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Hong Kong Universal Newborn Hearing Screening (UNHS) Care Path and Local Data at Child Assessment Service (CAS)

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Introduction

Children with hearing impairment greater than or equal to moderate grade in the better ear are classified as having significant hearing impairment. Early identification, diagnosis, and intervention are crucial to the successful management of these children to mitigate the possible adverse outcome of language and communication, learning, and social-emotional developments. Without appropriate language exposure and access, these children will fall behind their hearing peers in various aspects of development, and delays may continue to affect the children's lives into adulthood.[1] The Joint Committee on UNHS was formed to ensure the effective implementation of Universal Newborn Hearing Screening (UNHS) in Hong Kong, and to achieve an effective communication among various services in Hospital Authority (HA) and Department of Health (DH). A consensus on a common care path for the infants who are identified to have hearing impairment had been reached with contributions from multidisciplinary professionals.

International population-based studies have identified a consistent prevalence of approximately 0.1% of children having a permanent significant hearing impairment through review of health or education records, or both.[2] Pooled hearing impairment prevalence was 6.9 times higher among those admitted to NICU.[3] In children of primary school age, the prevalence increased to 2.83 per 1,000 children.[4] At Child Assessment Service (CAS) of the Hong Kong Department of Health (DH), new cases with a diagnosis of permanent childhood hearing impairment (PCHI) of moderate or greater degrees remained relatively stable over the past decade, with 67 new cases in 2018 and 51 in 2019. With the universal screening program in place, and referring to the mean number of births per year in Hong Kong over the period and CAS's catchment coverage of over 85% of the population, an incidence rate of about 0.1% of children having PCHI is estimated, comparable to the prevalence of developed countries.

The etiology of hearing impairment can be classified, according to its nature, as sensorineural, conductive or mixed hearing impairment. Genetic causes contribute to at least half of the cases of PCHI in which one-third have been associated with syndromes, while the remaining 70% are non-syndromic hereditary causes. Autosomal recessive is the most common inheritance pattern of non-syndromic genetic hearing impairment, comprising around 80% of cases.[5] Hearing impairment can also be classified according to the severity into mild (26-40 dB HL), moderate (41-70 dB HL), severe (71-90 dB HL) and profound (more than 90 dB HL). The rate of the coexistence of additional disabilities or medical conditions with hearing impairment in children is high. Most estimates suggest that between 30% and 40% of children with hearing impairment have one or more additional disabilities.[6] Studies have reported that the frequency of additional disabilities is similar across all levels of hearing impairment, pointing to the need for children with mild or unilateral impairment, as well as those with more significant impairment, to receive thorough medical and developmental evaluations.[7]

Children with significant hearing impairment are at risk of growing up with deficits in language, communication, cognition and literacy, psychosocial functioning and possible problems in balance and gross motor proficiency.[8] Many developed countries have changed from using the term "Universal Newborn Hearing Screening" to "Early Hearing Detection and Intervention (EHDI)" programs. The change underscores that successfully identifying and serving young children with PCHI, requires going beyond screening to address issues related to confirmatory diagnosis, medical and educational intervention, and coordination with the child's family.[9]

The program enables prompt detection and intervention for early-onset PCHI. However, children with progressive or late-onset hearing impairment might be missed. Professionals should be alert to children with risk factors for hearing impairment, such as positive family history, in-utero infection, significant craniofacial anomalies etc., and refer them for formal audiological evaluation whenever there is suspicion.

Universal Newborn Hearing Screening (UNHS)

HA hospitals provide universal newborn hearing screening and make initial diagnosis for infants or children with congenital hearing impairment. 2-stage Automated Auditory Brainstem Response (AABR) screening is offered to all neonates born in HA hospitals. Babies who failed the screening tests will be referred to undertake confirmatory Brainstem Auditory Evoked Potential (BAEP) test, recommended to be preferably before 4 months of age to facilitate early detection and subsequent interventions. Babies who failed confirmatory BAEP test will be referred to Department of Ear, Nose & Throat (ENT) for comprehensive assessment.

They will also be referred to paediatric clinics for follow-ups and investigations. Congenital Cytomegalovirus (CMV) infection is the most frequent non-hereditary cause of sensorineural hearing impairment worldwide. Urine CMV screening, within 3 weeks of age, is recommended for infants who have failed the newborn hearing screening twice. Early administration of antiviral treatment in those infected infants is proven to prevent hearing deterioration at 6 months and may potentially prevent hearing deterioration at > or =1 year.[10]

Maternal and Child Health Centre (MCHC) from Family Health Service provides screening for infants who had not been screened by the UNHS program of HA hospitals, currently by the 2-stage Automated Otoacoustic Emission (AOAE) method. First AOAE screening would be performed for infants aged between 2 weeks to 4 months, and if the first screening was failed, a second AOAE test would be offered preferably within one week. Those who failed AOAE test twice will be referred to hospital for confirmatory testing. Routine hearing and developmental surveillances are provided to all children even they passed the UNHS program.

Management of children with confirmed hearing impairment

After confirmation of significant hearing impairment, referrals should be made to Child Assessment Service (CAS) for comprehensive developmental follow up, and to Clinical Genetic Service (CGS), ophthalmologist or other specialties as clinically indicated. These children are referred to the Education Bureau (EDB) for hearing aid fitting and follow-up services. Hearing aid fitting may also be provided at ENT departments, especially for those for whom cochlear implants might be considered. For children with severe to profound hearing impairment, temporal bone high-resolution computed tomography (HRCT) and magnetic resonance (MR) imaging provide complementary information, and are often used in conjunction with the preoperative evaluation of paediatric candidates for cochlear implantation.[11]

CAS takes up the co-ordination role for multi-disciplinary management of these children. CAS Audiologists provide counselling and relevant information to parents. Together with audiologists, developmental paediatricians take comprehensive medical and family histories to identify possible risk factors and etiology. The strengths and weaknesses of the child in all developmental areas would be evaluated. A thorough evaluation of the child's level of communication and speech and language development is important. Speech therapist assessments include verbal comprehension, verbal expression, speech production and speech perception. Phonological errors and error patterns are analysed. Rehabilitation placement for Early Education and Training Centre (EETC) for deaf or Special Child Care Centre (SCCC) for deaf is generally recommended and arranged for them as soon as possible. A combined multi-disciplinary review assessment will be arranged before the child goes to primary school. Advice on school placement, accommodation, continual auditory and language training will be given accordingly.

Clinical Genetic Service (CGS) provides genetic assessment, testing and counselling for patients with hearing impairments and suspected genetic diseases. For non-syndromic hearing impairment, three genetic tests are available for the time being: GJB-2 gene, GJB-6 gene and mitochondrial m.1555A > G mutation. These genetic tests have pickup rates of around 30%. In selected patients, next-generation sequencing (NGS) is done through which all known related genes can be studied in a single assay.

Education Bureau (EDB) provides hearing aid fitting and follow-up services to children with persistent hearing impairment. Free bilateral hearing aids with regular replacements are provided to children with bilateral impairment to enable binaural listening. EDB also provides counselling to parents and audiological reports to schools to help them understand better the needs of these children.

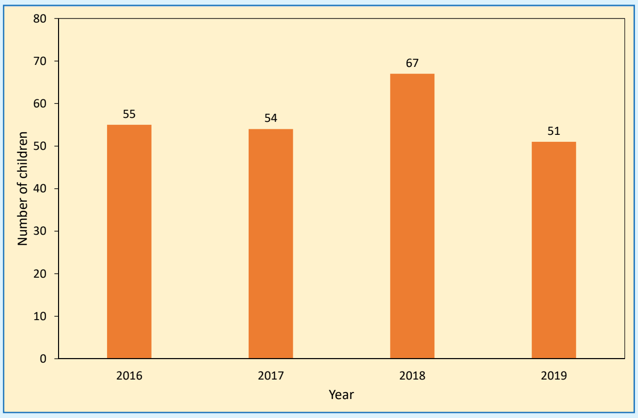
Children with severe to profound hearing impairment may not benefit from the use of hearing aids. Cochlear implantation would be considered for these children. A cochlear implant is an electronic device which allows the recipient to receive auditory information by electrical stimulation of the cochlear portion of the ear. In 2000, the Food and Drug Administration (FDA) approved implantation for children of 12 months of age. A recent review reported that there is extensive evidence to show implantation around 12 months of age offers the greatest chance of significant open-set speech understanding with resulting language acquisition rates that match those of hearing peers.[12] Timing of the intervention remains critical, with worse outcomes achieved for those receiving an implant beyond 2 years of age. There is also emerging evidence for the benefit of simultaneous or sequential bilateral implantation. Bilateral implantation optimises sound localisation and hearing in noise environment. It is essential to have intensive post-implant training, including comprehensive auditory training to develop listening skills, and speech-language therapy to maximise the benefits of the device. Having an implant does not preclude the use of signing or cued speech. Some rehabilitation interventions may continue to use signing or cueing. Auditory brainstem implant (ABI) may be indicated for patients who are deaf and ineligible for cochlear implant surgery due to abnormalities of the cochlea and cochlear nerve, for example, cochlea and cochlear nerve aplasia and hypoplasia, traumatic nerve avulsion, and cochlear ossification. ABI bypasses cochlear nerve to electrically stimulate second order neurons in the cochlear nucleus using a multichannel surface array in patients with cochlear and retrocochlear pathologies. ABI surgery under age 3 is associated with improved auditory perception and language development compared with older users.[13]

CAS epidemiological data on hearing impairment from 2016 to 2019

CAS receives referrals of cases screened positive for further diagnostic assessment, and referrals for children with confirmed hearing impairment. A well-structured hearing impairment database was established in CAS in 2016 for individual children's longitudinal data and group epidemiological data collection and analysis. Here we present the profile of children with PCHI seen at CAS from 2016 to 2019.

