Volume 21
No.1
December 2022

BRAINCHILD

The Official Publication of HKCNDP
Special Issue on Hearing Impairment

香港兒童腦科及體智發展學會
The Hong Kong Society of Child Neurology and Developmental Paediatrics

The Hong Kong Society of Child Neurology and Developmental Paediatrics
香港兒童腦科及體智發展學會

Email : enquiry@hkcndp.org
Website : www.hkcndp.org

Printer : Printhouse Production Center Limited
Flat D, 25/F Gee Chang Hong Centre, 65 Wong Chuk Hang Road
Wong Chuk Hang, Hong Kong

Our appreciation of thanks to 盧悅情 (a Form 5 student with hearing impairment) for the cover drawing

BRAINCHILD
The Official Publication of HKCNDP

The Hong Kong Society of Child Neurology and Developmental Paediatrics

www.hkcndp.org
December 2022 Volume 21 No.1

Special Issue on Hearing Impairment

CONTENTS

The Hong Kong Society of Child Neurology & Developmental Paediatrics

EDITOR'S NOTES for the December 2022 Issue

BrainChild on Hearing Impairment in Children – Editorial

Dr. Kwing Wan TSUI

It is my pleasure to present to you articles in the current issue of BrainChild on various aspects of deaf and hard-of-hearing (DHH) children. Dr Kelly Lau described the impact of hearing impairment faced by deaf and hard-of-hearing individuals at various stages of life, from childhood to adulthood. Our society should provide a discrimination free environment and promote resilience and adaptation in these individuals for living a fulfilling and mentally healthy life. McPherson et al provided a review on the development of early identification and management of DHH children in Hong Kong and the service provision through collaboration between health care and educational disciplines. It was recommended that our local program should continue to strive for meeting international benchmark by enhancing some areas, namely seamless service provision, reducing delays and flexible interagency intervention. To build up an inclusive society for people with handicaps, school is the first portal for them to enter our community. Tang et al summarized in their paper the sixteen years of efforts in establishing an inclusive education in mainstream school. They introduced the sign bilingualism and co-enrollment (SLCO) program in mainstream settings by including not only DHH students but teachers for achieving social integration, which is the core mission of the program. Examples of the SLCO approach were demonstrated and the results were shared in the article. Chan et al explained the benefit of Paediatric bimodal fitting using cochlear implant (CI) in one ear and hearing aid in the contralateral ear. They described the one-stop audiological management of paediatric bimodal cases, which ensured the best hearing experience for DHH children and let their growth to full potentials. Lau et al performed a study to evaluate the auditory word recognition ability of Cantonese speaking children with hearing impairment in different noise conditions. Impact of noise on word recognition has been clearly demonstrated and CanSWORT in noise, with further development, should provide information for more optimal setting to facilitate Cantonese recognition through environmental modification and fine-tuning of hearing aids. Besides integrated educational model for DHH children, we have included an article for introduction of Lutheran School for the Deaf (路德會啟聾學校), which is the only subvented special school in Hong Kong providing primary and secondary education for students with hearing impairment.

Finally, I would like to thank all the authors who contributed to this issue of BrainChild and members of the editorial board who spent their valuable time and efforts to make publication of this issue successful.

Dr. Kwing Wan TSUI

President

The Hong Kong Society of Child Neurology and Developmental Paediatrics

Children with Hearing Loss: Early Identification and Management in Hong Kong

Bradley MCPHERSON

Human Communication, Development and Information Sciences Unit,
Faculty of Education, The University of Hong Kong

Eddie CM WONG

Ear, Nose and Throat Department, Queen Elizabeth Hospital

Emily CY MA

Educational Audiology Service Section, Education Bureau

Abstract

Children with hearing loss have unique identification and management needs that must be met to avoid a wide range of adverse outcomes. Both health and educational services are involved in supporting children with hearing loss and their families. Early identification, preferably in conjunction with a universal newborn hearing screening programme, is essential for optimal intervention and habilitation. Health care systems that arrange prompt diagnosis of early identified cases of hearing loss then need to link effectively with audiological and educational support services. These two areas can provide appropriate amplification strategies for children with hearing impairment and place children within their most positive learning environments. There is a long history in Hong Kong of health and educational service provision for children with hearing impairment, dating back at least to the 1930s. The present article discusses international best practice recommendations for the identification and management of children with congenital or early onset hearing loss and considers the current level of Hong Kong service provision in relation to these recommendations. Challenges to optimal service provision in the Hong Kong context, and potential ways to enhance services for children with hearing impairment are suggested.

Introduction

The ability to hear is a basic human characteristic and a significant hearing impairment is a primary health disorder that warrants treatment whenever appropriate.[1] In children a major by-product of permanent hearing loss is the disruption of typical language acquisition, which places them at risk for delays in many associated areas, such as social development and educational achievement.[2] To minimise the negative impacts of hearing loss it is of great importance that children with hearing impairment are accurately identified and management of the condition commences at the earliest possible stage.[3-7] Globally, this fact has become widely acknowledged by professionals and policy-makers, and over the past three decades there have been steady improvements in the technologies and management systems in place to support early identification and intervention for children with hearing loss. In many jurisdictions, including Hong Kong, this has led to a significant lowering of the average age of identification and earlier invention support for children.[8,9]

International recommendations for best practice

Permanent childhood hearing impairment is a relatively low incidence condition, with prevalence rates of around 0.11% to 0.15% in developed economies.[10] An estimated prevalence for permanent hearing loss of moderate or greater degree for Hong Kong is 0.14%.[11] For this reason, services involve specialized screening, diagnostic and intervention procedures across a wide range of professional areas—audiology, education, medical genetics, otolaryngology, paediatrics, social work and speech therapy amongst others. To better guide the successful introduction and maintenance of identification and intervention programs many jurisdictions have created advisory expert panels to develop recommendations for best practice in this area. Examples of such recommendations include Belgium[12], England[13], and Ontario[14]. The most influential and widely cited recommendations are those of the Joint Committee on Infant Hearing (JCIH)[15,16], a US expert panel first established in 1969. The JCIH attempts, through extensive literature review and consensus opinion, to recommend best practice across the broad range of activities that support identification and intervention. JCIH recommendations are used throughout North America and also in many other developed economies as criteria for program quality evaluation.

Detailed JCIH recommendations fall within five main areas: (a) rationales for early identification of hearing loss in children and the value of program standards; (b) newborn screening procedures; (c) diagnostic and rehabilitative audiology services; (d) early intervention and family support services; and (e) medical evaluation and management standards. Some of the key JCIH 2019 recommendations include the "1-3-6 goals"—meaning that all infants should receive hearing screening before discharge from their birthing hospital and no later than 1 month of age, confirmation of hearing status for positive screen cases should occur no later than 3 months of age, and early intervention should commence at no later than 6 months of age. Intervention should include access to quality hearing aid instruments or whatever other technology is appropriate, including cochlear implants and supplementary assistive devices. Importantly, since 2000 JCIH has recommended quantitative indicators to benchmark the quality of early hearing detection and intervention programs, based primarily on numbers of program cases attaining targets related to the 1-3-6 goals. For example, 2007 JCIH benchmarks include the percentage of all newborn infants who complete screening by one month of age and the percentage of infants with significant hearing loss who receive amplification within one month of diagnostic confirmation of hearing loss.[15] Benchmark standards are intended to change as programs mature and should reflect continued improvements in outcomes. The 2019 JCIH guidelines suggest that programs already meeting the 1-3-6 benchmark "should strive to meet a 1-2-3 month timeline" to create an even more agile paediatric hearing health care system. Other initial JCIH quality benchmarks included screening ≥ 95% of newborns prior to hospital discharge and ≥ 95% infants receiving audiological evaluation by 3 months of age. However, these benchmark criteria can be difficult for programs to reach even today. For example, of three US states with over 1,400 hospitals and more than 1 million infant cases reviewed in a 2018 study only a few individual hospitals, and no states, achieved the second benchmark mentioned above.[17] Many programs have developed benchmark criteria that are closely related to those initially produced by JCIH. National performance indicators for programs in Australia include a target that ≥97% of infants complete a hearing screen before 1 month of age and that <4% of infants who are screened test positive for potential permanent hearing loss and are referred for audiological evaluation.[18] Another indicator of quality outcome is often based on the loss-to-follow-up rate, i.e, the number of infants who do not attend for diagnostic appointment after a positive screening result.

The JCIH 2019 position statement and similar documents acknowledge the importance of close linkage across service providers for a successful early detection and intervention program. Often services post-screening are not provided in the birthing hospital and effort needs to be made to ensure timely communication among a diverse range of service providers. Services need to be "delivered with a unified philosophy and by clinicians who communicate regularly with each other"[19] because the "effectiveness of each step in the process of identification of and intervention in [permanent childhood hearing impairment] is dependent on the success of the step before it, and is also dependent on the integration and coordination between the components".[20] The JCIH 2019 statement includes particular mention of the need for "seamless access" to service providers with specialist knowledge of intervention for children with hearing impairment. Yet feedback from parents and professional observers of many programs suggests that this level of communication and integration is not always achieved.[21,22]

Service provision in Hong Kong

Hong Kong has been a longstanding regional leader in the habilitation and education of children with hearing loss. The Hong Kong School for the Deaf was established in 1935.[23] Over the following decades a full range of services for children, including screening and early diagnosis, intervention and habilitation came to be provided. Three more special schools for children with hearing impairment were established from 1960 to 1970. With improvements in technology, the initial focus on specialised classroom education techniques broadened to optimising children's language and educational development through individualised amplification-assisted programs. With increased recognition of the many advantages of integrated education, supported by the benefits of modern hearing technologies, most children with hearing loss now attend ordinary schools.

Hearing screening for school children was initiated in 1968 by the then Education Department for Primary 1 students in government schools.[23] Universal newborn hearing screening (UNHS) for all Hospital Authority (HA) birthing hospitals was established in 2007, managed by paediatric or ear, nose and throat (ENT) departments.[24] This program offers 2-stage automated auditory brainstem response (AABR) screening for all babies before hospital discharge after birth. Positive cases are given an appointment for diagnostic audiological assessment[11] at a HA ENT clinic and also referred to a HA Audiology clinic for further investigation. In keeping with the current JCIH recommendations, diagnostic appointments are scheduled, whenever possible, before 3 months of age.

Maternal and Child Health Centres (MCHCs) provide an auxiliary screening service for those children who are not screened within the HA system, such as immigrant infants and those birthed at private hospitals that lack screening programs. MCHC uses a 2-stage automated otoacoustic emission (AOAE) protocol. After a second refer result parents are advised to enter the HA hospital system for further management. Typically, screening is also performed before 4 months of age—often the initial AOAE screen is performed within 2 weeks after first MCHC registration and a second screen if required is usually arranged for one week later.

After initial identification at HA or MCHC, referrals are made when indicated to the HA ENT Clinic, Department of Health Child Assessment Service (CAS), HA Clinical Genetic Service or and/or other specialities as needed. Referral for ophthalmologic services is frequently arranged in view of the high rate of vision impairment associated with hearing loss.[25] CAS assessment of referred children is conducted with a paediatrician within 2 months of referral. A management plan is created after a CAS team conference—the team is usually comprised of a paediatrician, audiologist, speech therapist (for children over 6 months of age) and medical social worker. Until children enter primary school CAS audiologists follow-up clients with hearing impairment on at least an annual basis.

The Clinical Genetic Service (CGS) of the Department of Health in Hong Kong is a government-funded, tertiary referral centre that provides clinical, laboratory, counselling services related to genetic disorders. Concerning non-syndromic-related hearing impairments, three gene tests are available at present (GJB2 gene, GJB6 gene and mitochondrial DNA Mito - RNR1 gene). Other available gene tests for hearing loss include branchio-oto-renal syndrome, type 1 (EYA1), congenital deafness with inner ear agenesis, microtia, and microdontia (FGF3) and Waardenburg syndrome, type 1 (PAX3). Turnaround time for results may take two to four months.

