlation between tasks assessing auditory processing, sensitivity of suprasegmental features and literacy of Chinese and English.

	1	2	3	4	5	6	7	8	9	10	11	12
1. 1 rise	-	.423**	.308	-.356*	-.450**	-337*	-.497**	-.383*	-.466**	-.238	-.195	-.299
2. Rise rove		-	.394*	-.172	-.281	-.200	-.276	-.290	-.221	-.250	.123	-.290
3. Intensity			-	.046	-.024	-.296	-.118	-.133	-.267	-.305	-.227	-.355*
4. Metric				-	.318*	.355**	.291*	.260*	.235	.114	-.080	.037
5. Tone Detection					-	.516**	.488**	.482**	.337**	.498**	.324*	.461**
6. Deedee						-	.380**	.281*	.416**	.555**	.236	.490**
7. English word reading task							-	.872**	.692**	.653**	.596**	.669**
8. Word identification								-	.640**	.613**	.576**	.641**
9. Word attack									-	.530**	.403**	.581**
10. Chinese word dictation										-	.777**	.842**
11. Chinese character recognition											-	.789**
12. One minute reading												-

*$p<.05$. ** $p<.01$.

The purpose of following such order is to allow the independent effects of age and I.Q. to be controlled before explaining the association between auditory processing, Chinese lexical tone detection and Chinese literacy. Table 6 and 7 show the regression between auditory processing and Chinese lexical tone detection and between Chinese lexical tone detection and Chinese literacy respectively. As shown in table 6, non-verbal intelligence and 1 rise auditory threshold were the strongest predictors to the performance of tone detection, accounting 38 % of the unique variance of the scores of tone detection. As from the inspection of table 7, score of tone detection scores task was a significant predictor to Chinese word dictation, word reading and one minute reading, accounting 14.7%, 8.3% and 14.8 % of unique variance to scores of Chinese word dictation, Chinese word reading and one minute reading task respectively.

Simple Regression Analysis of measurements of Auditory Processing Thresholds

To further investigate the interrelationship between 1 rise, rise rove task and intensity task based on correlation analysis, two linear regressions analysis were carried out. In the first regression, we took threshold of rise rove task as independent variable and threshold of 1 rise task as dependent variable. In the second regression, we took threshold of intensity task as independent variable and the threshold of rise rove task as dependent variable. The result showed that rise rove task significantly predicted 17.9% of the unique variance to 1 rise task (R^2 = .179, $F(1, 38) = 8.258$, p <. 01, 95% CI [40.924, 156.047]), and intensity task significantly predicted 15.5% of the unique variance to rise rove task (R^2 =.155, F(1,35) =6.440, p < .05, 95% CI [-6.280, 117.882]).

Table 6

Multiple hierarchical regression examining the contribution of measures of auditory processing to tone detection

		Std β	R^2
1.	Age	-.149	.092*
2.	Raven	.589	.209**
3.	1 rise	-.437	.174***
Total R^2			.475***
N			43

*p < .05. **p <. 01. ***p <. 001.

Table 7

Multiple hierarchical regression equations examining the contribution of scores of tone detection to measures of Chinese literacy

		Chinese Word dictation		Chinese word reading		One minute reading	
		Std β	R^2	*Std β*	R^2	*Std β*	R^2
1.	Age	.316	.161**	.329	.092*	.295	.116**
2.	IQ	-.053	.020	-.192	.000	-.119	.008
3.	Tone detection	.441	.147***	.331	.083*	.442	.148**
Total R^2			.328***		.175*		.272***
N			60		60		60

*p<.05. **p <.01. ***p<.001.

Discussion

This study intended to examine the ability of detection of English prosodic cues and the relationship between auditory processing, detection of Chinese lexical tone and Chinese literacy among dyslexic children in Hong Kong. As shown in the cognitive and linguistic profile of dyslexic children and age matched control group, dyslexic children displayed comparable intelligence but poorer literacy scores in both English and Chinese. This is consistent with the key features of definitions of dyslexia as suggested by Lyon et al. (2003). Further analysis of the tasks examining auditory processing, sensitivity to suprasegmental features of languages and literacy gives three implications.