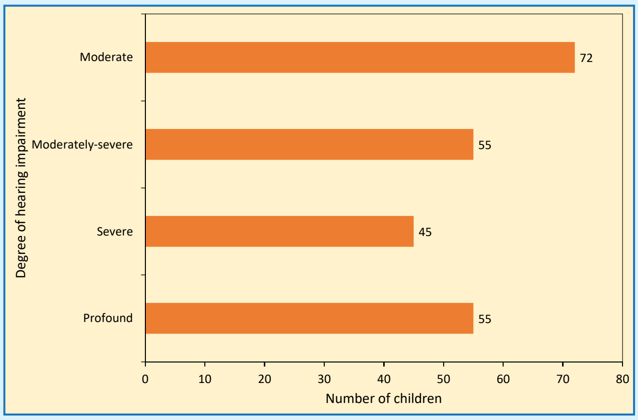
A total of 227 children were diagnosed to have permanent moderate or worse hearing impairment in the better ear in these 4 years (Figure 1). The overall male-to-female ratio was 1.08:1.

Figure 1. Number of children with significant hearing impairment between 2016 and 2019



Majority (89%) of children with significant hearing impairment at CAS were sensorineural in nature. 8% of children were with permanent conductive hearing impairment while 3% of them with mixed hearing impairment. Around half of all children (56%) were of moderate or moderately-severe degree of hearing impairment. 20% of them suffered from severe degree of hearing impairment while 24% of them had profound degree of hearing impairment (Figure 2). For the risk factors of hearing problem, 77 of them (34%) presented with one or more related risk factors. 11% of total children suffered from syndromal disease which is comparable to the incidence rate in international reports. The commonest ones were Down syndrome, Waardenburg syndrome and Noonan syndrome. Around 10% of children were found to have positive family history of significant hearing impairment. 5% of children associated with neonatal risk factor or confirmed in-utero infection while 3.5% children suffered from craniofacial abnormality.

Figure 2. Degree of hearing impairment



Age at screening, diagnosis and hearing aids prescription

Age at screening (month of birth) is shown in Figure 3. Overall, 188 children (94%) of known cases completed newborn screening within 1 month of age. The reason of failure to complete screening within 1 month of age included birth at private hospital, birth in China and declined screening by the parents etc. The method of screening was AABR in 82% of children. The screening history was unknown in some cases. At diagnosis, 34% of children of known cases were confirmed with significant hearing impairment within 3 months of age. 49% of children confirmed diagnosis within 6 months of age and total 60% of children with confirmed diagnosis within 12 months of age (Figure 4). It is noted that not all cases with significant hearing impairment presented at birth, some children suffered from late-onset hearing impairment and some children had progressive hearing impairment. Hearing aids prescription was performed within 6 months of age in 13% of children. 26% of children received hearing aids within 9 months of age while 33% of total children within 12 months of age. Cochlear implantation was performed in 44 children in which 25 of them received bilateral implantation. Three children received auditory brainstem implantation. Due to various factors, most children did not receive cochlear implantation at 12 months of age.

Figure 3. Age at screening

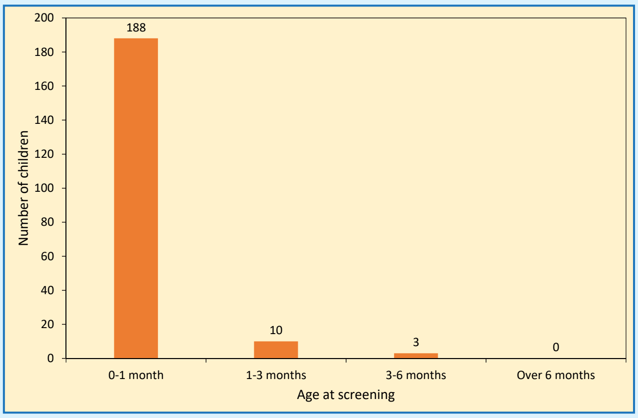
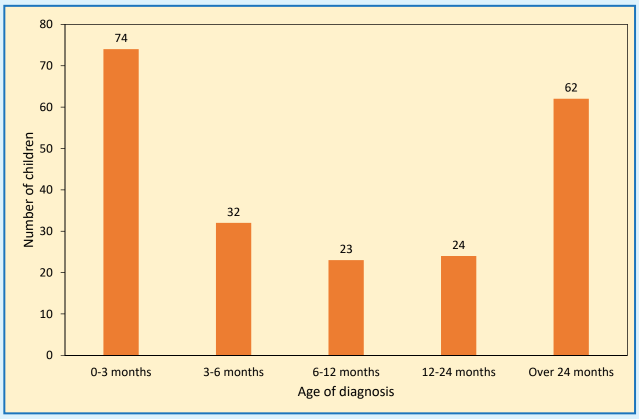


Figure 4. Age of diagnosis



Developmental profiles and co-morbid problems

Among children with significant hearing impairment, majority (83%) of them had some developmental problems in the initial developmental assessment. 29% of children assessed with borderline developmental delay while 20% of children with significant developmental delay. 12% of children suffered from language delay only in initial developmental assessment. 17% of children diagnosed with normal development while the remaining children with other problems, for example, motor delay. Other than hearing problem, some of these children also suffered from other disabilities. Five children had visual impairment and six children had cerebral palsy or other physical impairment. Ten children (4.4%) were diagnosed to have Attention Deficit/ Hyperactivity Disorder (ADHD) or inattention problem. Autism Spectrum Disorder (2.6%) and Anxiety Problem (0.9%) were less commonly diagnosed in these children. Four children (1.8%) were found to have dyslexia or at risk of dyslexia but the figure was likely to be underestimating, as many of these children were too young to be assessed for literacy.

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Impact of Noise on Aided Performance of Cantonese Word Recognition in Children with Significant Sensorineural Hearing Impairment

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Introduction

Children with hearing impairment always have complaints about hearing in noise. It is known that the presence of noise may cause degradation in their listening performance. The louder the noise, the more detrimental is the effect on speech perception.[1] As a result, they are at risk for reduced learning in a noisy or reverberant classroom. There are very few standardised speech tests developed for the Cantonese-speaking paediatric population, and the tests are mainly conducted in quiet. This implies that the test results may not truly reflect the speech perception abilities of children with hearing impairment in real life listening situations. It would be beneficial to develop a test that can show the impact of noise on their speech perception ability.

The aim of the present study was to investigate whether the four word lists of CanSWORT[2] were equivalent when presented in noise. Also, the impact of noise on children with various degrees of hearing impairment, as well as the adequacy of audiometric thresholds as a predictor of speech perception ability, would be examined. Our ultimate goal was to determine if CanSWORT, with the addition of noise, namely "CanSWORT $_{\text{in noise}}$", was valid for use with our Cantonese-speaking paediatric population and whether it could provide additional information beyond that coming from the traditional hearing tests.

Method

Participants

Fifty-eight children with hearing impairment (31 males, 27 females), aged three to eight years, were recruited from the Child Assessment Service (CAS) of the Department of Health. No cognitive, physical or behavioural impairment was reported. All participants were native Cantonese speakers. They were divided into four groups, namely moderate, moderately severe, severe and profound, based on their degree of hearing loss. According to Goodman's classification,[3] the degree of hearing loss was categorised as mild (26-40 dB HL), moderate (41-55 dB HL), moderately severe (56-70 dB HL), severe (71-90 dB HL) and profound (>90 dB HL). In this study, pure tone average was determined by calculating the mean of the 500, 1000, 2000 and 4000 Hz thresholds.

There were 16 children in the moderate hearing impaired group. Their mean age was 5.77 years (SD = 1.48; range = 3.58 to 8.58 years). The moderately severe group consisted of nine children. Their mean age was 5.34 years (SD = 1.49; range = 3.75 to 8.33 years). The 14 children in the severe group had a mean age of 5.09 years (SD = 1.37; range = 3.75 to 7.83 years). The profound group included 19 children with 5.29 years as their mean age (SD = 1.26; range = 3.25 to 7.67 years).