The roles of HA, MCHC, CAS and CGS in the Hong Kong early detection and intervention landscape is similar to that seen in many jurisdictions where government health services are a dominant player in the health care system. An unusual aspect of the Hong Kong system is the contribution of the Education Bureau (EDB) to the early intervention process. By the mid-1970s the Audiological Services Section of the then Education Department (ED) was providing hearing aids and auditory training to children diagnosed by or referred to the service).[23] Hearing aids for educational purposes were supported by the Hong Kong Lotteries Fund from 1971 until 1988, when funds were then directly allocated to the ED for this service provision. At this latter date, it was decided that the ED should continue to provide direct hearing aid services for school children, including infants, because no other agency had sufficient expertise to manage a paediatric fitting program. Direct provision of hearing aids by the EDB was continued until 2005. At that time outsourced service providers became hearing aid fitting and follow-up contractors for the EDB. In 2019, it was decided to revert the mode of outsourced provision to in-house provision. Hence, except for children with—or potential for—an implantable device (who are followed up solely by the Hospital Authority), most hearing-impaired children in Hong Kong identified with a need for intervention are referred after diagnostic work-up to EDB for amplification, as well as the school-based support services more typically performed by educational audiologists.[26]

JCIH recommendations have been widely supported in Hong Kong. A Hong Kong Joint Committee on Universal Newborn Hearing Screening—comprising experts from sectors including audiology, otolaryngology, paediatrics, medical genetics and education—held meetings from 2013 to 2017. This group reached a consensus on a standard care pathway for identified infants (Ma et al., 2020) that aligns with JCIH recommendations and benchmarks. Specifically, HA benchmarks are for hearing screening before 1 month of age, diagnostic examination to confirm permanent hearing loss before 3 months of age, as well as hearing aid fitting and other remedial services before 6 months of age. In 2018 UNHS in the Hong Kong HA system reached key quality benchmarks, including screening ≥ 99% of newborns prior to hospital discharge and ≥ 93% infants with positive screening results receiving audiological evaluation by 3 months of age.

Towards enhanced service provision in Hong Kong

Around 120 to 130 infants are identified in Hong Kong each year with significant permanent childhood hearing loss through the newborn hearing screening program and appropriate intervention services for these children are arranged. As with all such programs, there are challenges in achieving optimal outcomes. Research indicates that the newborn hearing screening process itself is well accepted by mothers at HA birthing hospitals in Hong Kong, with suggestions for improvement centred around provision of more background information prior to screening and more detailed explanation of screening results.[27] Beyond the detection stage, because system components cross institutional borders it can be difficult to achieve close coordination of services and arrange "seamless service provision" for children and their families. There can also be conflicting needs across service providers. For example, what is considered an adequate first-time diagnostic assessment may not provide enough information for a valid first-time hearing aid fitting. In these circumstances consensus engagement beyond JCIH recommendations is required. Expert advice is available from sources such as the American Academy of Audiology[28] and recognised centres of excellence[29,30] that can help resolve these issues.

Delays can occur in the identification and detection system at any stage. For all programs, the number of children with additional disabilities is high, perhaps 30-40% of all children with permanent hearing loss have additional impairment(s). These disabilities are most commonly developmental delay, cerebral palsy, impaired vision, and autism spectrum disorder.[31,32] Infants with complex and special needs are often difficult to test and families often have a range of services to attend. Meeting benchmarks in such cases requires much thought and sustained interdisciplinary planning.[33]

For many infants in Hong Kong identified with severe to profound bilateral hearing loss the optimal amplification strategy is usually cochlear implantation. Often this is arranged after a trial period with conventional hearing aids. After implantation infants may continue to use conventional amplification for the non-implanted ear. Such bimodal fittings have been problematic at times in the past in Hong Kong as the cochlear implant was maintained by HA and conventional hearing aid by EDB. A recent policy change provides parents and infants with a continuous, exclusively HA-based amplification service. This is an example of how a flexible interagency response can improve the intervention experience for families.

There are other challenges to the Hong Kong detection and intervention system. The JCIH (2019) guidelines recommend "follow-up for earmould impression taking and subsequent hearing aid fitting are highly recommended to be provided immediately and directly from the sector where diagnosis of hearing impairment was confirmed." This is now possible in Hong Kong for children with severe and profound grade deafness because EDB has commissioned HA to fit hearing aids for potential cochlear implant cases, in order to provide such a through-train service. A seamless care pathway in the HA setting from universal newborn hearing screening, confirmed diagnostic test, hearing aid fitting and cochlear implantation results in reduced service provision delays. Commencing in January 2020, the introduction of new 3D scanning and printing for earmould production in HA enabled faster earmould preparation and higher earmould quality. This has also helped to minimise fitting delays.

To meet a core service benchmark—ensuring infants are (a) accurately diagnosed, (b) fitted with customized amplification, and (c) provided with an appropriate management plan, by six months of age—there must be prompt referral of infants and children from HA diagnostic clinics (and private clinics at times). This is particularly the case for children who are not considered likely to be offered cochlear implant surgery. Effective communication and creative planning among the service partners remain essential to minimize unacceptable intervention delays. This could be further supported by service-wide data collection and analysis, on an annual basis. At present limited information is available on newborn hearing screening through the HA system and this allows performance in comparison to some benchmarks to be made. However, cross-institution data would help service providers better rate how overall service provision meets accepted performance targets.

Conclusions

Hong Kong has a long-established health and education support system for children with hearing impairment. A universal newborn hearing loss detection and intervention program has been in operation for over 13 years. The program consistently identifies the majority of infants born with significant hearing loss in Hong Kong and provides an intervention service that strives to meet international best practice benchmarks. Agencies are actively working to maintain and enhance their benchmark achievements. As international standards continue to evolve and improve, the complex ecosystem of Hong Kong agencies involved in the program needs to maintain and strengthen linkages across all partners.

References

1. Hyde M. Principles and methods of population hearing screening in EHDI. In: Seewald R, Tharpe AM, editors. Comprehensive Handbook of Pediatric Audiology. San Diego: Plural, 2011:283-337.
2. Fitzpatrick EM, Cologrosso E, Sikora L. Candidacy for amplification in children with hearing loss: A review of guidelines and recommendations. Am J Audiol 2019;28:1025-1045.
3. Ching TYC, Dillon H, Button L, Seeto M, Van Buynder P, Marnane V, Cupples L, Leigh G. Age at intervention for permanent hearing loss and 5-year language outcomes. Pediatrics 2017;140: e20164274.
4. Kennedy CR, McCann DC, Campbell MJ, et al. Language ability after early detection of permanent childhood hearing impairment. N Engl J Med 2006;354:2131–41.
5. Moeller MP. Early intervention and language development in children who are deaf and hard of hearing. Pediatrics 2000;106:1–9.
6. Olusanya B, Sirimanna A, McPherson, B. Timely sensory stimulation is crucial for optimal early childhood development. Lancet 2017; 390:2626.
7. Yoshinaga-Itano C, Sedey AL, Coutler DK, et al. Language of early-and later-identified children with hearing loss. Pediatrics 1998;5:1161–71.

8. Uus K, Bamford J. Effectiveness of population-based newborn hearing screening in England: ages of interventions and profile of cases. Pediatr 2006;117:e887-893.
9. Weichbold V, Nekahm-Heis D, Welzi-Mueller K. Ten year outcome of newborn hearing screening in Austria. Int J Pediatr Otorhinolaryngol 2006;70:235-240.
10. Davis A, Davis K, Mencher G. Epidemiology of permanent childhood hearing impairment. In: Newton VE, editor. Paediatric Audiological Medicine. 2nd edition. Chichester: Wiley-Blackwell, 2009:1-28.
11. Ma TPY, Chan WY, Koh c, et al. Hong Kong universal newborn hearing screening (UNHS) care path protocol under Joint Committee on UNHS. HK J Paediatr (New Series) 2021;26:168-174.
12. Vos B, Senterre C, Lagasse R, SurdiScreen Group, Levêque A. Newborn hearing screening programme in Belgium: a consensus recommendation on risk factors. BMC Pediatr 2015;15:160.
13. Public Health England. NHS Newborn Hearing Screening Programme Standards 2016 to 2017. London: Public Health England, 2016.
14. Ontario Infant Hearing Program. Protocol for universal newborn hearing screening in Ontario. Ottawa: Ministry of Children, Community and Social Services, 2019.
15. Joint Committee on Infant Hearing. Year 2007 Position Statement: Principles and Guidelines for Early Detection and Intervention Programs. Pediatrics 2007;120:898-921.
16. Joint Committee on Infant Hearing. Year 2019 Position Statement: Principles and Guidelines for Early Detection and Intervention Programs. J Early Detection Intervention Programs 2019;4:1-44.
17. Deng X, Finitzo T, Aryal S. Measuring early hearing detection and intervention (EHDI) quality across the continuum of care. eGEMs 2018;18:1-8.
18. Australian Institute of Health and Welfare. National performance indicators for neonatal hearing screening in Australia. Canberra: Australian Institute of Health and Welfare, 2013.
19. Madell JR, Flexer C. Collaborative team management of children with hearing loss. In: Madell JR, Flexer C, editors. Pediatric Audiology. Diagnosis, Technology, and Management. 3rd ed. New York: Thieme, 2019:279-286.
20. Leigh G, Schmulian-Taljaard D, Poulakis Z. Newborn hearing screening. In: Driscoll CJ, McPherson B, editors. Newborn Screening Systems. The Complete Perspective. San Diego: Plural, 2010:95-115.
21. Fitzpatrick E, Graham ID, Durieux-Smith A, Angus D, Coyle D. Parents' perspectives on the impact of early diagnosis of childhood hearing loss. Int J Audiol 2007;46:97-106.
22. Madell JR, Flexer C. Collaborative team management of children with hearing loss. In: Madell JR, Flexer C, editors. Pediatric Audiology. Diagnosis, Technology, and Management. New York: Thieme, 2008:210-217.
23. Lam CCC, Poon MT, Doo S, et al. Hearing impairment. In: Mak RHL, Lam CCC, Ho CCY, Wong MMY, editors. A Primer in Common Developmental Disabilities. Experience at Child Assessment Service, Hong Kong. Hong Kong: Child Assessment Service, Dept of Health, Hong Kong SAR, 2006:281-331.
24. Yu JKY, Ng IHY, Kam ACS, Wong TKC, Wong ECM, Tong MCF, Yu HC, Yu KM. The universal neonatal hearing screening (UNHS) program in Hong Kong: The outcome of a combined otoacoustic emissions and automated auditory brainstem response screening protocol. HK J Paediatr (New Series) 2010;15:2-11.
25. Sharma A, Ruscella MN, Chi DH. Ophthalmologic findings in children with sensorineural hearing loss. Arch Otolaryngol Head Neck Surg 2009;135(2):119–23.
26. Educational Audiology Association. Educational Audiology Scope of Practice. Pittsburgh: Educational Audiology Association, 2019.
27. Lam MYY, Wong ECM, Law C., Lee HHL, McPherson B. Maternal knowledge and attitudes to universal newborn hearing screening: Reviewing an established program. Int J Ped Otorhinolaryngol 2018;105:146-153.
28. American Academy of Audiology. Clinical practice guidelines. Pediatric Amplification. June 2013.
29. Bagatto M, Moodie S, Brown C, Malandrino A, Richert F, Clench D, Scollie S. Prescribing and verifying hearing aids applying the American Academy of Audiology Pediatric Amplification Guideline: Protocols and outcomes from the Ontario Infant Hearing Program. J Am Acad Audiol 2016;27:188–203.
30. Sininger YS, Hunter LL, Roush PA, Windmill S, Hayes D, Uhler KM. Protocol for rapid, accurate, electrophysiologic, auditory assessment of infants and toddlers. J Am Acad Audiol 2020;31:455-468.
31. Cupples L, Ching TYC, Crowe K, et al. Outcomes of 3-year-old children with hearing loss and different types of additional disabilities. J Deaf Stud Deaf Ed 2014;19:20-39.
32. Wakil N, Fitzpatrick EM, Olds J, Schramm D, Whittingham J. Long-term outcome after cochlear implantation in children with additional developmental disabilities. Int J Audiol 2014;53(9):587-94.
33. Mac Ardle B, Munro C. Medical management of the deaf child in a multidisciplinary context. In: Newton VE, editor. Paediatric Audiological Medicine. 2nd edition. Chichester: Wiley-Blackwell, 2009:309-328.