Firstly, this study revealed that threshold of perception of one rise amplitude envelope indirectly affects reading ability through the association of Cantonese lexical tone perception. As shown in the result of multiple regression analysis, the difficulty in reading Chinese among Hong Kong dyslexic children could be accounted by the deficits in sensitivity in Cantonese lexical tone. This finding was consistent with a study of detection of tonal contrast and Chinese literacy conducted by Cheung et al. (2009) that dyslexic children perceived tonal contrast less accurately than age-matched controls. This study also extended our knowledge that one of the contributing factors of deficits in Cantonese tone detection is higher threshold in rise time sensitivity to amplitude envelope. And here, we propose three different accounts of the relationship between rise time perception and Chinese lexical tone perception. On the cognitive account, rise time sensitivity indicated critical rhythm timing of speech across languages (Goswami et al., 2010). Deficit in rise time perception will lead to poorer metrical organization of speech and thus further affect segmental speech processing (Wang et al., 2012). As tonal and segmental perception both played an important role in Cantonese speech perception (Schirmer, Tang, Penney, Gunter, & Chen, 2005), deficits in segmental speech processing will inevitably affect perception of tonal contrast in Cantonese. From the neurological perspective, Gandour et al. (2004) used fMRI to investigate the selective attention to Chinese intonation and tone and proposed a neurobiological model of perception of Chinese lexical tone, which is composed of a variety of weightings of segmental and acoustic functioning of the brain. Insensitivity to rise time in dyslexic children implies deficits in segmental processing in the left hemisphere of the auditory cortex (Abrams, Nicol, Zecker, & Kraus, 2009). According to the model, this in turn lowers the weighting of processing of segmental features at the brain, so perception of lexical tone will be adversely affected. Temporal sequence framework, proposed by Goswami (2011), can also explain the causal link between rise time deficits and Cantonese lexical tone detection. According to her model, dyslexic children exhibit difficulties in distinguishing different modulation frequency ranges. This difficulty will result in slower temporal rate in speech processing and tracking of amplitude envelope, thus reducing the efficiency of syllabic segmentation. One of the impacts of the reduction of efficiency of syllabic segmentation is the poor sensitivity to the prosodic structure represented in syllabic level, which is revealed in deficits of lexical tone perception in this study.

Secondly, compared with normal children, Hong Kong dyslexic children exhibited significantly poorer performance in reading English words and non-words. However, poor English reading performance of dyslexic children could not be accounted by poor prosody sensitivity, as there was no significant difference in the prosodic sensitivity task between groups. The result was different from a similar study carried out in native English speaking children conducted by Goswami et al. (2009). In their study, dyslexic children performed significantly poorer than normal children in Deedee task, and both dyslexic and age matched control group performed above chance level. However, in our study, both normal and dyslexic children performed at nearly chance level in a similar task, showing that both groups of participants may find the task difficult. There are three reasons accounting for the different results obtained in this study and the study conducted by Goswami et al. (2009). First, the sensitivity of detecting stressed and unstressed syllables in Hong Kong children is too low for them to identify a correct stress pattern in this task. Meng et al. (2009) pointed out that negative prosodic transfer from the first language might account to the lower accuracy in identifying prosody pattern of English in English learning. So even the native English speaking dyslexic children at similar age was able identify the correct stress pattern for these test stimuli, it did not imply bilingual dyslexic children were able to identify stress pattern in a similar way. Second, children participating in this study were not familiar with the English film names in the test stimuli. They might not have the repertoire of the prosodic patterns of some unfamiliar names, so they were unable to compare the ‘standard’ prosodic pattern with the different stress pattern presented. Third, participants’ inaccurate preconceptions about the stress pattern of the test stimuli may also account for the chance level result of the participants. As Chan (2011) found that preconceptions about the pronunciation of an English word contributed to problems of perception of English speech sounds in University students in Hong Kong, similar problem may also exist in primary school age children.