Equipment and speech material

The test was carried out in a sound treated room within one of the Child Assessment Centres located in Ha Kwai Chung, Tuen Mun, Central Kowloon, Fanling, Shatin and Kwun Tong. An ambient noise, as measured using a Brüel & Kjær 2232 or Cirrus CR 252B sound level meter, ranged from 34 to 39 dBA on the days of testing.

Otoscopy was performed using a Welch and Allyn or Heine hand-held otoscope. Acoustic immittance measurement was made using a GSI 33 or GSI 38 middle ear analyser. A probe tone of 226 Hz was delivered to the child's ear while the pressure was varied from +200 to –400 daPa with a pump speed of 200 daPa/s. Pure tone audiometry was conducted using a GSI 61 clinical audiometer, coupled with a pair of TDH-39 headphones or 3A insert earphones.

The speech material was adopted from CanSWORT. It consists of four word lists, each of which consists of four equivalent lists of 20 disyllabic words. In the construction of CanSWORT, a series of stringent measurements of reliability and validity have been made. The child responds by verbally repeating the test item or expressing it by verbal description, gesture, or drawing. The test items are presented by a recorded male voice. In the present study, the four lists were combined to form a list of 80 disyllabic words. In order to simulate the real-world listening scenarios, the material was mixed with a Cantonese speech spectrum shaped noise[4] to create five noise conditions, namely signal to noise ratios (SNRs) of -8, -5, 0, +5 dB and in quiet.

The more difficult SNRs of -8 and -5 dB were chosen as it is suggested by Keogh et al[5] that classroom noise level may sometimes exceed a teacher's speech level. The range of SNRs for classrooms has been reported to be from approximately +5 dB to -7 dB.[6]

The computer software of CanSWORT $_{\text{in noise}}$ was installed on a laptop computer connected to a GSI 61 clinical audiometer to present speech material at 65 dBA via a loudspeaker to the child's ears. The loudspeaker was located at 0 degree azimuth and output measured 1.5 metres away at the centre of the child's head, the height of which was individually adjusted to the level of the loudspeaker.

Procedure

Otoscopy, immittance audiometry and pure tone audiometry were carried out. Air conduction thresholds for 250, 500, 1000, 2000, 4000 and 8000 Hz were obtained in both ears using Hughson-Westlake procedures.[7] Bone conduction thresholds for 500, 1000, 2000 and 4000 Hz were established with narrow-band masking noise in the non-test ear when necessary. Tympanometry was performed with tympanometric peak pressure measures between 100 and -150 daPa and static acoustic admittance between 0.2 and 1.8 ml.[8,9] Participants whose results fell out of these normal ranges would be scheduled for a review in three months.

The participants were users of hearing aid, cochlear implant or auditory brainstem implant. Sound field aided warble tone thresholds at 500, 1000, 2000 and 4000 Hz were measured. The mean aided thresholds were 30.89, 35.83, 38.80 and 38.13 dB HL for the moderate, moderately severe, severe and profound groups, respectively.

In CanSWORT $_{\text{in noise}}$, a software program was used to ensure automatic randomisation of item presentation order. The more difficult test conditions were presented first to minimise learning effects of the participants. Standard verbal instructions were given before the test began. Training items were presented until the child was familiar with the task. After the presentation of each test item, the tester would pause to let the participant respond. The participant was asked to express what had been heard by repeating the words exactly as heard, or by describing the meanings of the words, pointing to an object, using body gestures or drawing, etc. One point was awarded to a correct answer for each test item. Scoring ranged from 0 to 80 points for each of the five conditions, respectively. Scores obtained from five different SNRs were analysed using repeated measures ANOVA.

Results

The moderate hearing impaired group had a mean pure tone threshold of 47.50 dB HL averaged across 500, 1000, 2000 and 4000 Hz, while the moderately severe, severe and profound groups demonstrated mean pure tone thresholds of 61.11 dB HL, 80.98 dB HL and 104.28 dB HL, respectively. Among the 58 participants, 39 wore hearing aids (HA) binaurally, eight had bilateral cochlear implants (CI), two had monaural CI, eight adopted bimodal hearing with CI on one ear and HA on the other, and one had an auditory brainstem implant (ABI). The mean pure tone thresholds of the HA group and implant group were 93.75 and 106.25 dB HL, respectively.

To assess the internal consistency of CanSWORT $_{\text{in noise}}$, inter-list correlation was measured. Pearson correlations ranged from 0.855 to 0.984, significant at the 0.01 level (2-tailed) across all conditions for four lists, suggesting the four lists had high internal consistency. In addition, fourteen participants from the six assessment centres were randomly selected for intraclass correlation coefficient (ICC) calculation. The ICC(2,1) of the 80 items in five conditions lied between 0.931 and 0.999 and having $P < 0.001$, indicating high inter-rater reliability.

Effect of word list

Descriptive statistics of the four test lists at various SNRs are shown in Table 1.

Table 1. Mean test scores and standard deviation across the four lists and five noise conditions

	Mean test score			
Noise condition / List	List 1	List 2	List 3	List 4
Quiet				
Mean	17.60	17.53	18.34	18.00
SD	3.68	3.58	2.98	3.68
SN 5dB				
Mean	15.10	14.81	15.10	15.47
SD	5.25	5.31	5.15	5.28
SN 0 dB				
Mean	10.69	10.64	11.67	11.14
SD	5.97	6.09	6.23	6.16
SN -5 dB				
Mean	4.69	4.16	4.76	5.28
SD	5.19	4.55	5.46	5.53
SN -8 dB				
Mean	1.21	1.05	1.55	1.62
SD	2.53	1.99	2.64	2.81

Note: Each list score was out of a maximum of 20

ANOVA results showed a significant main effect for LIST, F(3, 148) = 12.36, P < 0.05). Nevertheless, the effect size was 0.186. According to Cohen,[10] an effect size of ≤0.3 is small. Therefore, although differences were noted among lists, the strength of the phenomenon was weak. As such, the four lists may be viewed as equivalent.

Effect of SNR

Descriptive statistics of the four hearing impaired groups at various SNRs are illustrated in Table 2. The main effect for SNR, F(2, 121) = 362.75, P < 0.05, indicated that the mean test scores differed significantly for the five noise conditions. Mean test scores gradually increased from SNR -8 dB to the quiet condition.

Table 2. Test scores and standard deviation across the five noise conditions

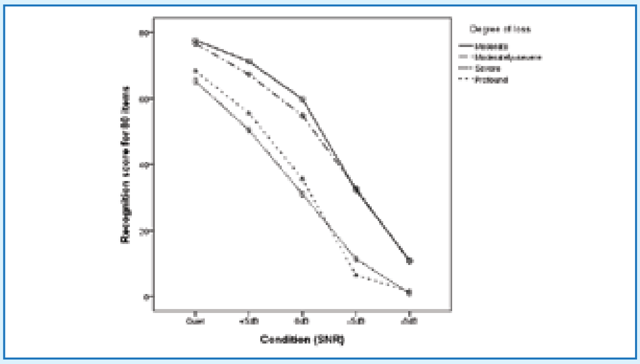
	Mean test score				
Group / SNR	-8dB	-5dB	0dB	+5dB	Quiet
Moderate (n=16)					
Mean	11.00	32.25	59.81	71.25	77.69
SD	12.05	21.95	16.65	9.88	3.03
Moderately severe (n=9)					
Mean	10.56	32.89	54.78	67.33	76.67
SD	12.57	25.52	23.87	15.07	5.29
Severe (n=14)					
Mean	1.00	11.36	31.07	50.43	65.29
SD	2.29	11.93	21.91	24.24	14.56
Profound (n=19)					
Mean	1.58	6.53	35.53	55.58	68.37
SD	4.48	7.16	21.76	21.73	17.37

Paired sample t-tests indicated significant differences in each of the groups across SNR with most groups reaching significance of P < 0.01.

Effect of hearing status

Performance of the four hearing impaired groups is shown in Figure 1.

Figure 1. Comparison of mean test score across the four hearing impaired groups



There was statistically significant difference in mean test scores according to degree of hearing impairment, F(3, 54) = 7.966, P < 0.05. Post hoc multiple comparisons revealed that there was a statistically significant difference in test scores between the moderate and severe hearing impaired groups, P < 0.002; and between the moderate and profound hearing impaired groups, P < 0.002.

Relationship between audiometric thresholds and test scores

Correlations between audiometric thresholds, both unaided and aided, and test scores are illustrated in Figure 2a and 2b.