Two Languages are Better than One: Establishing Inclusive Education for the Deaf and Hard-of-Hearing Children in Hong Kong Using a Sign Bilingualism and Co-enrollment Approach

Gladys WL TANG[1], Chris KM YIU[1], Kathy YS LEE[2], Jia LI[1], Qun LI[3], Chloe CM HO[1], David CF LAM[1]

[1]Centre for Sign Linguistics and Deaf Studies, The Chinese University of Hong Kong
[2]Department of Otorhinolaryngology, Head and Neck Surgery, The Chinese University of Hong Kong and Institute of Human Communicative Research, The Chinese University of Hong Kong
[3]Hearing Centre, Department of Otorhinolaryngology-Head and Neck Surgery, West China Hospital of Sichuan University

Abstract

This paper summarizes sixteen years of efforts in establishing an inclusive education programme for deaf and hard-of-hearing (DHH) and hearing children in a mainstream setting. Since 2006, The Centre for Sign Linguistics and Deaf Studies of The Chinese University of Hong Kong has been planting the Sign Bilingualism and Co-enrollment in Education Programme (The SLCO Programme) in a kindergarten, a primary and a secondary school in Hong Kong. The SLCO classroom differs from other inclusive ones in (a) having a critical mass of DHH children studying together with hearing children and enjoying a full curriculum in the same classroom, (b) the presence of Hong Kong Sign Language (HKSL) additional to Cantonese or other spoken languages, (c) an emphasis on co-teaching between a regular teacher and a deaf signing teacher or a teacher with proficient signing skills, and (d) encouraging co-learning between DHH and hearing children. This paper offers some theoretical underpinnings of the SLCO approach to educating DHH and hearing children in mainstream education and a summary of research findings concerning the DHH and hearing students' language development and social integration when receiving education in this environment.

Keyword: Sign Bilingualism, Co-enrollment, Deaf Education, Inclusive Education, Language & Literacy Development, Social Integration

1. Introduction

Traditionally deaf schools were the primary educational context for deaf and hard-of-hearing (DHH) students with various degrees of hearing loss. They were also the context for sign language transmission between generations of deaf students.[1] However, when advancements in assistive hearing technology and early intervention saw gains in DHH children's speech and language perception, it coincided with a change of special education philosophy from segregation to mainstream inclusive education for the deaf. This shift of educational context for the deaf has led to a dramatic reduction in the number of deaf schools globally and a discontinuity of sign language transmission. Hong Kong is no exception. The government started implementing integrative/inclusive education for DHH children after publishing the 1977 White Paper "Integrating Disabled into the Community: A United

Effort".[2] Meanwhile, a challenge to mainstream inclusive education for the deaf has been how to facilitate DHH children's access to information in the classroom. The current policy is early intervention, which is to provide universal screening and assistive hearing devices such as hearing aids or different types of implantation, and early speech and language therapy. In deaf education research, there have been reports on DHH children's underperformance in language and academic achievement as well as difficulty in social integration in mainstream education.[3]

Concomitant to these developments has been the emergence and rapid expansion of sign linguistic research since the 1960s, gradually unravelling the linguistic properties of sign languages as being structured, rule-governed and acquirable by children, similar as spoken languages. In addition, decades of sign linguistics research have revealed the potentiality of DHH children's bilingual development in spoken language and sign language, leading to the call for sign bilingual education for DHH children in deaf schools. However, the growing prominence of inclusive education for the deaf also motivates deaf education researchers to address whether sign language can be introduced into mainstream education to support mainstreamed DHH children who may encounter different degrees of information inaccessibility and become lost in the dynamic discourses of classroom interactions. Bringing in a sign interpreter is one option, as has been practised in many countries. However, research shows that DHH children are deprived of direct communication with their teachers and peers, thus reducing their opportunities for classroom participation and development of peer relations. An alternative proposal is to let sign language partner with spoken language directly through a pair of teachers collaborating in the classroom to maximize DHH children's participation in the pedagogical process and the hearing children's exposure to an additional visual language. In this paper, we will discuss this alternative approach as emerged in HK, now globally known as The Sign Bilingualism and Co-enrolment Education (The SLCO Programme). It is an evidence-based programme that draws insights from sign linguistics and deaf education research findings. In the next section, we will briefly summarize the theoretical underpinnings of such an approach.

2. Sign Bilingualism and Bimodal Bilingualism

As said, *Sign bilingualism* originates as a deaf education practice that emphasizes educating DHH children as early as possible in a deaf school context using a sign language initially to build a solid language foundation for their subsequent development of spoken language literacy, i.e. primarily learning how to read and write in a spoken language as a second language.[4] During the 1980s and in the aftermath of discoveries in sign linguistic research, sign bilingual education was reinstated in schools for the deaf in the Scandinavian countries, the United States, the United Kingdom, and Australia and has since spread to some countries in Asia.[5] Additional to language development was the promotion of Deaf Identity and Culture as preserved in the deaf school context. Cummins (2006) also applied his Linguistic Interdependence Hypothesis originally developed in the 1980s to account for bilingual education in spoken languages to support sign bilingualism in deaf education.[6]

Meanwhile, research developments in sign linguistics began to examine the processes involved in the simultaneous acquisition of a sign language and an oral language by hearing children born into deaf families (i.e. CODA), which stimulated further investigation into the bilingual acquisition of DHH children who were born into either deaf or hearing families. This paradigm of acquisition research involving a sign language and a spoken language is currently called *bimodal bilingualism*, such as American Sign Language and English,[7] Italian Sign Language and Italian,[8] The Sign Language of the Netherlands and Dutch;[9,10] HKSL and Cantonese,[11,12] and Brazilian Sign Language and Portuguese,[13] to name but a few. In the spoken language literature, the demarcation between *simultaneous bilingual acquisition* and *successive bilingual acquisition* rests upon whether the child acquirer is exposed to two spoken languages since birth or when the two spoken languages are introduced to the child in a row before they reach age 3-5.[14] When applied to bimodal bilingualism research, one may envisage simultaneous bilingual acquisition of hearing children born into deaf families in which one parent is deaf and the other hearing. On the other hand, when 95% of DHH children are born into hearing families whose parents have no prior exposure to sign language, these children may undergo successive bilingual acquisition before age 3-5 where their first language is an oral language (e.g. Cantonese in the context of Hong Kong) and their second language is a sign language. This latter situation to some extent reflects the bilingual development of most DHH children enrolled in The SLCO Programme, albeit at a much earlier age with most starting at around age 2 and some at 1. There are a few DHH children whose parents are deaf and signing and these children will acquire HKSL and Cantonese simultaneously. In summary, a child's early exposure to a natural language, sign or spoken, is crucial for triggering their innate language-building mechanisms. It is of paramount importance for DHH and hearing children since early language input supports their subsequent and continuous development in language and literacy skills, cognitive skills, socio-psychology, and ultimately education.[3] Emerging research findings suggest that, except for a difference in the visual/manual versus auditory/oral modality, bimodal bilingual children, DHH and hearing alike, demonstrate similar processes as hearing children acquiring two spoken languages. Their outputs reveal a rule-governed development of two grammatical systems and cross linguistic interactions. Bimodal bilingual acquirers are also found to code-switch (commonly known as *code blending* in sign linguistics research), such as in HKSL and Cantonese,[11] just as hearing bilinguals code-switch between two oral languages. The promotion of early bimodal bilingualism for DHH children has gained empirical support in recent studies. The negative impact of language deprivation during the early years due to a lack of sufficient linguistic triggers for language acquisition via the auditory mode has been documented.[15,16] This is especially so when there is a time lag for clinical treatment, prescription of assistive hearing devices and long-term speech and language therapy. Sign language offers an alternative trigger to language acquisition via a visual modality, laying an essential foundation to support DHH children's language development across the life span.

3. Co-enrollment education

Co-enrollment education for DHH and hearing children saw its origin in the 'TRIPOD Model School Program' in California of the United States in 1982 as an alternative model for educating DHH children in a mainstream setting. It emphasizes[17]:

a. A critical mass of DHH children to co-learn with their hearing peers in class, usually in the ratio of one DHH student to three or four hearing students,
b. Collaborative teaching between a Deaf teacher or a hearing teacher with proficient signing skills, and a regular hearing teacher who uses speech, and

c. All children, DHH and hearing, access a full and regular curriculum with an academic standard equivalent to other regular schools

Since then, co-enrollment programming started to burgeon globally in Spain, The Netherlands, Belgium, Germany, Italy, Israel, Japan, Austria, and Australia, which standardly adopts a sign language in parallel with spoken language to support DHH children's information accessibility and direct communication in classroom interaction.[18] In Asia, Hong Kong took the lead and The SLCO model is subsequently adopted in a mainstream kindergarten in Quzhou of mainland China,[19] the kindergarten and primary sections of a through-train school in Macau,[20] and a primary school and a kindergarten in Singapore,[21] all with government support and involvement in establishing a through-train education for the deaf in a mainstream setting, which is a unique feature of the SLCO Programme globally.

Viewing The SLCO classroom from an ecological perspective, co-enrollment immerses teachers and students, DHH or hearing, into an environment in which they are cushioned to develop bimodal bilingualism. With daily interactions, they have ample opportunities to develop group identity and appreciate each other's differences in hearing status, language skills and preferences for communication modes, academic abilities and other characteristics.

4. The SLCO Programme of Hong Kong

The SLCO Programme was launched at a mainstream kindergarten in 2006, a mainstream primary school in 2007, a mainstream secondary school in 2013 – to complete the through-train model in mainstream. It aims to initiate evidence-based practice in deaf education, drawing reference from research on bimodal bilingualism and co-enrollment in deaf education. Every year, the Programme arranges for five to six age appropriate DHH children to study with about 15 to 20 hearing children in a K1 class of the kindergarten. Unless arranged otherwise, these children will follow the system until they graduate from secondary education.

The SLCO Programme adopts a whole school approach and the principles of pedagogical organization as put forward by the TRIPOD Programme. For DHH children to study with hearing children also implies the Programme will adhere to a full curriculum for mainstream education as prescribed by the Education Bureau. It regards direct communication among the participants in the classroom as the most effective way to nurture partnership in teaching and learning, inculcating a sense of group identity when the children study in this unique learning environment. From a language acquisition perspective, since both Cantonese and HKSL input are consistently available in the classroom environment, it provides an 'acquisition-rich' environment for bimodal bilingual development of both the DHH and hearing participants. In a SLCO classroom at the junior level, a Deaf signing teacher usually co-plans and co-teaches with a regular teacher. The Deaf teacher also provides HKSL input to all hearing participants through instructing and interacting in HKSL. Both DHH and hearing students are free to 'tune into' either oral Cantonese or HKSL to access information or interact with each other in class. Over time, one observes DHH children adopt more oral Cantonese when interacting with their hearing peers and teachers, who might switch to HKSL when interacting with those DHH peers with poor speech perception. This language choice is subject to the participants' perceived language abilities of themselves and their interlocutors. Even the regular teachers acquire HKSL through interacting with the Deaf signing teachers and DHH students and become bimodal bilingual themselves. In other words, HKSL becomes part of the linguistic repertoire of many students and teachers at school. For DHH children, they have a rich environment to acquire oral Cantonese, supported by regular speech and language therapy training and they can enjoy inclusion and a full curriculum. It should be noted that teachers sometimes use fingerspelling during the English lessons and signed Chinese during the Chinese lessons to fulfil some specific pedagogical objectives. Otherwise, HKSL and oral Cantonese are the two primary languages the participants adopt in the SLCO school environment.