Thirdly, although dyslexic children had higher threshold in both 1 rise and rise rove task, marginal significance was noted in 1 rise task but not in rise rove task. Such finding was different from another study conducted by Goswami, Fosker, Huss, Mead, and Szűcs (2011) on native English speaking children that dyslexic children had significantly higher threshold in rise rove task than chronological age control group. There are three possibilities to account for the difference of results. First, normal children in this study made use of intensity cue to facilitate rise time perception. This hypothesis was justified as normal group performed significantly better than dyslexic group in 1 rise task but not in rise rove task. The only difference between 1 rise and rise rove task was that the loudness of the stimuli only varied in rise rove task but not 1 rise task. In other words, participants could not use the intensity as a cue to identify rise time in rise rove task (Kuppen et al., 2011). Second, normal children consistently use intensity to detect rise time in rise rove task. This is revealed from the results of simple regression analysis that threshold of intensity discrimination could significantly predict the variance in rise rove task. This implied that normal children, who had better intensity discrimination ability, consistently use intensity cue to identify rise time in rise rove task. Therefore, the performance of normal children in rise rove task was not as good as 1 rise task and no significant result was yielded. Third, normal children frequently rely on intensity variation in reading Chinese. This hypothesis is supported by the findings of Wang et al. (2012) that threshold of intensity threshold task predicted tone awareness and onset deletion. Both parameters were important in identifying segmental and suprasegmental features in reading Chinese. Tseng and Lee (2004) also found that intensity variation in Chinese could predict prosody organization and information inherent in speech and transmitted through intensity changes may be perceptually useful in breaking Chinese words and phrases.

There are three limitations in the study. The limited number of dyslexic participants (*N* = 14) may reduce to power of the statistical results. To overcome this, we have recruited more age-matched normal controls. However, it will be more preferable if more dyslexic participants can be invited in the study. The non-random sampling method of this study can only reveal part of the tone or stress perception characteristics of dyslexic children. To increase the explanatory power of our hypothesis, our study can be repeated with a stratified sampling method according to the relative population in different districts and different levels of academic achievements. Also, as revealed from the nearly chance level accuracy of Deedee task, the participants may find the task stimuli too difficult and unfamiliar to them. The task can be further improved by including more familiar words and adjusting the difficulty of the stimuli so as to cater the ability of English lexical stress detection for bilingual children in Hong Kong. Despite from the inappropriate task stimuli, it is still worthwhile to examine whether English prosody sensitivity contribute to English reading difficulty among dyslexic children in Hong Kong since a study conducted on a group of local secondary students revealed that word level stress sensitivity correlated with reading comprehension (Chen & Wang, 2011). It is likely that such correlation between prosody sensitivity and reading exists in younger children as well.

To conclude, this study highlighted the importance of detection of suprasegmental features of Chinese and English on reading. In Chinese, reading and writing difficulties in dyslexic children could be explained by deficits in lexical tone perception. Perceptual deficits of amplitude envelope rise time contributed to the deficits of tone perception. Also, normal children tended to use intensity cues to detect rise time in speech. Therefore, lexical tone perception and auditory threshold of rise time can be thought of an additional linguistic marker in diagnosis of dyslexia. Although both normal and dyslexic children in this study performed at chance level in English prosody sensitivity task, we provided further direction to study the sensitivity to English lexical stress of normal and dyslexic school age children. Further modification on familiarity and difficulty of the stimuli of English prosodic sensitivity task can help yield a more significant result in demonstrating the sensitivity of detection of prosodic features of English of Hong Kong school age children.