Figure 2a. Relationship between aided thresholds and test scores

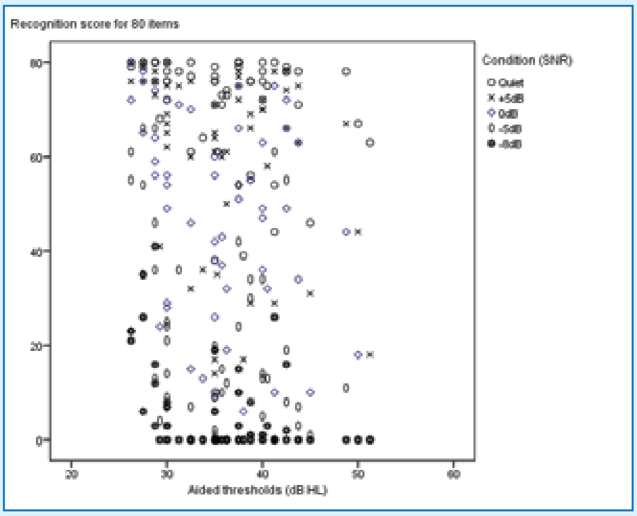
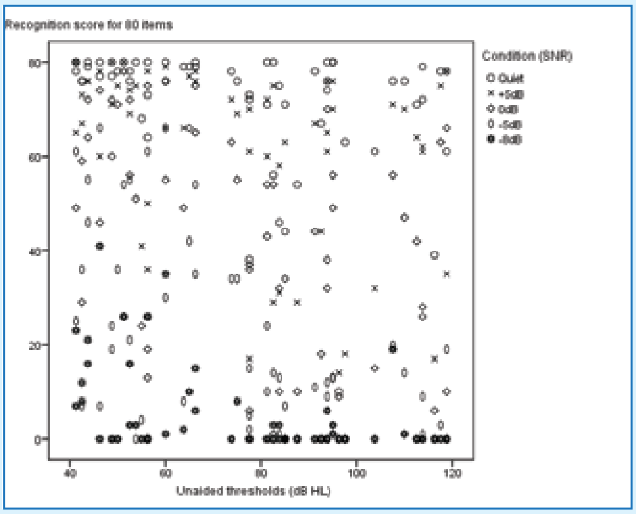


Figure 2b. Relationship between unaided thresholds and test scores



Pearson product-moment correlation coefficients were measured to assess the relationship between pure tone thresholds of aided and unaided conditions and the speech perception scores under different noise conditions (Table 3).

Table 3. Relationship between pure tone thresholds and CanSWORT $_{\text{in noise}}$ scores under different noise conditions

Pearson correlation coefficient	Quiet	+5 SNR	0 SNR	-5 SNR	-8 SNR
Unaided PTA	-0.322*	-0.342**	-0.442**	-0.567**	-0.455**
P	0.014	0.008	0.001	0.000	0.000
Aided PTA	-0.216	-0.330*	-0.375**	-0.382**	-0.401**
P	0.104	0.011	0.004	0.003	0.002

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Results revealed a trend of negative correlation between pure tone thresholds and CanSWORT $_{\text{in noise}}$ scores, suggesting better hearing thresholds, both aided and unaided, were associated with higher CanSWORT $_{\text{in noise}}$ scores. However, the strength of correlation was weak, meaning that there was minimal relationship between them.

Discussion

Our results show that CanSWORT $_{\text{in noise}}$ has high internal consistency and high inter-rater reliability. Besides, the four word lists, when presented in the five different noise conditions, are equivalent. Thus, this word recognition in noise test is applicable for testing Cantonese speaking children with significant hearing impairment.

The significant effect of SNR suggests that children with hearing loss using amplification benefit from an increase in SNRs. According to the recommendations of the American Speech-Language-Hearing Association[11] and the British Association of Teachers of the Deaf,[12] SNR should be +15 dBA or higher in occupied classrooms. Maintaining a good SNR is a target for hearing related professionals, parents and teachers. In order to achieve this, education for teachers and parents on the special needs of children with hearing impairment, as well as the technology available, such as the use of FM systems, should be further promoted.

Besides, our findings agree with Kei and Smyth[13] that speech perception of Cantonese-speaking children with hearing impairment cannot be predicted from their pure tone hearing thresholds. Heinrich et al[14] claims that hearing sensitivity, as measured by pure-tone audiometry, can only partly explain the speech understanding ability of a person, while the different aspects of cognition, particularly working memory and attention, also contribute to the speech perception result. Our test results further confirm that speech audiometry should be included as part of the test battery to provide more comprehensive audiological information for a child.

Clinical applications

CanSWORT $_{\text{in noise}}$ scores are a good indicator of how well an individual can perceive speech in noise. Given its high validity and reliability, it can be considered a potential assessment tool for evaluating the spoken word recognition ability of young children with significant hearing impairment, particularly those who have complaints about understanding speech in noise. A child's performance should be evaluated by comparing his/her own test scores across different noise conditions, as well as comparing his/her score to the mean score of the same hearing impaired group. With this assessment tool, audiologists can monitor a child's progress in speech recognition before and after undergoing an aural rehabilitative program.

Since the test scores of CanSWORT $_{\text{in noise}}$ can provide clinical evidence of how a child actually performs when hearing in noise, it would make it easier for audiologists to identify the special needs of the child and make recommendations on remedial services accordingly. They include needs for fine tuning of hearing aids, preferential classroom seating, use of FM systems, communication tactics and environmental modifications, etc. As parents' awareness of the impact of noise on speech recognition is raised, their consensus and cooperation would subsequently be increased which are essential for successful implementation of the recommended measures.

Limitations of the study

Some limitations have been identified with the present study. In order to investigate the equivalence of the test lists under different noise conditions, participants were required to listen to the four lists five times under different SNRs. Although an attempt was made to minimise learning effect by letting the participants listen to the more difficult condition first, i.e. in the order of SNR -8 dB, -5 dB, 0 dB, +5 dB and quiet, a learning effect for the test items could not be completely ruled out.

The test was shown to be very demanding for our participants as they had to listen to 80 disyllabic words in each of the five noise conditions, meaning that they had to respond to four hundred test items in total. As the test required immediate response to the speech items presented, a high degree of concentration on the task was required. The average test time for a child was 60 to 90 minutes. Although breaks were given whenever required, negative factors, including fatigue, inadequate patience and lack of interest, might still adversely affect the test scores for some participants.

The sample size (n=58) of our study is rather small. Adopting purposive sampling of CAS cases, we have excluded from our study hearing impaired children with other developmental problems, such as global developmental delay, autistic spectrum disorder and attention deficit problems. Hence, the sampling method chosen has limited the generalisation of the speech test profiles to the entire paediatric population with significant hearing loss.

Interpretation of the results of CanSWORT $_{in\ noise}$ must be made with caution. The mean test scores obtained in this study, to a certain extent, reflected the word perception ability of the four hearing impaired groups. Nonetheless, the data cannot be applied to children with normal hearing or children with non-significant hearing impairment. In addition, it should be noted that our data are derived from aided test conditions. At this stage, CanSWORT $_{in\ noise}$ should be used for evaluating speech perception when a child is unaided.

Despite the clinical value of CanSWORT $_{in\ noise}$, clinicians should bear in mind that word recognition does not equate to speech comprehension which involves grasping the ideas and facts presented in the connected discourse.[15] The listener must perceive and attend to relevant speech features, such as the pitch, timing, and timbre of the target speaker's voice, as well as ascribe meaning to the speech sounds. It is important that as a hearing impaired child grows older, his/her speech understanding ability is further evaluated with other speech tests.

Future directions

It is important to develop CanSWORT $_{in\ noise}$ applications with more data for children with significant hearing impairment. Besides, establishment of normative data for children with normal hearing, as well as use of the test under unaided conditions, should be further developed.

The detrimental effect of reverberation on speech recognition has not been taken into account in this study. The combination of noise and reverberation may interfere with children's acoustic-phonetic (bottom-up) processing, thus weakening their performance in word recognition.[6,16-19] In light of the reverberation factor, CanSWORT $_{in\ noise}$ scores still may not fully reflect the word recognition ability of children in everyday listening scenarios. Future studies should bring more insights to a child's speech understanding across various acoustic environments e.g. noise-plus-reverberation condition, where the real-world situations can be better simulated.

The evaluation of the ability to understand connected discourse has the highest face validity in predicting a child's ability to understand conversational speech[20] because it provides a true representation of the speech encountered in everyday life.[13,21] The University of Queensland Understanding Everyday Speech Test (UQUEST) includes passages based on real-life situations that are familiar to school children.[15] It has been found to be sensitive to hearing deficits in children and adults.[5,22] A similar test in Cantonese would be a valuable tool for assessing older children.

Conclusion

Although the precise nature of the effects of noise upon the cognitive processes of children is not fully known, the impact of noise on word recognition has been clearly demonstrated in this study. It is expected that CanSWORT $_{in\ noise}$, with further development, can be included as part of the test battery for evaluating the performance of Cantonese-speaking children with hearing impairment as young as three years of age.