In many countries, including Hong Kong, implementing bilingual and multilingual education is the norm rather than the exception. Under those circumstances, children as young as age 2 or 3 begin to acquire a second language at daycare centres and kindergartens, alongside acquiring their first language. The SLCO classroom represents a form of bilingual education since HKSL is paired up with either oral Cantonese, Putonghua or English, depending on the subjects. One advantage of this model of bilingual education is that both languages occur in parallel in the educational process without interfering with each other since they are transmitted in different modalities, practically emitting a voiced language and a silent language simultaneously to cater for the diverse needs of students when they access information in the classroom. Future research is needed to verify how DHH and hearing children process subject contents when similar information comes simultaneously from two modalities. Preliminary comments from both DHH and hearing children suggest that they tend to access information from both modalities. Some hearing children reported watching the signing of the Deaf teacher sometimes when they found it hard to process the regular teachers' information through speech. Alternatively, some DHH with high speech perception abilities claimed using both HKSL and Cantonese to access information. On the other hand, DHH children with poor speech perception skills rely heavily on HKSL when accessing lesson contents.

Sixteen years have elapsed since the establishment of The SLCO Programme in Hong Kong in 2006. It has so far supported 84 DHH and 790 hearing children who study together in the SLCO classes. Since 2019, it has graduated 14 DHH and 71 hearing children from secondary education. A great majority of these signing DHH children continue to pursue post-secondary education in various disciplines such as environmental sciences, health care, food health and business, legal studies, languages, fashion and image design, and creative design and media according to their aspirations and potentials, and some of SLCO DHH and hearing students are pursuing their first degree study in environmental resources management, bimodal bilingual studies, and special education, an unprecedented phenomenon for signing deaf students in Hong Kong's deaf education. As for the teachers of the SLCO Programme, past years have seen the graduation of many Deaf and hearing teachers from different professional training programmes including MSc in Deaf Education, M.A. in Sign Linguistics, Postgraduate Diploma in Education (Special Education), B.Ed. in Special Education, B.A. in Bimodal Bilingual Studies, Diploma in Deaf Education, Professional Diploma in Sign Interpretation, and Certificate in Sign Language Teaching. Improvement in the educational opportunities of signing DHH students and Deaf teachers indeed escalate the need for educational sign interpreting to support them in pursuing education at the post-secondary level. When such a provision is in place, Hong Kong's deaf education will align itself with international standards in terms of compliance with Article 24 of The United Nations Convention on the Rights of Persons with Disabilities (CRPD), namely the respect for and provision of sign language to support deaf people's pursuit of education at all levels, including the employment of teachers with disabilities who are qualified in sign language. The DHH and hearing children's proficient sign language skills acquired through The SLCO Programme will also qualify them for specialized training in sign language-related professions such as sign language teaching, sign interpretation, and deaf or special education, creating a unique workforce for Hong Kong society currently in dire need of sign language professionals. Concurrent with the development of SLCO education in mainstream settings, many auxiliary programmes to promote bimodal bilingualism to support children's early language development have been set up, including baby signing programmes for typically developing infants, DHH infants and children with other disabilities (https://www.slco.org.hk/en/service_fs2.php). There are also programmes for parents on how to support DHH children's oral language development (http://www.speakalongcuhk.com/tc/; http://www.cslds.org/babyhearingloss/), preschool sign-supported reading programmes for DHH children, and mainstream DHH children's support (http://www.cslds.org/mainstreamsupport/sharing.php). In 2016, a non-government charitable organization - SLCO Community Resources (https://www.slco.org.hk/en/) - was set up with funding support from The Chinese University of Hong Kong's Sustainable Knowledge Transfer Project Fund. Its mission is to promote bimodal bilingualism across the life span, educating the society about the benefits of learning sign language as an additional language for all ages in typical and atypical populations.

Having introduced The SLCO Programme, we will summarize some of the empirical findings accumulated until today. All assessments conducted by The Centre for Sign Linguistics and Deaf Studies of The Chinese University of Hong Kong had obtained consent from teachers as well as parents of the DHH and hearing children. The project passed the requirements of the Survey and Behavioural Research Ethics Committee of The Chinese University of Hong Kong. A majority of the DHH children who participated in the various studies had severe to profound hearing loss, were either implanted or using hearing aids, and only a few showed other disabilities such as attention deficit and hyperactivity.

5. Empirical Findings

5.1. Language Development

5.1.1. Spoken Language Development

Many educators and parents are always puzzled by if not worried about the effects of acquiring a sign language on the oral language development of DHH children. This question is particularly relevant for the DHH children who receive education in the SLCO environment. An initial investigation was reported in Tang et al. (2014) in which the focus was on their grammatical knowledge of oral Cantonese, written Chinese and HKSL.[22] Written Chinese was included since one difficulty commonly faced by DHH children is under-achievement in literacy skills where knowledge of grammar plays a crucial role and bars them from education. Twenty DHH children from Primary 1 to 5 with either severe or profound hearing loss took part in the study. Fourteen of them were implanted and six wore hearing aids. At the time of the experiment, their mean age was 10 years 2 months and they had four to seven years of HKSL exposure. They also received speech and language therapy in oral Cantonese regularly. Their knowledge of HKSL grammar, such as word order, verb morphology, classifier constructions, and non-manual expressions was assessed using a pre-standardized HKSL Elicitation Tool (HKSL-ET) developed by The Centre for Sign Linguistics and Deaf Studies. As for their knowledge of oral Cantonese, the Cantonese Grammar subscale of the Hong Kong Cantonese Oral Language Assessment Scale was used.[23] Lastly, the children's knowledge of written Chinese, which follows the grammar of Mandarin Chinese was measured using the Chinese Grammar Assessment (CGA) developed by The Centre for Sign Linguistics and Deaf Studies. Results from 1-tailed Pearson Product correlations revealed a significantly positive relation among the accuracy scores of all three measurements (i.e. oral Cantonese & written Chinese: r=0.790**, p=0.000; HKSL & oral Cantonese: r=0.663**, p=0.001; HKSL & written Chinese: r=0.591**, p=0.003). Such a finding suggests that the development of the three languages was closely related to one another, where a positive development of one language is correlated significantly with a positive but not a negative development of the other languages.

This finding offers the first piece of evidence disproving the negative impact of learning HKSL on the development of Chinese, oral or written. Given the situation that Hong Kong children are learning the grammars of oral Cantonese and written Chinese almost simultaneously, one can assume that these DHH children in The SLCO Programme are acquiring three grammars at a young age and HKSL seems to provide a cushion with which they develop the grammars of the two spoken languages that share many linguistic characteristics.

The next study focuses specifically on the oral Cantonese development of the DHH children in The SLCO Programme. As said, given the DHH children's hearing loss and family backgrounds, the school environment would play a pivotal role in supporting their bimodal bilingual development. When the social atmosphere is supportive enough, DHH children would be cushioned linguistically to learn both signed and spoken languages with ease and to switch between modalities when interacting with teachers and peers. That the SLCO environment has a ratio of one DHH child to four or five hearing children offers many opportunities for DHH children to practice speech daily if they manage to develop DHH-hearing peer relations over time so they continue to sign or use speech when interacting with their DHH and hearing peers (see next section on social integration). The presence of both hearing and DHH peers to co-participate in learning and to communicate flexibly in either signed language or spoken language would be hard to obtain when a child is the only DHH student at a mainstream school.

Lee et al. (2014) reported on the oral language abilities of DHH children in mainstream education.[24] In the first study, they assessed the oral language development of fourteen young SLCO DHH children, nine boys and five girls, over a period of three years. The children were assessed for the first time at junior primary and again (i.e. repeated measure) when they reached senior primary three years later. During the initial assessment, the children's mean chronological age was 7 years 6 months. One DHH child had mild, one had moderate-severe and twelve had severe to profound hearing loss. Eight of them wore hearing aids and six a cochlear implant. Ten DHH children came from Primary 1, three from Primary 2 and one from Primary 3. In this project, Hong Kong Cantonese Oral Language Assessment Scale (HKCOAS) was adopted.23 Results indicated DHH children's improvement of oral Cantonese in five subscales over a span of three years, namely Cantonese grammar, textual comprehension, word definition, lexical-semantic relations and story retelling, but no improvement under expressive vocabulary. This finding shows that receiving education in the SLCO environment does not negatively impact DHH children's oral Cantonese development.

Lee et al.'s (2014) second study compared the oral Cantonese development of SLCO DHH and non-SLCO DHH children in mainstream schools, where one major difference is the presence and absence of sign language input in the learning environment.[24] Using cluster analysis, they grouped twelve SLCO DHH with sixteen non-SLCO DHH children for comparison. Note that the non-SLCO DHH group had more children with mild to moderately severe hearing loss whereas the SLCO group had more DHH children who had severe to profound hearing loss. To generate a baseline for comparison, an independent t-test was performed on the composite scores of HKCOLAS of these two groups of DHH children and no significant difference between them was shown. The two groups of DHH children were assessed again three years later when they reached Primary 4 to Primary 6. The procedure of repeated measures comparing the language scores of these children was used while controlling for their hearing level and speech perception abilities. Generally speaking, the findings indicated an interactive effect of education programme (SLCO vs non-SLCO mainstream) and duration (3 years). The SLCO DHH children performed significantly better than the non-SLCO DHH children in the composite scores and four out of the six subscales, namely Cantonese grammar, textual comprehension, lexical-semantic, and story retelling, suggesting a faster rate of oral Cantonese development among the DHH children studying under the SLCO environment. No significant difference was observed in word definition and expressive vocabulary. It could be due to the fact that many SLCO DHH children had severe to profound hearing loss which might affect their perception and expressive skills. Taken together, the findings again suggested that exposure to sign language in the SLCO environment does not impact DHH children's oral language development negatively.

Next, we turn to the DHH children's vocabulary and Chinese grammar development. Li and Tang (2020) adopted Li's (2000) Pre-school and Primary Chinese Literacy Scale (PPCLS) to track the vocabulary development of twenty SLCO DHH children and their sixty SLCO hearing classmates annually over a period of four years.[25] PPCLS has been used to measure the vocabulary size of children from Kindergarten to Primary 3 in regular schools. It has four subscales and involves primarily character/word identification and vocabulary expression (i.e., receptive and expressive vocabulary). In Li and Tang's study, baseline measurements were collected at the point when the DHH and hearing children entered the SLCO primary school and subsequent measurements were taken at the end of Primary 1, 2 and 3. In terms of age, the DHH children (mean age: 7 years 1 month) were generally ten months older than their hearing peers at each grade. Twelve DHH children had a cochlear implant and eight hearing aids. Results showed an increase in vocabulary size among the SLCO DHH and SLCO hearing children over time. Repeated measures showed an interactive effect between grade and hearing status, where the SLCO hearing children's improvement was significantly better than the SLCO DHH children's. Detailed analysis revealed that both the DHH and hearing children's measurement targeting receptive vocabulary reached the ceiling early, as exemplified in Subscale A (i.e. character-picture matching) and Subscale B (i.e. listen and point at a character). However, significant differences were shown in measurements of expressive vocabulary, as shown in Subscale C (i.e. point and read) and especially Subscale D (i.e. read and create a word/sentence verbally). Next, the researchers found a significant positive correlation between the SLCO DHH children's PPCLS scores and their scores of the Cantonese Spoken Word Recognition Test (CanSWORT).[26] Based on this result, they divided the SLCO DHH children into low speech perception and high speech perception groups, using 70% accuracy as a cut-off. At Primary 3, the SLCO DHH children with low speech perception (DHH_{Low}) and high speech perception (DHH_{High}) showed comparable performance with their SLCO hearing peers in Subscale A (DHH_{Low} = 0.97; DHH_{High} = 0.97; hearing = 0.97) and Subscale B (DHH_{Low} = 0.98; DHH_{High} = 0.99; hearing = 0.998) whereas the performance of both groups of DHH children especially those with low speech perception was poorer in performance than their SLCO hearing peers in Subscale C (DHH_{Low} = 0.53; DHH_{High} = 0.69; hearing = 0.85) and Subscale D (DHH_{Low} = 0.29; DHH_{High} = 0.42; hearing = 0.65). These results suggest that the SLCO DHH children performed on par with their SLCO hearing peers on receptive vocabulary; however, they lagged behind their hearing peers in expressive vocabulary.