References

Abrams, D. A., Nicol, T., Zecker, S., & Kraus, N. (2009). Abnormal cortical processing of the syllable rate of speech in poor readers. *The Journal of Neuroscience, 29*(24), 7686-7693.

Chan, A. Y. W. (2011). The Perception of English Speech Sounds by Cantonese ESL Learners in Hong Kong. *TESOL Quarterly, 45*(4), 718-748.

Chan, D. W., Ho, C. S. H., Tsang, S. M., Lee, S. H., & Chung, K. K. H. (2007). Prevalence, gender ratio and gender differences in reading-related cognitive abilities among Chinese children with dyslexia in Hong Kong. *Educational Studies, 33*(2), 249-265.

Chen, H. C., & Wang, Q. (2011). *The Roles of Prosodic Sensitivity and Phonological Awareness in Second Language Learners' Reading Development.* Paper presented at the 16th Conference of Pan-Pacific Association of Applied Linguistics.

Cheung, H., Chung, K. K. H., Wong, S. W. L., McBride-Chang, C., Penney, T. B., & Ho, C. S. H. (2009). Perception of tone and aspiration contrasts in Chinese children with dyslexia. *Journal of Child Psychology and Psychiatry, 50*(6), 726-733.

Corriveau, K., Pasquini, E., & Goswami, U. (2007). Basic Auditory Processing Skills and Specific Language Impairment: A New Look at an Old Hypothesis. *Journal of Speech, Language and Hearing Research, 50,* 647-666.

Francis, A. L., Ciocca, V., Ma, L., & Fenn, K. (2008). Perceptual learning of Cantonese lexical tones by tone and non-tone language speakers. *Journal of Phonetics*, *36*(2), 268-294.

Gandour, J., Tong, Y., Wong, D., Talavage, T., Dzemidzic, M., Xu, Y., . . . Lowe, M. (2004). Hemispheric roles in the perception of speech prosody. *Neuroimage, 23*(1), 344-357.

Gerrits, P. A. M. (2001). *The categorisation of speech sounds by adults and children*. Utrecht: LOT Utrecht, the Netherlands

Goswami, U. (2011). A temporal sampling framework for developmental dyslexia. *Trends in Cognitive Sciences*, *15*(1), 3-10.

Goswami, U., Fosker, T., Huss, M., Mead, N., & Szűcs, D. (2011). Rise time and formant transition duration in the discrimination of speech sounds: the Ba–Wa distinction in developmental dyslexia. *Developmental Science, 14*(1), 34-43.

Goswami, U., Gerson, D., & Astruc, L. (2009). Amplitude envelop perception, phonology and prosodic sensitivity in children with developmental dyslexia. *Journal of Reading and Writing, 23*, 995-1019.

Goswami, U., Wang, H. L. S., Cruz, A., Fosker, T., Mead, N., & Huss, M. (2010). Language-universal Sensory Deficits in Developmental Dyslexia: English, Spanish, and Chinese. *Journal of Cognitive Neuroscience, 23*(2), 325-337.

Hayes, B. (2011). *Iambic and trochaic rhythm in stress rules.* Paper presented at the Proceedings of the Annual Meeting of the Berkeley Linguistics Society.

Ho, C. S. H., Chan, D. W. O., Tsang, S. M., & Lee, L. H. (2000). *The Hong Kong test of specific learning disabilities in reading and writing (HKT-SpLD).* Hong Kong, China: Chinese University of Hong Kong and Education Department, HKSAR Government.

Ho, C. S. H., & Fong, K. M. (2005). Do Chinese Dyslexic Children Have Difficulties Learning English as a Second Language? *Journal of Psycholinguistic Research, 34*(6), 603-618.

Huss, M., Verney, J. P., Fosker, T., Mead, N., & Goswami, U. (2011). Music, rhythm, rise time perception and developmental dyslexia: Perception of musical meter predicts reading and phonology. *Cortex*, *47*(6), 674-689.