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The Relationship between the Age of Hearing Aid Fitting/ Cochlear Implantation and the Aided Hearing Level with Language and Literacy Abilities before Primary School Entry in a Group of Children with Significant Bilateral Hearing Impairment in Hong Kong

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Introduction

Permanent childhood hearing impairment is a common birth defect, where significant bilateral hearing impairment is present in approximately 1 to 3 per 1000 live births and in 2 to 4 per 100 neonates in intensive care unit populations.[1-4] Oral language development is highly dependent upon what an infant can hear. The inability to hear disrupts communication and when present from birth, affects social, emotional and linguistic development. It also has great impact on educational achievement and quality of life.[5-8]

Recent studies found that many children with permanent hearing impairment could achieve language abilities similar to hearing peers if comprehensive interventions were started early. Improved outcomes are associated with identification and intervention by six months of age.[9-13] Universal neonatal hearing screening is therefore important to reduce the age at confirmation of congenital hearing impairment.[14] Many outcome studies, however, included all grades of hearing impairment range from mild to profound level, affecting the overall outcome of the studied population. There have been no previous studies in Hong Kong looking at language and literacy outcomes of children with significant hearing impairment and how these are related to particular demographics and intervention profiles. This paper attempts to provide preliminary answers to these questions.

In Hong Kong from 2007 onwards, universal neonatal hearing screening was implemented through a two-stage screening model using Automated Auditory Brainstem Response (AABR) protocol at Hong Kong Hospital Authority (HA) birthing hospitals. Neonates who failed the screening will be assessed by confirmatory Brainstem Acoustic Evoke Response (BAER) in hospitals. Neonates born at private hospitals without hearing screening can be screened at Maternal and Child Health Centers (MCHCs) using Automated Otoacoustic Emission (AOAE). Those who failed AOAE screening will be forwarded to audiologists of ENT Departments or Department of Health Child Assessment Service (CAS) for confirmatory diagnosis. All neonates who failed BAER will be referred to ENT Departments and to CAS for further management. In addition to providing comprehensive assessments, CAS also serves to coordinate various medical and rehabilitation follow-up. Children with significant hearing impairment are seen by a multidisciplinary team and they would be followed according to standardized protocols. Referrals are made to specialized habilitation and support groups. Referrals are also made to the Hong Kong Education Bureau (EDB) if hearing aid prescription is indicated.

We believe it is important for a child to achieve effective aided hearing soon after he/she has been diagnosed to have significant hearing impairment. The earlier effective aided hearing is achieved, the longer period the child can be exposed to language and environmental stimulations during the critical period.

The objective of this study is to investigate the association between effective hearing age, aided hearing level and other factors with language and literacy outcomes in a group of children with significant hearing impairment at CAS.

Method

Participants

The children in this retrospective cohort study were those born between 1 January 2004 and 31 December 2007 inclusive, with confirmed permanent bilateral hearing impairment equal to or exceeding 56 dB HL. The study gained approval by the Hong Kong Department of Health and its Ethics Committee.

Data was first obtained from the in-house computer database system in CAS (CASIS). Children with the ICD-10 codes for moderately severe hearing impairment or worse in the better ear were included. Details of the identification, diagnosis and management of all these children were obtained by case record review. Children were excluded if any of the following criteria was met: children with unilateral hearing impairment, Cantonese was not their first language, children with limited intelligence or intellectual disabilities, presence of congenital abnormalities, cases lost to follow up or who have died before language and literacy assessments.

At the critical developmental point of primary school entry, each child was assessed for hearing function, intellectual function, language skill and literacy skill. All assessments were administered by the relevant professionals - audiologist for hearing function, clinical psychologist for intellectual function and literacy development, and speech therapist for oral language abilities.

Independent variables

The following data were reviewed and recorded: socio-demographic, paternal and maternal educational level, child's gender, age at diagnosis, hearing level at diagnosis, effective hearing age (age in months at which effective hearing was achieved with hearing aids or with cochlear implants), aided hearing level, speech therapy (ST) commencing age, ST training duration and intellectual function.

Intellectual function was measured by standardised assessment tools. Most of the children were assessed with the Hong Kong Wechsler Intelligence Scale for Children (HK-WISC).[15] This test had been widely used as an assessment tool in Hong Kong before the availability of newer tools, and was normed for the Cantonese speaking children aged 5 to 15 years. It provided information about a child's verbal or crystallized intelligence and performance or fluid intelligence. The newer tool, The Wechsler Intelligence Scale for Children – Fourth Edition (Hong Kong) [WISC-IV(HK)][16] was also locally normed and used in some of the children of this cohort. Wechsler Preschool and Primary Scale of Intelligence – Revised Edition (WPPSI-R) Taiwanese (Chinese) Version was used in some cases. The performance intelligence score (PIQ) of each child was charted as a reference for the intellectual function as most children could not complete the verbal part of the tests. We included all children with PIQ of average range or above i.e. PIQ≥80.

Outcome variables

Language function: Language skills were assessed with Reynell Developmental Language Scales - Cantonese version (RDLS-C)[18] or for older children with the Hong Kong Cantonese Oral Language Assessment Scale (HKCOLAS).[19] These tests have local norms and are widely used in Hong Kong Cantonese-speaking children. RDLS-C assesses verbal comprehension (VC) and verbal expression (VE). VC scores were taken as the children's language abilities since VE performances were highly affected by phonological and articulation disorders in these children. Children with the VC scores at or above minus one standard deviation (SD) were considered as having normal language ability; at minus one to above minus two SDs were considered as mild language delay; at minus two to above minus three SDs were considered as moderate language delay and those at and below minus three SDs were considered as severe language delay. HKCOLAS assesses several aspects of children's language abilities which includes Cantonese grammar, textual comprehension, word definition, lexical-semantic relations, narrative and expressive nominal vocabulary. In this study, children assessed with scaled scores of 7 or above in 5 or more subsets were considered as having normal language ability, those with scaled scores of 6 in two subsets (with other subsets' scaled scores above 6) were considered as mild language delay; those with scaled scores of 4 or 5 in two subsets (with other subsets' scaled scores above 5) were considered as moderate language delay; and those with scaled scores of 3 or below in two subsets or more were considered as severe language delay. These language outcomes were further dichotomised into two groups of normal and language delay groups in the final multiple logistic regression analysis.

Literacy skills: Literacy skills were tested by The Hong Kong Test of Specific Learning Difficulties in Reading and Writing for Primary School Students (HKT-SpLD);[20,21] The Hong Kong Reading Ability Screening Test for Preschool Children (RAST-K);[22] and informal assessment with a tool consisting of Chinese single character and two-character word lists. This variable was dichotomised into children having normal literacy skills as one group and those having weak literacy skills or at risk of dyslexia into another group.

Statistical analysis

The Statistical Package for Social Sciences was used in conducting the statistical analysis. Bivariate analysis was performed to examine the relationship between the independent variables and the outcome variables of language and literacy abilities. Chi square test was used to analyze nominal or ordinal data while independent t-test was used to analyze interval data. Independent variables which were shown to be related to the outcome variables ($P<0.1$) in bivariate analysis were selected to be analysed again in multivariate logistic regression. Model chi square statistic, which is a global test of parameters, was used to test if any variable or subset of variables was related to the outcome. Any relationship with P<0.05 was considered statistically significant in multivariate logistic regression.

Results

Sample characteristics

Within the set period, 96 cases were drawn from the CASIS with the coding of bilateral moderately severe hearing impairment or worse. Hearing impairment in these cases were stable. 33 cases were excluded because of intellectual disabilities. Three cases were excluded because of multiple congenital abnormalities in addition to intellectual disabilities. Eight cases were lost to follow-up, three cases have passed away. Three cases were excluded because they were non-Cantonese speakers. One case who received auditory brainstem implant subsequent to CI did not acquire oral language and only used signing, and was excluded from the study. There were 45 cases remaining which were entered into the study.

The male to female ratio was 29 to 16 (64% : 36%). The mean severity of hearing impairment in our sample was 89 dB HL. The mean age at achieving effective hearing was 24 months and the mean aided hearing level was 37 dB HL. The mean age of starting ST was 29 months and the children on average received 47 months of ST training. There were 35 children with average PIQ and 10 children with high average or above PIQ. 44 children were tested for language skill; one child was not tested because of parental refusal. Of those 44 children tested, 14 children (31%) showed normal language abilities while 30 children (67%) were found to have mild language delay or below. 43 children were tested for literacy. 36 children (80%) had normal literacy skills while seven children had weak literacy skills or assessed to be at risk of dyslexia. Summary of other socio-demographic data was shown in Table 1.

Bivariate analysis

Factors associated with language outcome

Language outcome was divided into two groups, those with normal language ability and those who performed at less than minus one SD below the mean in standardised tests. As shown in Table 2, among the various factors, PIQ and father's education were found to be related to the language outcome with P=0.01 and P=0.07 respectively. The effective hearing age was found to be associated with the language outcome with P=0.06. Hearing level at diagnosis, mother's education, aided hearing level and ST commencing age or ST training duration failed to show any association with language outcome.

Factors associated with literacy outcome

Literacy outcome was defined as those with normal literacy skills and those assessed with weak skills or at risk for dyslexia. As shown in Table 2, hearing level at diagnosis, aided hearing level and ST commencing age were correlated with literacy with P=0.088, P=0.072 and P=0.029 respectively. Father's and mother's educational levels were also significantly correlated with literacy outcome with P=0.012 and P=0.005 respectively. However, ST training duration and PIQ did not show any association with the literacy outcome.