Li and Tang also compared the Primary 1 scores of both SLCO DHH and SLCO hearing children with the grade-matched scores of 134 regular hearing children reported in Li et al.'s (2011).[25,27] They found that the SLCO DHH children displayed a similar rate of development as the regular hearing children during their first year of primary education, although the SLCO DHH children' performance was shown to be lagging behind the regular hearing children's slightly at the end of Primary 1 (SLCO DHH children = 0.39 vs regular hearing children= 0.41). On the other hand, while both groups of hearing children started at a similar level initially at Primary 1, it was the SLCO hearing children who performed better than the regular hearing children at the end of Primary 1 (SLCO hearing children= 0.50 vs regular hearing children= 0.41). Taken as a whole, the findings suggest that the SLCO DHH and SLCO hearing students' learning of HKSL in the SLCO environment did not create any negative impact on their Chinese vocabulary development. Additionally, the SLCO hearing children benefitted from the learning environment as they performed better than the regular hearing children reported in Li's study, at least by the end of Primary 1.

Another important component for literacy skills development of HK students is knowledge of written Chinese grammar, which follows the grammar of Mandarin Chinese, not oral Cantonese. Tang et al. (under review) reports on a study that used a pre-standardized version of CGA with a total of 75 items distributed over 12 typical Chinese grammatical structures to measure DHH children's morphosyntactic and syntactic knowledge of written Chinese.[28] A total of 29 SLCO DHH and 176 SLCO hearing children who were classmates of the DHH children from Primary 1 to 4 participated in the study. All SLCO DHH children had severe to profound hearing loss, twenty were implanted, eight wore hearing aids and one had an auditory brainstem implant. Preliminary analysis showed that the SLCO hearing students who studied in the SLCO environment significantly outperformed their DHH peers at all grades. Further analysis revealed that this significant difference in performance seemed to stem from the difference between the DHH and hearing children's progress of Chinese grammatical knowledge during the first two years of primary education. The hearing children made significant strides in Chinese grammatical knowledge between the beginning and end of Primary 1 whereas the DHH children only showed significant improvement from the end of Primary 1 to the end of Primary 2. This difference suggests that DHH children need one more year of intensive training to acquire the grammatical structures competently.

Further analysis revealed generally high accuracy scores among the SLCO DHH and SLCO hearing children by Primary 3 and 4 (P3: DHH children = 0.84 vs Hearing children = 0.92; P4: DHH children = 0.86 vs Hearing children = 0.92), suggesting that the knowledge of written Chinese grammar of both groups of children was developing incrementally over time albeit at different rates. Analyzing the children's development of individual grammatical structures, they observed that the scores of many individual grammatical structures did not show significant group differences by Primary 3 and 4. Using scores lower than 80% as a reference, structures posing difficulty to DHH children were *bei*-passives (P3 = 0.78; P4 = 0.80), relative clauses (P3 = 0.66 ; P4 = 0.68), double object constructions (P3 = 0.76; P4 = 0.75) and locative constructions (P3 = 0.50; P4 = 0.55). In contrast, a score lower than 80% was found in relative clauses (P3 = 0.74; P4 = 0.74) with the SLCO hearing children. That hearing children had much fewer number of grammatical structures achieving a score lower than 80% might account for the group differences.

Taken together, the findings further prove that studying in the SLCO environment with an additional language – HKSL – did not bring detrimental effects on the learning of Chinese, including oral Cantonese and written Chinese, to both DHH and hearing children. While both DHH and hearing children developed knowledge of written Chinese incrementally from Primary 1 to 4 as the data showed, it was the SLCO hearing children who attained very high accuracy scores from Primary 2 onwards. By Primary 4, the SLCO hearing data showed that 11 out of 12 of these grammatical structures had reached a mean accuracy score between 85% and 98%. A similar developmental trajectory was observed among the DHH children, albeit at a slightly slower rate. By Primary 4, 7 out of 12 of these grammatical structures had reached a mean accuracy score between 86% to 98%. Moreover, both groups seemed to experience similar ease and difficulty in terms of acquiring the grammatical structures. There were structures that both groups found easy to acquire, such as negation and aspect, whereas both showed difficulty in developing knowledge of relative clauses and locative constructions. Future reports will involve how regular mainstream hearing children perform on a finalized version of CGA. With this norm, one can compare the performance of DHH and hearing children who receive education in the SLCO environment with non-signing DHH children who study in other mainstream environment.

5.1.2. HKSL Development

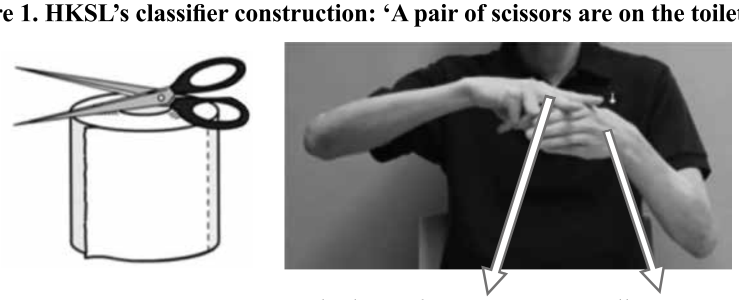
An investigation on the overall development of HKSL by the DHH children in The SLCO Programme was reported in Tang and Yiu (2016).[29] In that study, 15 severe to profoundly deaf children from the first cohort of The SLCO Programme were recruited, out of whom 3 were born of deaf parents who used HKSL as a language for daily communication. Data were extracted from three annual assessments on their HKSL performance to establish a longitudinal profile. The chronological age of these children ranged from 7 years 3 months to

12 years 2 months and the duration of exposure to HKSL varied between 2 to 5 years, except for the deaf children who were born of deaf parents. A pre-standardized HKSL-Elicitation Tool was used, which consisted of a few production tasks that targeted 3 major grammatical domains – word order, classifier constructions and verb morphology. Results indicated an overall improvement in the children's knowledge of the three major grammatical structures of HKSL over time. Additionally, the DHH children born of hearing parents lagged behind those born of deaf parents in their performance. This result was expected because the latter group had a longer duration of HKSL exposure. Before mastering the grammatical structures in HKSL, these children, especially those in the lower grades, used their knowledge of oral Cantonese or written Chinese to produce HKSL sentences. For instance, the negator NOT_HAVE in HKSL usually occurs in a clause-final position, such as, CAT FRY EGG NOT_HAVE 'The cat did not fry the egg'. Some of the DHH children, however, tended to sign NOT_HAVE before the main verb, resulting in a Cantonese-based word order: *HAVE ONE CAT NOT_HAVE FRY EGG ('有隻貓冇煮雞蛋'). Note also that some DHH children started the HKSL sentence with a sign HAVE. HAVE in HKSL occurs not in a clause-initial but a clause final position when it functions as a possessive verb (e.g. MOM HANDBAG HAVE 'Mother has a handbag') or as a perfective marker (e.g. YESTERDAY MOM FRY FISH HAVE 'Mother fried fish yesterday'). However, its Cantonese/Chinese equivalent '有' ('have') is clause-initial when it is used as an existential marker (e.g. 有隻飛機飛走咗 'A plane has flown away'). This is another piece of evidence suggesting a strong cross linguistic interaction between Cantonese/Chinese and HKSL in DHH children's spontaneous productions, a natural process of language acquisition involving more than one language.

To further investigate the interaction of HKSL and Chinese, Tang and Li (2018) investigated the acquisition of a representative structure in HKSL that utilizes space in organizing its grammar – classifier construction.[12] This construction is said to exist in almost all sign languages in the world. HKSL, just as other sign languages, has different types of verbs each with specific morphological properties. Some type, which is normally referred to as 'plain verbs', is very simple, like LOVE and THINK, and requires no morphological affixation. The type they focused on in their study is the most complex construction because the verb comes with a whole host of different morphemes agglutinating to it. The basic morphophonological template of this verbal predicate is [**movement + 1 or 2 classifier handshapes**]. The movement of the sign refers to the verb root and the handshapes the arguments (i.e., participants of the verbal predicate), like (1) below:

(1) TOILET_ROLL *be-located+CL$_{SASS}$:toilet roll$_a$* *(1 handshape)*
"A toilet roll exists here,"
SCISSORS *be-located+CL$_{SASS}$: scissors$_b$ // CL$_{SASS}$: toilet roll$_a$* *(2 handshapes)*
"A pair of scissors are on the toilet roll".

Figure 1. HKSL's classifier construction: 'A pair of scissors are on the toilet roll'



SCISSORS *be-located+CL$_{SASS}$: scissors$_b$ // CL$_{SASS}$: toilet roll$_a$*

In (1), the noun TOILET_ROLL is signed first and the existential predicate is realized by a classifier construction (i.e. *be-located+CLSASS: toilet rolla*) signed at a locus in space (i.e. -a refers to a spatial location). The classifier handshape (i.e. *CLSASS*) referring to TOILET_ROLL requires half-closed fingers and thumb (i.e. C-handshape to refer to a cylindrical object) of the left hand. In this example, the palm of the left hand faces sideward contralaterally (i.e. the toilet roll 'stands'). Next, the existence of a pair of scissors (i.e. on top of the toilet roll) is realized by the right hand articulating another classifier construction (i.e. be-located+*CLSASS*: scissorsb) on the radial side of the left hand (i.e. '//' implies two handshapes simultaneously realized in space) to mean 'on'. The classifier for SCISSORS, which adopts a V-handshape, is signed 'horizontally' on top of the left hand (i.e. A pair of scissors 'lies' on top of the toilet roll). Clearly, the word order and the grammatical elements in HKSL are quite different from those of an oral Cantonese sentence equivalent in meaning '把鉸剪喺卷廁紙上面' ('A pair of scissors is on top of the toilet roll'). The Cantonese sentence adopts a subject-verb-object order that ends with a localizer '上面' ('on top'). In HKSL, the locative object (i.e. TOILET_ROLL) is signed first before the subject (i.e. a pair of scissors), resulting in an object-verb-subject-verb order and no localizers are allowed because the spatial relation of the two entities is expressed by the spatial configuration of the two hands. Occasionally, one finds a subject-object-verb order in adult HKSL data. In the sign language acquisition literature, classifier constructions are acquired as late as 5-7 years old by DHH children because of the linguistic complexities involved. How did DHH children of HKSL acquire such complex constructions given the availability of HKSL input in the SLCO environment? The data to be reported here form part of a large set of data elicited using the HKSL-Elicitation Tool mentioned above. The assessment involved picture description like the example above prompting the children to produce HKSL sentences based on 16 pictures. The data were elicited by a team of native Deaf signers trained to support sign linguistics research.

In Tang and Li (2018), 15 DHH children were invited to participate in the project, whose parents were all hearing and who acquired HKSL second to oral Cantonese at a young age.[12] Two deaf children born of deaf parents served as controls. They acquired HKSL since birth and Cantonese at a young age, through early intervention. Three native Deaf signers of HKSL also participated to serve as adult controls. At the time of the elicitation, the chronological age of these children ranged from 8 years 10 months to 14 years 5 months. The age at which these children were exposed to HKSL was from 4 years 2 months to 7 years 2 months. Using duration of HKSL exposure as a criterion, they assigned the 15 DHH children to four groups (duration of HKSL exposure: Group 1 = 7 years; Group 2 = 6 years; Group 3 = 5 years; Group 4 = 4 years). Among these 15 DHH children, 11 were profoundly deaf, 3 were severely deaf and 1 had moderately severe hearing loss. Nine out of fifteen DHH children were implanted and the rest wore hearing aids.