Information Services Department. (2012). *Hong Kong: The facts (Education)*. Hong Kong: Information Services Department, Hong Kong administrative Region Government.

Ingesson, S. G. (2007). *Growing up with Dyslexia: Cognitive and Psychosocial Impact, and Salutogenic Factors.* (Doctoral Publication), Lund University, Sweden.

Kuppen, S., Huss, M., Fosker, T., Fegan, N., & Goswami, U. (2011). Phonological Awareness in Low-IQ Readers and Typically Developing Controls. *Scientific Studies of Reading, 15*(3), 211-243.

Levitt, H. (1971). Transformed up-down methods in psychoacoustics. *The Journal of the Acoustical society of America, 49*, 467.

Lyon, G., Shaywitz, S., & Shaywitz, B. (2003). A definition of dyslexia. *Annals of Dyslexia, 53*(1), 1-14.

Meng, M. L. H., Meng, H., Tseng, C. Y., Kondo, M., Harrison, A., & Viscelgia, T. (2009). *Studying L2 Suprasegmental Features in Asian Englishes: A Position Paper.* Paper presented at the Interspeech, Brighton.

Meng, X., Sai, X., Wang, C., Wang, J., Sha, S., & Chou, X. (2005). Auditory and speech processing and reading development in Chinese school children: behavioural and ERP evidence. *Dyslexia, 11*(4), 292-310.

Raven, J. C. (1960). *Guide to the standard progressive matrices: sets A, B, C, D and E,* London: HK Lewis.

Schirmer, A., Tang, S. L., Penney, T. B., Gunter, T. C., & Chen, H.C. (2005). Brain responses to segmentally and tonally induced semantic violations in Cantonese. *Journal of Cognitive Neuroscience, 17*(1), 1-12.

Shu, H., Peng, H., & McBride-Chang, C. (2008). Phonological awareness in young Chinese children. *Developmental Science, 11*(1), 171-181.

Tong, X., & McBride-Chang, C. (2010). Chinese-English biscriptal reading: Cognitive component skills across orthographies. *Reading and Writing, 23*(3-4), 293-310.

Tseng, C. Y., & Lee, Y. (2004). *Intensity in relation to prosody organization.* Paper presented at the 2004 International Symposium on Chinese Spoken Language Processing.

Wang, H. L. S., Huss, M., Hämäläinen, J. A., & Goswami, U. (2012). Basic auditory processing and developmental dyslexia in Chinese. *Reading and Writing, 25*(2), 509-536.

Woodcock, R. W. (1998). *Woodcock reading mastery tests, revised*. Circle Pines, MN: American Guidance Service.

Appendix A: Details of the auditory processing task

Rise time with One Amplitude Envelope Onset (1 Rise test) (Kuppen et al., 2011; Wang et al., 2012)

This task was in AXB format. In each trial, three 800ms tones with 500 ms inter-stimulus interval (ISIs) were presented. Two standard tones (the second tone and either the first or third tone) had 15 ms linear rise time envelop 735 ms steady state, and a 50 ms fall time. The last tone varied the linear onset rise time logarithmically with the longest rise time being 300 ms. Three cartoon dinosaurs will be introduced to the participants. They were told that each dinosaur would make a sound and children were asked to choose a dinosaur with a softer rising sound.

One amplitude rise time task with intensity roving (Rise rove) (Kuppen et al., 2011)

This task was in 2 IFC format. Same stimuli as 1 rise task were used. The intensity of each stimulus varied randomly in each trial. That meant intensity could not be used as a cue to rise time. Again, participants were asked to choose the dinosaur with a softer rising sound.