Multivariate logistic regression analysis

It was of interest to explore the relative contribution of the statistically significant factors in bivariate analysis to the language and literacy outcomes. We conducted a series of multivariate logistic regression analyses using those factors as predictors to examine how they would predict the language and literacy outcomes.

Factors predicting language outcome

The effective hearing age significantly predicted the language abilities (model chi-square=7.853; P=0.049). Given the effective hearing age, PIQ could also significantly predict the language abilities (block chi-square=6.556; P=0.010). In the final model, a child with hearing aid at the age between 0-12 months has 9.875 times (95% confidence interval: 1.109-87.910) the odds of having normal in language abilities than a child with hearing aid at the age between 13-24 months. A child with average PIQ has 0.060 times (95% confidence interval: 0.007-0.512) the odds of being normal in language than a child having high average or above PIQ. Table 3 summarizes the results of these regression analyses.

Factors predicting literacy outcome

The aided hearing level was shown to be a significant predictor of literacy abilities (model chi-square=8.983; P=0.011). Given the aided hearing level, parental education also significantly predicted the literacy outcome (block chi-square=6.181; P=0.045). Table 4 summarises the results of these regression analyses.

Discussion

Early diagnosis of hearing impairment is essential to allow timely intervention. In Hong Kong, early diagnosis is achieved through universal newborn hearing screening. However, there may be variable time lag before the child achieves effective hearing through the fitting of hearing aids or cochlear implants. Factors including the degree of hearing impairment, cognitive ability, family participation, age of entry to early intervention, parental education and use of hearing aids or cochlear implants have all been previously reported to have impact on the spoken language outcomes in preschool children.[23-25]

In the present study, we investigated similar factors affecting the language and literacy development in a group of children with moderately severe or worse hearing impairment in Hong Kong. Among the variables, effective hearing age played a significant role in association with language outcome in both bivariate analysis and multiple regression analysis. In previous studies, it was shown that PIQ is the strongest predictor of language outcomes for children with hearing impairment up to the age of five.[26] Together with early effective hearing age, both factors contributed to good language outcome in this report, while aided hearing level and parental educational level were both shown to be significant contributing factors to literacy outcome in multiple logistic regression in this study.

There were limitations in this study. Since the prevalence of children with moderately severe hearing impairment or worse was low, the total number of cases in this study was limited. Children with hearing aids and cochlear implants were analysed together in our study. Differences in development and response between these two groups cannot be ruled out.

Longitudinal follow up studies on language and literacy outcomes in children with hearing impairment are currently carried out in Australia, United States, Finland and England. A larger longitudinal prospective cohort study on Hong Kong children with significant bilateral hearing impairment, utilising standardised protocols from identification to diagnosis and management through preschool and school-age, will be desirable for investigating contributing factors to language and literacy outcomes in the future.

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Table 1. Summary of sample characteristics (n=45)

Characteristics	n	%	
Sex			
Male	29	64.4	
Female	16	35.6	
Performance IQ			
Average	35	77.8	
High Average	4	8.9	
Superior	4	8.9	
Very superior	2	4.4	
Father education			
Unknown	1	2.2	
Primary	4	8.9	
Lower secondary	8	17.8	
Upper secondary	21	46.7	
Sixth form	11	24.4	
Tertiary education			
Mother education			
Unknown	1	2.2	
Primary	2	4.4	
Lower secondary	14	31.1	
Upper secondary	18	40.0	
Sixth form	1	2.2	
Tertiary education	9	20.0	
Language			
Severe language impairment	16	35.6	
Moderate language impairment	10	22.2	
Mild language impairment	4	8.9	
Normal	14	31.1	
Missing	1	2.2	
Literacy			
Suspected dyslexic	1	2.2	
Weak literacy	6	13.3	
Normal	36	80.0	
Missing	2	4.4	
	Mean	SD	Median
Aided hearing level (in dB)	37	7.33	35.00
Hearing level at diagnosis (in dB)	89	14.93	90.00
Effective hearing age (in months)	24	15.06	19.00
ST commencing age (in months) *	29	15.64	25.00
ST training duration (in months) *	47	15.56	48.00

* 1 missing case is excluded from calculation

Table 2. Factors associated with outcomes: bivariate analysis

	Language outcome					Literacy outcome				
	Normal		Language Impairment			Normal		Weak literacy or suspected dyslexic		
	n	%	n	%	P	n	%	n	%	P
Sex										
Male	9	31.0	20	69.0	1.00	22	78.6	6	21.4	0.391
Female	5	33.3	10	66.7		14	93.3	1	6.7	
Performance IQ										
High average to very superior	1	70.0	3	30.0	0.01 *	10	100.0	0	0.0	0.172
Average	7	20.6	27	79.4		26	78.8	7	21.2	
Father education										
Upper secondary or above	12	38.7	19	61.3	0.07	29	93.5	2	6.5	0.012 *
Lower secondary or below	1	8.3	11	91.7		7	58.3	5	41.7	
Mother education										
Upper secondary or above	11	40.7	16	59.3	0.19	26	96.3	1	3.7	0.005 **
Lower secondary or below	3	18.8	13	81.3		9	60.0	6	40.0	
Aided hearing level										
Moderate to moderately severe	0	0.0	6	100.0	0.16	4	57.1	3	42.9	0.072
Mild	14	36.8	24	63.2		32	88.9	4	11.1	
Effective hearing age										
0-12 months	8	61.5	5	38.5	0.06	11	100.0	0	0.0	0.251
13-24 months	2	14.3	12	85.7		11	78.6	3	21.4	
25-36 months	2	28.6	5	71.4		7	87.5	1	12.5	
>=37 months	2	20.0	8	80.0		7	70.0	3	30.0	
	n	Mean (SD)	n	Mean (SD)	P	n	Mean (SD)	n	Mean (SD)	P
Hearing level at diagnosis (in dB)	14	86.07 (14.70)	30	89.67 (15.25)	0.47	36	89.64 (14.89)	7	97.14 (8.09)	0.088
Start ST age (in months)	14	23.21 (14.40)	29	31.62 (15.95)	0.10	36	26.75 (14.26)	6	42.00 (20.89)	0.029 *
ST training duration (in months)	14	47.07 (18.12)	29	46.59 (14.81)	0.93	36	48.33 (15.83)	6	37.00 (14.00)	0.108

*P < 0.05 **P < 0.01

Table 3. Factors predicting language: multivariate logistic regression analysis

Variable	P	Odds ratio	95% CI	Model chi square	P	Block chi square	P
Step 1				7.853	0.049*		
Effective hearing age							
0-12 months	REF	REF					
13-24 months	0.040*	9.875	1.109-87.910				
25-36 months	0.404	2.567	0.281-23.450				
>=37 months	0.092	7.307	0.724-73.759				
Step 2				14.409	0.006**	6.556	0.010 *
Performance IQ							
Average	REF	REF					
High average to very superior	0.010*	0.060	0.007-0.512				

*P < 0.05 **P < 0.01

Table 4. Factors predicting literacy: multivariate logistic regression analysis

Variable	P	Odds ratio	95% CI	Model chi square	P	Block chi square	P
Step 1				8.983	0.011*		
Aided hearing level	0.110	1.144	0.970-1.349				
Hearing level at diagnosis (in dB)	0.466	1.033	0.947-1.127				
Step 2				15.163	0.004**	6.181	0.045*
Father education							
Lower secondary or below	REF	REF					
Upper secondary or above	0.173	0.198	0.019-2.033				
Mother education							
Lower secondary or below	REF	REF					
Upper secondary or above	0.253	0.204	0.013-3.112				

*P < 0.05 **P < 0.01

Sign Bilingualism and Co-enrollment Programme for Students with Hearing Impairment in Hong Kong

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Introduction

Different educational approaches for students with hearing impairment are in place in Hong Kong. There is one remaining special school (Lutheran School for the Deaf) for students with hearing impairment in Hong Kong, following the sequential closing down or changing of services at other such previous special schools. All the teachers receive professional training, and use spoken language with the help of various forms of sign language (not including Hong Kong Sign Language) in classroom teaching and extra-curriculum activities. The school considers that spoken language, written language and sign language are all important areas for children development. Today, students with severe hearing impairment in the better ear and with at least limited intelligence are eligible to apply to the Lutheran School for the Deaf. Those with hearing impairment together with other significant comorbidities, such as intellectual disabilities, will be admitted to special schools that cater for those other needs.