Results revealed that the performance of the native adults displayed a consistently typical word order: (a) ***locative object – verb*** to place the object in space to denote existence, then followed by (b) ***subject – verb+locative object*** to denote the spatial configuration of the two entities, which signifies a typical classifier construction. The two deaf children born of deaf parents performed likewise in terms of word order. As for the 15 DHH children, it was shown that as their duration of HKSL exposure increased, so was improvement in their accuracy scores on word order (Group 1=92%; Group 2=58%; Group 3=22%; Group 4=21%). Before acquiring this order, the DHH children, especially those belonging to Groups 3 and 4 produced many signed sentences with a word order ***subject-verb-object*** where the verb was plain (e.g. PUT or HAVE). In a stimuli testing the same concept involving a dog and a bionic hand, many DHH children at the junior levels adopted a lexical sign PUT and added an upward-pointing sign at the end of the sentence, e.g. *BIONIC_HAND PUT DOG IX_{up} '隻機械手放狗上面'(A bionic hand is placed on the back of the dog) or *DOG IX_{up} HAVE BIONIC^HAND '狗上面有隻機械手'(A bionic hand is on the back of the dog'). Clearly both sentences resemble oral Cantonese word order with grammatical properties of oral Cantonese. However, it needs highlighting that in HKSL such a SVO word order is allowed in sentences other than classifier constructions. They involve plain verbs as mentioned above, e.g. TEACHER LIKE/LOVE STUDENT; however, such a SVO order is generally disallowed in classifier constructions. Therefore, one plausible explanation for the SLCO DHH children's performance is that their concept of SVO word order was doubly enhanced by that of oral Cantonese and plain verbs of HKSL. When attempting to construct sentences in HKSL involving a specific verbal predicate like a classifier construction, they simply adhered to the SVO order initially, a demonstrable piece of evidence of cross linguistic interaction in the acquisition process. What deserves our attention is the DHH children's growth of knowledge of linguistic complexity with classifier constructions over time. During the interim, these DHH children, while maintaining the same SVO order, started to increase the morphological complexity of the 'verb' through affixing more morphemes to the verb root, as seen by their attempts to use the two hands to represent the subject and the object (i.e. two classifiers) meaningfully configurationally. Mastery of classifier constructions demonstrating abilities to produce a complex verbal predicate gradually emerged among the children of Groups 1 and 2 whose duration of exposure was longer, with a concomitant change of word order to an OVS order that typifies classifier construction in HKSL.

Taken as a whole, both studies on the SLCO DHH children's acquisition of HKSL indicated immersing DHH children in an acquisition rich environment with consistent input in HKSL encourages sign language development over time. Zooming in on their acquisition of a complex linguistic construction such as classifier constructions in HKSL also shows how properties of Cantonese and HKSL interacted with each other in the acquisition process. This acquisition phenomenon reveals the natural propensity of bilingual children in utilizing their developing grammatical knowledge of both HKSL and oral Cantonese/written Chinese in tackling a complex acquisition task.

5.1.3 Metalinguistic awareness

In the literature, metalinguistic awareness has been found to be an essential component for literacy acquisition.[30] Specifically, it refers to one's metacognitive ability to reflect on language that is structured at different linguistic levels. Since bilinguals need to develop two or more linguistic representations and to manage their attention when processing the associated languages online, they are found to have greater metalinguistic awareness and cognitive flexibility than monolinguals, and better skills for approaching unknown languages. In The SLCO Programme, one manifestation of the children's metalinguistic awareness is their ability to differentiate the grammar of HKSL from that of Chinese, either oral

Cantonese or written Chinese, just as many hearing bilingual children of spoken languages. Before sign linguistics research came into the scene, a common debate among deaf educators globally was whether DHH children should be exposed to a form of signing reflecting the grammar of a spoken language (e.g. signed Chinese) or that of a natural sign language (e.g. HKSL) for literacy skills development in a spoken language (e.g. Chinese). Under extreme circumstances, DHH children's low achievement in a spoken language (e.g. Chinese) was said to be associated with the interference of their knowledge of a sign language (e.g. HKSL). This misconception prevailed for decades until recently counterevidence was shown with findings from bimodal bilingual acquisition research.

As pointed out previously, the positive correlation of oral Cantonese, written Chinese and HKSL of the DHH children in The SLCO Programme implies that the interaction among the developing grammars of these languages indeed brings positive learning outcomes. It underlies The SLCO Programme's emphasis on immersing children in an educational environment in which there is daily naturalistic linguistic input in oral and sign languages for children to develop knowledge of the different grammatical systems in parallel and as early as possible. However, when some teachers of the deaf, the regular teachers and peers are hearing are present in the SLCO learning context, who are Cantonese-speaking and who are also L2 learners of HKSL with different degrees of proficiency, the SLCO DHH children are bound to be exposed to some signed Chinese produced by the hearing participants. Seen in this light, the DHH children's ability to differentiate the grammar of HKSL from Chinese becomes crucial in justifying their bilingual development.

Tang, Yiu and Lam (2015) recruited 18 DHH children from cohorts 1 to 4 of The SLCO Programme to take part in a language differentiation task.[31] These children had severe to profound hearing loss and about 50% of them were implanted. Their age ranged from 9 years 8 months to 15 years and they were studying at Primary 4, 5, 6 and Secondary 1. They were exposed to HKSL since kindergarten alongside their oral Cantonese development with support from speech and language therapy. The task involved five types of grammatical constructions which are different in linguistic organization between HKSL and signed Chinese. A total of 32 items were designed, 16 went to HKSL with appropriate mouth gestures (i.e. a natural component of signing) and the remaining 16 were divided between signed Chinese with mouthing (i.e. a common form of signing that adopts the mouth patterns of oral Cantonese) and signed Chinese without mouthing (i.e. an uncommon form of signing if it follows the oral Cantonese grammar). The children watched the signed sentences on a computer and categorized them into either HKSL or signed Chinese. Using 75% as an achievement threshold, results revealed that by Primary 4, 16 out of 18 DHH children were able to distinguish between HKSL and signed Chinese with mouthing, and many of them scored way above 75% and even reaching 100%. On the other hand, only 13 out of 18 of them could distinguish HKSL from signed Chinese without mouthing. That signed Chinese with mouthing was more distinguishable than signed Chinese without mouthing was predicted because in the latter condition DHH children were given no visual cues thus forcing them to rely on their metalinguistic awareness of the grammatical distinctions between HKSL and Chinese in judging the signed sentences. Even so, a majority of DHH children (i.e. 72%) managed to display such knowledge distinction in the task.

Taken as a whole, early and consistent exposure to HKSL and oral Cantonese input in the SLCO environment has a positive impact on the children's ability to identify relevant linguistic input for language acquisition and early linguistic differentiation. A post-hoc questionnaire survey with these children revealed that their sensitivity towards the signing varieties was quite high. 83.33% of them reported their awareness of the differences in the two grammatical systems. The result might suggest that availability of signed Chinese input from output of second language hearing learners in the school environment may compromise HKSL acquisition until the DHH children's knowledge of Cantonese has reached a sufficient level for them to reject signed Chinese as potential linguistic input for sign language acquisition. During a post-hoc focus group discussion, it was found that DHH children with a better performance in the differentiation task were more articulate in their explanation about the linguistic differences between HKSL and signed Chinese, reflecting their relatively higher level of metalinguistic awareness in not just judging but also articulating linguistic differences.

A further study on SLCO DHH children's metalinguistic awareness was reported in Sze and Tang (2017) in which they examined 15 SLCO DHH children from Primary 2, 4 and 6 with age ranged from 7 years 9 months to 12 years 6 months.[32] The stimuli contained locative sentences in Chinese, such as "檯上面有一支筆/有一支筆喺檯上面" "There is a pen on the table", and a corresponding signed sentence in HKSL, primarily expressed in classifier constructions. As said, simultaneously representing two entities existing in a spatial configuration does not require use of prepositions like 'on' or 'under' in HKSL (see the example in Figure 1). In contrast, oral Cantonese requires either an existential verb (e.g., *jau5* 'have'), or a locative verb (e.g., *hai2* 'co-verb') plus a localizer (e.g., *soeng6min6* 'on top of/above') in a sequential representation.

The children were invited to participate in two tasks: sentence production and judgement. In this report, we will focus on the judgement task, which consisted of two sub-tasks. The first subtask assessed DHH children's ability to detect syntactic and semantic errors in locative constructions in written Chinese and HKSL. The second sub-task was language differentiation, which consisted of a set of signed sentences designed to represent signed Chinese and HKSL, like the former study by Tang et. al (2015). Findings from the first sub-task revealed an improvement in performance according to grade level, from Primary 2 to Primary 6. As for the second sub-task, which required the DHH children to rate the grammaticality of a set of signed locative constructions that varied between signed Chinese and HKSL on a 5-point Likert scale, the findings revealed that even DHH children at Primary 2 level were able to distinguish signed Chinese from HKSL.

To conclude, both studies offer some concrete evidence that bimodal bilingual DHH children were aware that Chinese and HKSL have independent grammars. The findings corroborate Meisel's (2004, p.98) proposal based on empirical data of spoken language bilingual children that 'early separation of linguistic systems is not the exception but the rule in the simultaneous acquisition of various languages'.[14] In The SLCO Programme, additional to oral Cantonese training with clinicians, these children received input from their hearing age peers and parents at home as a majority of them were born of hearing parents. They also began to receive exposure in HKSL at around age 3 or earlier. Currently, more and more children born into Deaf signing parents join The Progrmame since they acquire HKSL as their first language. Therefore, given this language acquisition condition, these DHH children were able to differentiate the two languages as early as Primary 2 even if they were presented in the signing mode. In other words, early exposure to two languages in a bilingual mode does not lead to linguistic confusion but early differentiation (ref. Meisel 2004). In fact, it is not uncommon to find the DHH children switching to signed Chinese sometimes when they interact with their hearing peers and teachers to accommodate their inadequate signing skills as second language learners.

5.2 SLCO School Environment and Social Integration

An important consideration when setting up The SLCO Programme was how to ensure active participation by DHH children in the mainstream classroom. A corollary consideration was how to inculcate a sense of belonging among the DHH and hearing children by reducing diversity due to hearing status to a minimum. As mentioned, The SLCO Programme emphasizes inclusion of a 'critical mass' of DHH children in a regular classroom to study with hearing students (i.e. co-enrollment) and the development of bimodal bilingualism (i.e. acquisition of spoken and sign languages) among the participants, teachers and students alike. It is the development of bimodal bilingualism in the SLCO classroom that eventually nurtures collaboration and empathy among the hearing and deaf participants in the teaching and learning process.

Yiu (2015) examined if DHH children in the SLCO environment displayed a positive perception of their classroom participation comparable to their hearing peers.[33] A 28-item Classroom Participation Questionnaire (CPQ) adopted previously by Antia, Sabers and Stinson (2007) was translated into Chinese and administered to 17 severe or profoundly deaf and 62 hearing children studying from Primary 4 to 6 of The SLCO Programme.[34] Results revealed no significant statistical differences between the CPQ scores of the DHH children and their hearing peers, both of whom gave a very high rating to classroom participation (DHH = 3.11/4 vs hearing = 3.28/4). However, the DHH children did indicate some difficulty in participating specifically in group discussions and comprehending other students' responses to teachers, owing to the complexity of group learning activities or sitting arrangements. Correlation of the DHH children's CPQ subscales and their performance in written Chinese grammar, oral Cantonese and HKSL assessments showed that the subscales *understand teachers, understand students, positive affect* correlated neither with the children's oral Cantonese nor HKSL but with their grammatical knowledge of written Chinese and levels of hearing loss. The high ratings of classroom participation of both DHH and hearing children echo Antia et al. (2009) proposal that classroom participation is one of the major factors reflecting DHH students' academic status and performance in a mainstream classroom.[35] They further argued that besides paying attention to how hearing levels affect DHH students' classroom communication, more attention should be paid to their literacy skills which play a significant role in their overall participation in class. Yiu (2015) further suggested that the language-rich environment has nurtured a community of DHH and hearing bimodal bilinguals who are ready to utilize their linguistic resources to engage themselves more actively in classroom learning and interactions.33 Bimodal bilingualism supports direct communication between DHH students and their hearing teachers and peers instead of sign interpretation, and a flexibility of code choice according to the hearing status and language preference of the interlocutors.