Intensity variation (Intensity ABABA) (Kuppen et al., 2011; Wang et al., 2012)

This task was also in 2 IFC format. There were two monkeys on the screen. Each monkey produced five sequential sounds. The sounds were either had same intensity (AAAAA) or varied intensity (ABABA). Participants were asked to choose the monkey that had alternative loud and soft sound. Each stimulus was a pure tone at 500 Hz, with 200 ms long in duration, 50 ms ISI and 50 ms rise and fall times. A continuum of forty stimuli of intensity ranging from 10 dB to 16 dB was used. There was 0.15 dB intensity difference between each step.

Musical metrical perception task (Metric task) (Huss, Verney, Fosker, Mead, & Goswami, 2011).

There were 24 trials in this task. The task was in 2 IFC format. Each stimulus was a series of note with an underlying pulse rate of 120 bpm. There were twelve 'same' trials. Identical notes were played twice in these trials. The remaining twelve trials were 'different'. The 'different' note was created by elongating the accented note by either long period of time (100 msec) or short period of time (166 msec). The pattern of different trials was presented in Fig. 1. The sound files were created using Sibelius Version 4 from a sound set produced by Native Instrument (Kontakt Gold). The notes sounded musical with appropriate timbre and slow decay times. Fourteen trials were in 4/4 time and 10 trials were in 3/4 time. The proportion of same and different trials in each type of note was 1:1. The participants were asked to judge whether two stimuli presented in one trial were same or different.

Figure 1 Depiction of all the musical arrangements used as the “different” trials in the musical metrical perception task. Each arrangement was recorded with an underlying pulse rate of 500 msec. The more intense beat in a sequence is marked “>”, and the position and

extra length of the lengthened accented beat are also marked. Wav files numbers correspond to file names in the task . (Huss et al., 2011)

Appendix B: Language, social and musical background questionnaire

1. 今日日期 (日/月/年): _________________

2. 填問卷者: 母親 父親 其他：___________

第一部分:

子女的資料:

3. 姓:____________________ 名:_____________________

4. 出生日期（日／月／年）:________________________________ 5. 性別: __________

6. 出生國家:__________________________ 7. 慣用手: 左 右

8. 如果不是在香港出生，你的子女什麼時候來香港？（月/年）__________

父母的資料:

9. 請註明您家庭收入的範圍（港幣）：

_____ <10,000

_____ 10,000-20,000

_____ 20,000-30,000

_____ 30,000-40,000

_____ 40,000-50,000

_____ >50,000

請註明每位家長的最高教育水平和職業:

10. 母親

a. _____曾讀小學（未畢業）

b. _____小學畢業生

c. _____初中畢業生

d. _____高中畢業生

e. _____大學或學院文憑

f. _____大學或學院學位畢業生

g. _____研究生或其他專業學位

職業: ____________________

11. 父親

a. _____曾讀小學（未畢業）

b. _____小學畢業生

c. _____初中畢業生

d. _____高中畢業生

e. _____大學或學院文憑

f. _____大學或學院學位畢業生

g. _____研究生或其他專業學位

職業: ____________________

第二部分:

請就您的子女的語文能力回答下列問題：

1. a) 請圈出您的子女能理解的語言：

廣東話　　英語　　其他（請註明：____________________）

您會怎樣評價您的子女對下列語言的理解呢？請圈出適當的數字。

		弱				強
i.	廣東話	1	2	3	4	5
ii.	英語	1	2	3	4	5
iii.	其他（請註明：____________________）	1	2	3	4	5

請大概描述您的子女對下列語言的理解：

i. 廣東話:

____

ii. 英語:

____

iii. 其他（請註明：____________________）

____

b) 請選出您的子女能說的語言：

廣東話　　英語　　其他（請註明：____________________）

您會怎樣評價您的子女對下列語言的說話能力呢？請圈出適當的數字。

		弱				強
i.	廣東話	1	2	3	4	5
ii.	英語	1	2	3	4	5
iii.	其他（請註明：____________________）	1	2	3	4	5

請大概描述您的子女對下列語言的說話能力：

i. 廣東話:

____

ii. 英語:

____

iii. 其他（請註明：____________________）

____

2. 除父母以外，您的子女有定期接觸其他照顧他／她的人（如祖父母，外傭等）嗎？

有　沒有

如有，請註明他（們）跟您的子女的關係及他們說的語言。

____

3. 除了回校上學，您的子女有參與其他語言或校外課程嗎？　有　沒有
如有，請註明課程：____________________
課堂密度：　每天　每星期一次　其他（請註明：____________________）

4. 您的子女的第一語言是甚麼？（如適用，請圈出多於一個語言）
廣東話　英語　其他（請註明：____________________）

5. a) 如您的子女會說廣東話，他／她是何時學的？
您的子女開始學廣東話的年齡：____________________

b) 您的子女在哪裡學廣東話的呢？
家中　學校　社區　其他（請註明：____________________）

c) 您的子女每隔多久會說廣東話呢？
每天　每星期一次　每月一次　其他（請註明：____________________）
不適用
請註明您的子女每天說廣東話的時間的百分比　_________%

d) 您的子女現在會在哪裡說廣東話呢？（請圈出所有適用選項）
家中　學校　社區　其他（請註明：____________________）

6. a) 如您的子女會說英語，他／她是何時學的？
您的子女開始學英語的年齡：____________________

b) 您的子女在哪裡學英語的呢？
家中　學校　社區　其他（請註明：____________________）

c) 您的子女每隔多久會說英語呢？
每天　每星期一次　每月一次　其他（請註明：____________________）
不適用
請註明您的子女每天說英語的時間的百分比　_________%

d) 您的子女現在會在哪裡說英語呢？（請圈出所有適用選項）
家中　學校　社區　其他（請註明：____________________）

7. a) 如您的子女除了廣東話和英語外還會說其他語言，哪是甚麼？他／她是在哪裡學的呢？

其他語言：____________________

您的子女開始學它的年齡：____________________

b) 您的子女在哪裡學它的呢？

家中 學校 社區 其他（請註明：____________________）

c) 您的子女每隔多久會說它呢？

每天 每星期一次 每月一次 其他（請註明：____________________）不適用

請註明您的子女每天說它的時間的百分比 ________%

d) 您的子女現在會在哪裡說它呢？（請圈出所有適用選項）

家中 學校 社區 其他（請註明：____________________）

<u>第三部分:</u>

我們想知道更多有關您的子女的音樂背景。請回答下列問題。

1. 您的子女曾經上過音樂班嗎？ 有 沒有

如有，請回答下列問題。（如適用，可選多於一個選項）

單獨課 _______ 小組課 ______ 學校課堂 ______

聲樂 ______ 樂器 ____

課堂開始日期: ____

一星期的堂數: ____

一堂的時間: ____

您的子女在每一課之間有家練習嗎？ 有 沒有

每日練習時間：________ 小時

受音樂訓練的總時間：________ 月 （由九月至六月）

2. 您的子女在家中有聽音樂嗎？ 有 沒有

如有，您的子女喜歡聽甚麼類型的音樂呢？

____

3. 有家長是音樂家嗎？（專業或興趣亦可）有 沒有

如有，請描述：

____

<u>總評估：</u>

1. 總括而言，您會怎樣描述您的子女的廣東話及英語的雙語程度呢？

非雙語　　不流利雙語　　流利雙語

1　2　3　4　5

1 –	主要說一種語言 –只懂另一語言的少數詞彙
2 –	弱雙語 –能有限地以關鍵詞作基本對話（沒理會文法） –需多聽一次句子才能理解
3 –	不平衡雙語 –能有作基本對話（含少數文法錯誤） –不需多聽一次句子便能理解 –未能作流暢對話
4 –	基本雙語 –能作流暢對話 –不是每天運用第二語言
5 –	流利雙語 –能作流暢對話；每天運用兩種語言 –曾在以英國為主要語言的國家居住

研究員的判斷：__________