The majority of students who have significant hearing impairment only are admitted to mainstream schools where the communication modes are spoken and written language. Sign language is not applied. The global shift toward inclusive education for individuals with hearing impairment, also referred to as deaf and hard-of-hearing (DHH) learners, aims to address their holistic needs in accessing the full curriculum as well as to learn with their hearing age peers in a regular school environment. However, most students with hearing impairment educated in the current mainstream environment continue to encounter various degrees of difficulties in learning, and not many of them are able to pursue higher education. Furthermore, it has been reported that they were often unable to establish close relationships with their hearing peers.[1,2] Consequently, they felt lonely and being isolated in school.[3-5]

Historically from the 1930s to the 1970s, deaf education in Hong Kong was mainly conducted in special school settings.[6] In 1977, The White Paper of the Hong Kong Government "Integrating the Disabled into the Community" led to significant changes in special education delivery.[7] Today more and more students with hearing impairment, from mild to profound hearing losses, are studying in mainstream schools and are educated under an "oral-only" approach without exposure to signing and Hong Kong Sign Language (HKSL). In 2012, the United Nations Committee on the Rights of Persons with Disabilities issued a statement saying that "it takes note of the difficult situation of persons with hearing impairments in accessing information due to lack of official recognitions of the significance of sign language by Hong Kong, China".[8] Sign language was developed to facilitate the communicative needs of deaf people. Surprisingly, among the 150,000 people with hearing impairment in Hong Kong, less than 4,000 are competent in signing. The importance of sign language in the early development of deaf children has received limited attention. Oralist education seemed the only option for them in the mainstream setting. There is a still a common misconception among the public that sign language will hinder the development of oral language development. However, how well is the oral language performance in students with hearing impairment within the current Hong Kong educational system by using the solely auditory-oral approach? In a recent study examining the oral language outcomes of 98 Cantonese-speaking mainstream primary school students with mild to profound hearing impairment, 18% of the participants exhibited mild to moderate language impairment while 41% of them showed severe language impairment. When correlating the degrees of language and hearing impairment, language impairment was present in 20% of students with mild grade hearing impairment, and in 92 % of students with profound grade hearing impairment. The challenges associated with the acquisition of Cantonese grammatical knowledge and the processing of speech signals with a higher auditory demand made it extremely difficult for students with hearing impairment to cope with the academic demand in a typical classroom in Hong Kong where they adopt a "biliterate and trilingual" language policy.[9]

Sign bilingualism and co-enrollment

In 1880, the International Congress on Education of the Deaf,[10] commonly known as the "Milan Congress", passed a resolution to remove the use of sign languages from schools for the deaf around the world. Sign linguistics research since the 1960s have shown that natural sign language is indeed not gesture, but a visual language with a full-fledged language system, including grammar and other components. In the 1960s and 1970s, sign linguistics emerged as a subdiscipline of linguistic study.[11,12] In response to the disappointing educational outcomes of the oralist approach in education, deaf schools that endorsed sign language led to the initial application of sign bilingualism, with acquisition of both sign and spoken language abilities.

In addition to the use of sign bilingualism, the concept of co-enrollment was developed. Co-enrollment stresses the importance of enrolling a critical mass of students with hearing impairment to study alongside a larger group of hearing peers using an appropriate deaf-hearing ratio. The dual input of a sign language and a spoken language to support bimodal bilingual acquisition by both the majority-hearing students and minority students with hearing impairment is the cornerstone of the programme. Today, a ratio of 1:3 or 1:4 hearing impaired to hearing students is observed in many programmes. In a co-enrollment classroom, dual language input is provided by the regular hearing teacher who teaches orally and a teacher for the deaf who signs. Both deaf and hearing teachers tend to the educational needs of both hearing students and students with hearing impairment, whichever medium of instruction they are using. Incorporating a sign language into a regular school setting can support both hearing and hearing impaired students to access the same and regular curriculum. Hearing students who become immersed in a sign bilingual environment at a young age also will become linguistically competent in sign language, using it to facilitate their own comprehension of curriculum contents in class when obtaining them solely through the hearing teacher's speech fails.[13]

According to Kirchner,[14] one of the founders of the TRIPOD Co-enrollment program, co-enrollment programming promotes (a) direct communication between students with hearing impairment and hearing students as well as their teachers (i.e. the "no interpreters" approach), (b) equal access to a regular curriculum through team teaching with a regular teacher and a teacher for students with hearing impairment, providing both spoken and sign languages, (c) opportunities for engaging students with hearing impairment in academically challenging tasks, and (d) socio-emotional support by creating a bimodal bilingual peer group in school that shares common linguistic resources. Since the establishment of the TRIPOD program in California in the United States, more and more such co-enrollment practices at the kindergarten and primary levels have been set up at the turn of the century, including the Arizona program, the Twin-School programs in Norway and the Netherlands, programmes in Italy, Taiwan, Japan, and Spain, and in 2006, through the Jockey Club Sign Bilingualism and Co-enrolment in Deaf Education Programme, in Hong Kong.[15-17]

Most of the co-enrollment programmes today endorse the use of natural sign language. Natural sign language is a language that naturally occurs and evolves in the deaf community. It has unique grammatical rules, including word order, use of quantifier predicates, use of non-handed features, use of sign language space, etc. This applies to Hong Kong's natural sign language (HKSL), with grammatical structures that are independent and different from those of standard Chinese or Cantonese.

The Sign Bilingual and Co-enrolment (SLCO) in deaf education programme in Hong Kong

In view of the overwhelming evidence of the importance of effective communication for hearing impaired in education, and the prevailing difficulties experienced by Hong Kong's students with hearing impairment in mainstream schools using oral language only as their mode of instruction, the Chinese University of Hong Kong launched the 7-year Sign Bilingualism and Co-enrolment in Deaf Education (SLCO) Programme in 2006 with the support of the Hong Kong Jockey Club. This project was designed to evaluate the effectiveness of an education model with sign bilingualism and co-enrollment on the language development of deaf and hearing students, from the perspective of sign language development, literacy and oral language development. There are four key elements that form the foundation of the SLCO programme: a whole-school approach toward promoting deaf and hearing collaboration; involvement by deaf individuals in school practices, especially deaf-hearing co-teaching practices in the SLCO classroom; an enriched linguistic context to support bimodal bilingual development of hearing and hearing impaired students; and their active participation in school and social activities.[18]

The SLCO project aims to design and test out the model, collect longitudinal data for documentation and further application, as well as to develop teaching materials, train teachers and related professionals. The SLCO school programmes commence at kindergarten and extend to secondary grades.

1. SLCO Kindergarten Programme
   The SLCO Programme is implemented at the Peace Evangelical Centre Kindergarten (Ngau Tau Kok). Five to six children with hearing impairment are admitted each year, and one class at each grade is designated for implementing the programme. Each of these classes is supported by collaborative teaching between a hearing teacher and a deaf adult. It provides deaf and hearing students a sign bilingual learning environment, which enhances classroom participation. In addition to daily contact with hearing students, deaf students also continuously develop their oral language and literacy through learning support sessions and language training by speech therapists. A through-train primary and secondary school arrangement, thereby ensuring these students will continue to receive this mode of education when they transition.

2. SLCO Primary School Programme
   The SLCO Primary School Programme is currently delivered at the Oblate Primary School. Deaf and hearing teachers cooperate in co-teaching. Students with hearing impairment receive additional learning support from teachers, and language training from speech therapists. The use of both sign language and spoken language in the classroom enables all to participate actively in class, learn subject knowledge effectively and advance in language abilities. The school also trains hearing students to become "Junior Sign Interpreters", enabling students to use their sign language ability to serve as interpreters for classmates with hearing impairment as needed.

3. SLCO Secondary School Programme
   The SLCO Secondary School Programme commenced in 2013 at the Notre Dame College. The aim of the programme is to nurture competence in Chinese, English and Hong Kong Sign Language for students with hearing impairment, and nurture the inclusive attitude of both hearing and hearing impaired students. In 2019, the programme saw the first batch of co-enrolled sign bilingual deaf and hearing students graduate from secondary school and apply for university education.

4. SLCO Satellite Programmes
   Satellite Programmes adopt a part of the Sign-bilingual Co-enrolment Programme approach with the aim of supporting more students with hearing impairment who are studying in regular mainstream schools. Semple Memorial Secondary School, Lock Tao Secondary School and The Air Cargo Community Day Crèche of Hong Kong Society for the Protection of Children have started to enroll students with hearing impairment under the support of the SLCO Programme.

   As the students grow up, follow-up evaluation focuses on educational progress, adaptations and arrangements particularly at transition points, as well as family support structures. On-going support, advocacy and consultation with educators and other professionals would foster the unique characteristics and strengths of each individual child as he or she goes through various developmental stages including the adolescent period.

5. Preschool Sign Bilingual Development Programmes
   Preschool elements include the Baby Signing Programme for children with hearing impairment from 0-3 years of age. The aim of the programme is to allow these young children to build up a solid language foundation through natural sign language. Through this, future oral language and literacy development will be

facilitated. Parents of these children learn to sign with their children, and parent-child interaction is thereby enhanced. The programme is also open to hearing children, whereby their early language development will also be enhanced through the additional input of signing.

Chinese literacy development is also provided through The Sign Bilingual Chinese Literacy Programme, designed for deaf children aged 3-6 years. The Programme uses natural sign language, spoken language and written language to assist in reading in children with hearing impairment. Teachers would use sign language to facilitate reading activities and to strengthen the knowledge of Chinese grammar. The aim is to enhance the children's oral language expression and literacy. The Programme is also open to normally hearing children.