In the literature on deaf education, DHH children are seldom clustered in one mainstream school due to low incidence deafness and sometimes government policy. Consequentially, they develop feelings of loneliness and isolation when they fail to communicate with their peers and teachers at school. In fact, self-perception as a D/deaf person needs to be negotiated as a lifelong process through interactions with the external environment, especially with the people whom the DHH children meet daily at school. According to Hintermair (2014), DHH children are at risk in inclusive settings when they are the only deaf person at school and co-enrollment education offers a promising alternative due to the programming requirement of having a critical mass of DHH children studying with a group of hearing peers. He cited such positive outcomes from co-enrollment programmes in The Netherlands, Austria, Spain and Hong Kong.[36]

In the Hong Kong study, Yiu et al. (2014) investigated the social integration between the DHH and hearing children of The SLCO Programme.[37] Social integration is defined as students' abilities to interact with, make friends with, and be accepted by peers. This study involved 16 DHH and 286 hearing children from Primary 4 to 6, with the latter group constituted by 224 children from regular classes and 65 children from the SLCO classes. A great majority of DHH children had severe to profound hearing loss, and their age ranged from 9 years 7 months to 14 years 1 month. Seven of them were implanted at an average age of 2 years 10 months and eight others wore hearing aids. The survey involved three measures: (i) social acceptance in play and study conditions using peer ratings, (ii) hearing children's attitudes towards DHH children using a 5-point Likert scale, and (iii) DHH children's attitudes towards deafness using a 5-point Likert scale. Yiu et. al. predicted that these three factors interacted with one another in bringing about social integration between the DHH and the hearing children.

Results from peer ratings of these SLCO students indicated a significantly high social acceptance of the DHH and the hearing children towards each other under the study and play conditions, with a mean rating of 4.4. out of 6. Additionally, solidarity among the DHH children saw a statistically significant difference with DHH children giving a higher rating to their DHH peers than hearing peers. The stronger development of DHH-DHH peer relations is understandable when DHH children have a chance to meet other children of a similar hearing status, especially in the school context which occupies a large chunk of their daily life. As for the hearing children, there was no significant difference in the ratings they gave to their hearing peers and DHH peers, suggesting they did not perceive their DHH peers as *different* members of the SLCO class. Factor analysis of the 289 hearing children's attitudes towards their DHH peers found four factors underlying their attitudes in the order from the highest to the lowest mean ratings based on a 5-point scale: positive actions (4.02) > positive perception of DHH children's personalities and behaviours (3.96) > negative reactions and perceptions (3.78) > tolerance towards communication difficulties (3.01). Generally speaking, the mean ratings of these four factors were high except for 'tolerance towards communication difficulties'. While the overall mean rating of this factor was low, a gradual improvement in ratings towards senior primary levels was found, suggesting that duration of co-enrollment education has a positive impact on raising the children's tolerance for communication difficulties.

As for the DHH children's attitudes towards their deafness, factor analysis found four factors underlying their attitudes ordered from the highest to the lowest mean ratings based on a 5-point scale: optimism for coping (4.7) > readiness for social contact (4.4) > reaction to worries and frustrations (4.1) > acceptance of deafness (3.9). In all, the high mean ratings of the DHH children indicated that they were satisfied with this mode of education and were ready to cope with challenges and connect with people around them. More fine-grained analysis revealed that the more positively the DHH children accepted their deafness the higher they rated their DHH peers and the more positive ratings they received from their hearing peers. As for the hearing children, the more ready they rejected 'negative actions and perceptions', or the more tolerant they were toward communication difficulties, the higher the ratings they received from or rendered to their DHH peers. Taken as a whole, duration of SLCO education has a positive impact on the participants' attitudes towards each other, especially the nurturing of understanding and empathy towards among themselves and towards each other. For the DHH students, the duration of SLCO experiences interacts with acceptance of their deafness and resilience in copying with challenges.

6. Discussion and Conclusion

This paper discusses the philosophical foundations of SLCO education and its impact on DHH and hearing children's language development, attitudes towards deafness and sign language, and social integration. There are two general observations. First, there is a positive gain among the DHH children in terms of their oral Cantonese, written Chinese and HKSL development, as evidenced by a positive correlation among the three languages and subsequent studies on the positive gain in terms of vocabulary size and grammar of written Chinese as well as HKSL. Although the HKCOLAS scores of DHH children showed a wide gap in their oral language development compared with appropriate age norms initially, this gap gradually narrowed as they moved to senior grades. Their performance in PPCLS and CGA also indicated that they could catch up with their hearing peers of the SLCO Programme within the span of their primary education. That the DHH children utilized their linguistic resources of Cantonese in their HKSL assessment offers concrete evidence of cross linguistic interaction as a means to support their daily communication and learning at school, which indirectly bolsters their metalinguistic development in HKSL and Cantonese, a characteristic of bilingual children's abilities. The growth of such knowledge over time enables them to differentiate the grammatical properties of HKSL and Chinese at an early age. The methodology of Sze and Tang (2017), in which the age range was experimentally set as early as when these children reached Primary 2, could be further extended downward in future research to explore how early these children can differentiate the grammar of Cantonese and HKSL in bilingual acquisition. The hearing children also benefitted from SLCO education; at least, they outperformed the non-SLCO hearing children from other mainstream schools in their vocabulary development, as shown by their PPCLS results. Further research is necessary to shed light on how young hearing children acquire HKSL and develop bimodal bilingualism to address the issue of age of acquisition of hearing young learners from a second language acquisition perspective.

The second observation is positive social integration between the DHH and hearing children who study together in the SLCO environment. The findings revealed increasing acceptance in group membership and positive attitudes towards sign language and deafness as a function of duration of SLCO education in the SLCO classrooms between the two groups of DHH and hearing children. The findings also showed that it was sign language and the DHH children's level of hearing loss that accounted for the degree of acceptance between the DHH and the hearing students. In the SLCO classroom, effective communication in the SLCO environment occurs when both groups of students have attained a level of HKSL and oral Cantonese, supported by their growing capacity for switching between languages flexibly. In our research, even DHH children with very poor speech perception despite implantation could find a way to interact with their hearing peers who were so willing to interact with them in sign language, to learn sign language from them so to speak. Therefore, we argue that when bimodal bilingualism underlines the linguistic repertoire of these children, they see the potentiality for using cross-modal communication to establish rapport and develop peer relations.

Yiu et al. (2019) highlighted four essential ingredients for the development of co-enrollment programming.[38] They are:

a. whole-school approach towards promoting deaf and hearing collaboration;
b. involvement by deaf individuals in school practices, especially deaf-hearing co-teaching practices in the SLCO classroom;
c. an enriched linguistic context to support bimodal bilingual development of DHH and hearing participants, especially children; and
d. DHH and hearing children' active participation in school and social activities.

The whole school approach ensures the sharing of a common goal and resources within the school system, which facilitates planning for SEN support, formal and informal learning activities, teaching assignments especially for those teachers with proficient signing skills to be responsible for the SLCO classes, and adjustments of parents' expectations. One special feature of The SLCO Programme is the involvement of Deaf teachers to co-teach with the regular hearing teacher in the SLCO classes. They not only jointly deliver not only curriculum contents but also impart linguistic input in HKSL and oral Cantonese to support DHH and hearing children's bimodal bilingual development. Collaboration between the two teachers offers an excellent manifestation in front of the whole class of DHH and hearing children in terms of how mutual support in classroom could lead to the realization of shared pedagogical goals. That both teachers are responsible for teaching all students in class regardless of hearing status conveys a message to the students that both teachers are prepared to share the teaching and caring responsibilities for all the students. With improved bilingual proficiencies, one can see more and more active participation and interactions in either Cantonese or HKSL in class, as the hearing children could interact with the Deaf teacher in HKSL or the DHH children with the hearing teacher and peers in oral Cantonese and HKSL. These essential ingredients for developing co-enrolment education are taken up in McGuire (2021, pp.41),[39] in which she argued that sign bilingualism and co-enrolment education offers 'a pathway to belonging, or ibasho in Japanese education'. Co-enrolment education goes beyond addressing DHH children's needs for information accessibility in the classroom to building true inclusion; it creates 'opportunities for peer interactions, meaningful communication and belonging'

As models of co-enrolment education for DHH and hearing children are still evolving globally and subject to adaptations based on local circumstances, more research is necessary to document the benefits of co-enrolment education, not only development in language and socio-psychology, but also cognition and academic achievement of DHH and hearing children. As far as Hong Kong is concerned, the emphasis on facilitating bimodal bilingual development of DHH and hearing children to achieve social integration constitutes a core mission of The SLCO Programme. To achieve this, the inclusion of Deaf signing teachers is instrumental to the success of social integration. These teachers are the DHH and hearing children's linguistic as well as social role models, and bridges for the children to access the Deaf Community when they become teens. From the perspective of deaf education, The SLCO Programme has widened deaf signing children's opportunities to pursue a full curriculum in mainstream education without barriers, enjoying inclusion and opening their door to post-secondary education, an opportunity they seldom obtain previously.

Acknowledgement

The authors would like to thank The Hong Kong Jockey Club Charities Trust, The Lee Hysan Foundation, and Fu Tak Iam Foundation for their generous donations enabling us to innovate SLCO education in Hong Kong to benefit deaf and hearing children. The programme would not have been successful without the support of the parents of both DHH and hearing children, educators from the Catholic Diocese of Hong Kong, The Missionary Oblates of Mary Immaculate, and Peace Evangelical Centre Limited. Efforts of the Deaf and hearing teachers of the Progamme will not be forgotten. Part of the research reported in the paper was supported by two research grants to Gladys Tang (GRF#14611315, GRF#450513).