Since the completion of the JC SLCO project in 2014, the school programme and related research, materials and tools production and a range of services continued through the establishment of a non-government organisation and continued support from CUHK.

Language performance and academic attainment

Experience overseas showed positive outcomes on language skills and socio-emotional development.[15] A number of past studies have reported positive gains in in spoken language and literacy development. Kreimeyer et al[19] reported academic data obtained on the Stanford Achievement Test–ninth edition showed that reading comprehension scores of the co-enrolled students with hearing impairment were above those of the students with hearing impairment normative sample (i.e. students with hearing impairment from schools for the deaf) during both the second and third years of the programme. Obtaining significantly better results in reading comprehension, which is an area that is traditionally weak for students with hearing impairment, speaks highly of the co-enrollment model. There was no significant difference in reading vocabulary among the co-enrolled students with hearing impairment, national normative of students with hearing impairment and the hearing group. Similarly, Hermans et al[20] observed a significant growth rate in receptive vocabulary in Dutch with their twelve students with hearing impairment in the Twin-School Program, although difference still existed when compared with the hearing age norms. In Madrid, initial positive gains in vocabulary knowledge were also found with a group of co-enrolled students with hearing impairment studying in four sign bilingual regular schools.[21] Eight out of 12 young students with hearing impairment scored above age norms in the spoken Spanish Child Development Inventory test.[22] And 11 older children revealed age-appropriate development based on their vocabulary scores of PPVT-III Peabody[23] and the Spanish version of K-Bit.[24]

Since sign bilingualism and co-enrollment in deaf education is new to Hong Kong, evidence on its effectiveness has just begun to emerge. Empirical evidence so far on its effectiveness has been accumulating, largely showing positive gains in vocabulary, grammar, reading comprehension skills, as well as socioemotional development.

In its baby signing programme, children as young as nine months old were observed to begin using basic signs covering objects such as “car”, “apple”, “flower,” and concepts such as “I don’t like “and “ I want”, in contrast to typical children who normally acquire meaningful single words after one year of age.

In 2014, Tang et al[25] tested the effect of five years of sign bilingualism and co-enrollment education on the language development of a group of 20 students with severe to profound hearing impairment, from Primary 1 to Primary 5. Tests conducted included The Hong Kong Cantonese Oral Language Assessment Scale: Cantonese Grammar subtest (HKCOLAS-CG),[26] The Assessment of Chinese Grammatical Knowledge (ACGK)[27] and Hong Kong Sign Language Elicitation Tool (HKSL-ET) by Centre for Sign Linguistics and deaf Studies, CUHK.[28] A positive correlation was found between development of syntactic and morphosyntactic knowledge of oral Cantonese, written Chinese which is based on Mandarin grammar, and Hong Kong Sign Language (HKSL). No adverse effects on the development of oral Cantonese or written Chinese when children with hearing impairment also learned and used HKSL. This result speaks against the misconception that acquiring sign language impedes the development of spoken language children with hearing impairment. Centroid method of hierarchical clustering was applied to categorise the children with hearing impairment based on their performance of HKCOLAS-CG, ACGK-Primary and HKSL-ET into different clusters.

It was observed that despite sharing similar levels of hearing loss, deaf children with better speech perception abilities were able to perform well on the oral language assessment, and speech perception was a crucial determinant for the development of Cantonese grammar in the Hong Kong Cantonese context, where there is no formal written mode for this dialect. The combined effects of early sign language exposure, early fitting of hearing aids, and strong speech perception abilities are essential for development of the three languages - oral, sign and written in students with hearing impairment.

Social integration

Social integration refers to the creation of a "society for all, including the disadvantaged or vulnerable groups and persons".[29] In the education context, Stinson and Antia[30] defined social integration as students' abilities to interact with, make friends with, and be accepted by peers. The extent of social interactions, social relationships and social acceptance by hearing peers as well as peers with hearing impairment shows how well students with hearing impairment are assimilated into the school community. Evidence on social integration between hearing and hearing impaired students in co-enrollment programmes is generally positive. The long-term effects of co-enrollment on school status, popularity, happiness and satisfaction as well as degree of loneliness was similar between students with and without hearing impairment.[31] It showed that students with hearing impairment studying in a co-enrollment programme were neither socially isolated, lonely nor possessing of self-image poorer than their hearing age peers. In the United States, Anita and Metz[32] further confirmed the positive outcomes in terms of social interaction during class and lunchtime between the students with and without hearing impairment, in terms of social acceptance, social skills development, and social rankings in the co-enrollment classroom, and that all the students were equally accepted. In addition, no significant differences on either the self-rated or teacher-rated social behaviour between the two groups.

Yiu and Tang[33] in Hong Kong also observed highly positive social acceptance between hearing and hearing impaired students in the co-enrollment programmes. Many of the ratings showed that students were either neutral or positively inclined toward each other. There were more positive counts than negative counts for both groups of students in both "play" and "study" conditions. There was an even higher intragroup rating among the students with hearing impairment themselves when compared with the intragroup rating among hearing students. This suggested a stronger sense of mutual support among the students with hearing impairment in the programme, likely due to their critical mass in the setting. As a minority group in the school community, they also identified themselves with each other more readily and interacted with each other more frequently. Overall, there were no indications that they were less (or more) socially accepted in the co-enrollment classroom when compared with their hearing counterparts.

The study also looked into attitudes of students with and without hearing impairment in the co-enrollment programme respectively:

Attitudes of students with hearing impairment were explored, covering (1) acceptance of deaf identity, including their willingness to accept or disclose their deaf identity and related difficulties to others, (2) reactions to worries and frustrations, (3) optimism related to coping, reflecting their ability to cope with deafness, and (4) readiness for social contact, relating to their acceptance or reluctance to maintain social contact with others. Results showed that while students with hearing impairment in the co-enrollment classes had positive and optimistic attitudes toward their hearing loss, accepting their deaf identities required more time to realize.

Attitudes of hearing students towards students with hearing impairment were explored, covering (1) positive actions relating to the caring and supportive responses of hearing students toward their hearing impaired peers, (2) negative reactions and perception, relating to the hearing students' negative perceptions and behaviors toward them, (3) positive perception, reflecting hearing students' perceptions of the personalities and behaviors of their hearing impaired peers, and (4) tolerance to communication difficulties, reflecting hearing students' reactions to the possible difficulties they perceive when communicating with hearing impaired peers through signed or oral language. Results showed that hearing students had positive perceptions of their hearing impaired peers and were ready to render positive actions, care, and support, but for them to understand and accept the communication difficulties facing these peers took more time. In addition, 74 hearing students from the co-enrollment classes with one to six years of SLCO experience (average 4.2 years) were found to have significantly more positive attitudes toward their hearing impaired peers than the 215 students without SLCO experience. The impact of SLCO experiences on cultivating a positive culture toward deafness and students with hearing impairment was clearly demonstrated.

Looking forward

In 2010 members attending an international Congress on the Education of the Deaf (ICED)[34] held in Vancouver rejected all resolutions passed at ICED Milan Congress in 1880 that denied the inclusion of sign languages in education program for Deaf students. They also acknowledged and sincerely regretted the detrimental effects of the Milan conference; and called upon all nations of the world to remember history and ensure that educational programs accepted and respected all languages including sign language and all forms of communication. Representatives of the ICED 2010 Vancouver Organizing Committee, the British Columbia Deaf Community, the Canadian Association of the Deaf, and the World Federation of the Deaf had issued the following statements: (1) Call upon all nations to include sign languages of their Deaf citizens as legitimate languages and to treat them as equal to those of the hearing majority, (2) Call upon all nations of the world to ratify and adhere to the principles of the United Nations, specifically those outlined in the Convention on the Rights of Persons with Disabilities, which state that education is to be delivered with an emphasis on the acquisition of language and academic, practical, and social knowledge, (3) Call upon all nations to promote and support equal and appropriate access to a multi-lingual / multicultural education, and (4) Call upon all nations to involve their Deaf citizens to assist parents of Deaf infant, children, and youth in the appreciation of the Deaf culture and the use of sign language. Nevertheless, in 2012, the United Nations Committee on the Rights of Persons with Disabilities stressed, "it takes note of the difficult situation of persons with hearing impairments in accessing information due to lack of official recognitions of the significance of sign language by Hong Kong, China".[8(p196)]

The Sign Bilingual Co-Enrollment model is an innovative educational approach that benefits both deaf and hearing students. Not only can students with hearing impairment learn without linguistic barriers, hearing students can also learn how to respect people with individual differences. Further, hearing students may acquire signed language and use it for social interactions with their hearing impaired peers.[35] A deaf-hearing inclusive community may be fostered, where cognitive and social abilities of hearing impaired students can be fully realised.

Future research may involve comparative analysis of developments in students with hearing impairment studying in a co-enrollment environment as compared those in regular mainstream settings. Through robust arguments on its theoretical foundation and solid data on its positive impact, Sign Bilingualism and Co-enrollment in deaf education might hope to become accessible to all students with hearing impairment who could benefit from it.

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