References

1. Brentari D, editor. Sign Languages [Internet]. 1st ed. Cambridge University Press; 2010 [cited 2022 Mar 29]. Available from: https://www.cambridge.org/core/product/identifier/9780511712203/type/book
2. Hong Kong. CSecretariat. Integrating the disabled into the community : a united effort white paper. H.K.: Govt. Printer, October; 1977.
3. Knoors H, Marschark M. Teaching Deaf Learners: Psychological and Developmental Foundations [Internet]. Oxford University Press; 2014 [cited 2022 Mar 29]. Available from: https://oxford.universitypressscholarship.com/view/10.1093/acprof:oso/9780199792023.001.0001/acprof-9780199792023
4. Hoffmeister R, Henner J, Caldwell-Harris C, Novogrodsky R. Deaf Children's ASL Vocabulary and ASL Syntax Knowledge Supports English Knowledge. The Journal of Deaf Studies and Deaf Education. 2021 Dec 16;27(1):37–47.
5. Tang G, Adam R, Obe KS. Chapter 10. Educating bilingual and multilingual deaf children in the 21st century. In: Morgan G, editor. Trends in Language Acquisition Research [Internet]. Amsterdam: John Benjamins Publishing Company; 2020 [cited 2022 Mar 29]. p. 183–204. Available from: https://benjamins.com/catalog/tilar.25.10tan
6. Cummins JD. The Relationship between American Sign Language Proficiency and English Academic Development : A Review of the Research. In 2007.
7. Lillo-Martin D, de Quadros RM, Chen Pichler D, Fieldsteel Z. Language choice in bimodal bilingual development. Front Psychol [Internet]. 2014 Oct 20 [cited 2022 Mar 29];5. Available from: http://journal.frontiersin.org/article/10.3389/fpsyg.2014.01163/abstract

8. Donati C, Branchini C. C. Donati, C. Branchini (2012). Challenging linearization: simultaneous mixing in the production of bimodal bilinguals. In: T. Biberauer; I. Roberts (ed.). Challenges to linearization. vol. 114, pp. 93-128, Berlin: Mouton De Gruyter. In 2012. p. 93–128.
9. Bogaerde B. Input and Interaction In Deaf Families. 2000 Jan 1;
10. Baker A, van den Bogaerde B. Code-mixing in signs and words in input to and output from children. In: Plaza-Pust C, Morales-López E, editors. Studies in Bilingualism [Internet]. Amsterdam: John Benjamins Publishing Company; 2008 [cited 2022 Mar 29]. p. 1–27. Available from: https://benjamins.com/catalog/sibil.38.04bak
11. Fung CH-M, Tang G. Code-blending of functional heads in Hong Kong Sign Language and Cantonese: A case study. Bilingualism. 2016 Aug;19(4):754–81.
12. Tang GWL, Li J. Acquisition of Classifier Constructions in HKSL by Bimodal Bilingual Deaf Children of Hearing Parents. Front Psychol. 2018 Jul 23;9:1148.
13. Quadros R, Lillo-Martin D, Chen Pichler D. [What bimodal bilingual have to say about bilingual developing?]. Letras de hoje. 2013 Jul 1;48:380–8.
14. Meisel J. The Bilingual Child. In: The Handbook of Bilingualism. 2008. p. 90–113.
15. Hall ML, Hall WC, Caselli NK. Deaf children need language, not (just) speech. First Language. 2019 Aug;39(4):367–95.
16. Humphries T, Kushalnagar P, Mathur G, Napoli DJ, Rathmann C, Smith S. Support for parents of deaf children: Common questions and informed, evidence-based answers. International Journal of Pediatric Otorhinolaryngology. 2019 Mar;118:134–42.
17. Kirchner CJ. Co-enrollment: An effective answer to the mainstream debacle. In 2004. p. 161–73.
18. Marschark M, Antia S, Knoors H, editors. Co-Enrollment in Deaf Education [Internet]. 1st ed. Oxford University Press; 2019 [cited 2022 Mar 29]. Available from: https://oxford.universitypressscholarship.com/view/10.1093/oso/9780190912994.001.0001/oso-9780190912994
19. Zhang H-Y. Sign bilingualism and co-enrolment education practices in a kindergarten in Quzhou. the 2021 International Talk Series on Co-enrolment Education; 2021 Dec; The Centre for Sign Linguistics and Deaf Studies of The Chinese University of Hong Kong.
20. Lei W. The first step to achieving ‘Deaf CAN’ in the mainstream education-The SLCO Programme in Macao. the 2021 International Talk Series on Co-enrolment Education; 2021 Dec; The Centre for Sign Linguistics and Deaf Studies of The Chinese University of Hong Kong.
21. Chong, S.L., Choo, M., Neo, S.N., & Yee, C. Finding from a co-enrollment Model for Deaf Students in Singapore. 2021 International Congress on the Education of the Deaf – The Power of Connection; 2021 Jun; Brisbane, Australia.
22. Tang G, Lam S, Yiu KC. Language Development of Deaf Children in a Sign Bilingual and Co-enrollment Environment. In: Marschark M, Tang G, Knoors H, editors. Bilingualism and Bilingual Deaf Education [Internet]. Oxford University Press; 2014 [cited 2022 Mar 29]. p. 313–41. Available from: https://oxford.universitypressscholarship.com/view/10.1093/acprof:oso/9780199371815.001.0001/acprof-9780199371815-chapter-13
23. T’sou B, Lee T, Tung P, Man Y, Chan A, To C, et al. Hong Kong Cantonese oral language assessment scale. Hong Kong: City University of Hong Kong. 2006;
24. Lee, K., Lau, T., Lam., F., Tang, G., Yiu, Chris K-M. The oral language development of deaf children in a sign bilingualism and co-enrollment program. 2014 Symposium on Sign Bilingualism and Deaf Education; 2014; The Centre for Sign Linguistics and Deaf Studies of The Chinese University of Hong Kong.
25. Wang Q, Andrews J, editors. Literacy and deaf education: toward a global understanding. Washington, DC: Gallaudet University Press; 2020. 446 p.
26. Ng I, Lam JHS, Lee K. The Cantonese Spoken Word Recognition Test (CanSWORT). 2017.
27. Li H, Rao N, Tse SK. Bridging the gap: a longitudinal study of the relationship between pedagogical continuity and early Chinese literacy acquisition. Early Years. 2011 Mar;31(1):57–70.
28. Tang, G., Li, Q., Yiu, C. K-M., & Li, J. Chinese grammatical development of d/Deaf and Hard-of-Hearing children in a sign bilingualism and co-enrollment program.
29. Tang G, Yiu CK-M. Developing Sign Bilingualism in a Co-Enrollment School Environment [Internet]. Marschark M, Spencer PE, editors. Oxford University Press; 2015 [cited 2022 Mar 29]. Available from: http://oxfordhandbooks.com/view/10.1093/oxfordhb/9780190241414.001.0001/oxfordhb-9780190241414-e-13

30. Bialystok E. Acquisition of Literacy in Bilingual Children: A Framework for Research: Acquisition of Literacy in Bilingual Children. Language Learning. 2007 Jun;57:45–77.
31. Tang G, Yiu K-M, Lam S. Awareness of Hong Kong Sign Language and Manually Coded Chinese by Deaf Students Learning in a Sign Bilingual and Co-enrollment Setting. In 2015. p. 117–48.
32. Tang G, Sze F. Metalinguistic awareness in the bimodal-bilingual acquisition of locative sentences in Chinese and Hong Kong sign language by deaf/hard-of-hearing children. Rivista di psicolinguistica applicata : XVI, 2, 2016 [Internet]. 2016; Available from: http://digital.casalini.it/3940754
33. Yiu, C. K-M. Classroom participation of deaf and hard-of-hearing students in a sign bilingualism and co-enrollment (SLCO) education setting. 22nd International Congress on the Education of the Deaf: Educating Diverse Learners: Many Ways, One Goal.; 2015; Athens, Greece: Deaf Studies Unit, University of Patras.
34. Antia SD, Sabers DL, Stinson MS. Validity and Reliability of the Classroom Participation Questionnaire With Deaf and Hard of Hearing Students in Public Schools. Journal of Deaf Studies and Deaf Education. 2007 Apr 1;12(2):158–71.
35. Antia SD, Jones PB, Reed S, Kreimeyer KH. Academic status and progress of deaf and hard-of-hearing students in general education classrooms. J Deaf Stud Deaf Educ. 2009;14(3):293–311.
36. Hintermair M. Psychosocial Development in Deaf and Hard-of-Hearing Children in the Twenty-first Century. In: Marschark M, Tang G, Knoors H, editors. Bilingualism and Bilingual Deaf Education [Internet]. Oxford University Press; 2014 [cited 2022 Mar 31]. p. 152–86. Available from: https://oxford.universitypressscholarship.com/view/10.1093/acprof:oso/9780199371815.001.0001/acprof-9780199371815-chapter-7
37. Yiu KC, Tang G. Social Integration of Deaf and Hard-of-Hearing Students in a Sign Bilingual and Co-enrollment Environment. In: Marschark M, Tang G, Knoors H, editors. Bilingualism and Bilingual Deaf Education [Internet]. Oxford University Press; 2014 [cited 2022 Mar 30]. p. 342–67. Available from: https://oxford.universitypressscholarship.com/view/10.1093/acprof:oso/9780199371815.001.0001/acprof-9780199371815-chapter-14
38. Kun-man Yiu C, Tang G, Chi-man Ho C. Essential Ingredients for Sign Bilingualism and Co-Enrollment Education in the Hong Kong Context. In: Co-Enrollment in Deaf Education [Internet]. Oxford University Press; 2019 [cited 2022 Mar 30]. p. 83–106. Available from: https://oxford.universitypressscholarship.com/view/10.1093/oso/9780190912994.001.0001/oso-9780190912994-chapter-5
39. McGuire JM. Sign Bilingual Co-Enrollment Programs as Pathways to Ibasho. ESJ. 2021;15(0):41–56.

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

Luciana SP LAU, Rosa LY TSE, Sandra FP WONG

Child Assessment Service, Department of Health, Hong Kong

Abstract

The aim of this study was to evaluate the auditory word recognition ability of Cantonese speaking children with hearing impairment in different noise conditions using the Cantonese Spoken Word Recognition Test (CanSWORT). Participants were 58 hearing impaired children aged three to eight years, attending kindergartens or primary schools in Hong Kong. They were divided into four groups, namely moderate, moderately severe, severe and profound, according to their degree of hearing loss. The speech material was delivered to the participants in the sound field at 65 dBA in five listening conditions, at signal-to-noise ratios (SNRs) of -8, -5, 0, +5dB and in quiet. CanSWORT, with the addition of noise, namely CanSWORT in noise, was used to assess children with their amplification devices (hearing aids, cochlear implants or brainstem implant). The results showed there was no significant difference in the scores across the four test lists, whereas significant differences were noted across the noise conditions and participant groups. In addition, low correlations were found between hearing thresholds and the CanSWORT in noise scores.

These results suggested that the four CanSWORT word lists, when applied in the stated noise conditions, were equivalent and could be used interchangeably. The speech recognition ability of our participants was found to be dependent on the SNR and the degree of hearing impairment, and this ability could not be predicted from audiometric thresholds. CanSWORT in noise is a potentially useful tool for assessing speech recognition ability in noise for Cantonese speaking children with significant hearing impairment.

Introduction

Poor ability to understand speech is one of the key factors contributing to the communication difficulties of hearing impaired children in school and at home.[1] Reduced temporal and frequency resolution in the impaired ears make comprehension of auditory information difficult.[2,3] The presence of background noise and poor classroom acoustics make listening and learning even more challenging.[4,5] The combined effects might actually lead to a 40% to 50% reduction in speech perception.[6] For young children with normal hearing, at least +6 dB SNR is required, whereas for a listener with hearing loss, +15 dB SNR is needed for optimal auditory comprehension.[7,8]

The current behavioural test tools for evaluating the aided performance of children with hearing impairment include play audiometry, visual reinforcement audiometry and distraction test in which children listen to pure tones, warble tones or narrow band signals in the sound field. In fact, the hearing thresholds obtained from these tests only reflect sound detection ability. They do not predict how well a child is able to understand speech in real-life situations. It is known that children with identical audiograms may demonstrate different speech and language abilities.[5] Therefore, speech audiometry should also be included when assessing the hearing performance of children.

There are, however, very few standardized speech tests developed for the Cantonese speaking paediatric population. In the Cantonese Hearing in Noise Test (CHINT)[9], the patient uses binaural hearing to repeat sentences both in a quiet environment and with competing noise using an adaptive presentation method. The CHINT is designed for testing children aged six years and above.

The Cantonese Basic Speech Perception Test (CBSPT)[10] evaluates the speech perception performance for children as young as three years of age. The test domains include sound detection ability, suprasegmental and segmental speech perception. Children respond by identifying pictures corresponding to the presented items in a closed-set format. The CBSPT gives a comprehensive and analytical view of a child's speech recognition at a fundamental level. Ceiling effects, however, may occur for hearing impaired children who have used hearing devices for some time. Additionally, the CBSPT cannot assess a child's speech perception abilities in more difficult test conditions, such as testing in an open-set response format or testing with competing noise.

The Hong Kong Cantonese Tone Identification Test (CanTIT)[11] is a validated assessment tool which measures Cantonese tone perception ability for children as young as three years. It consists of 75 monosyllabic word items. Children respond to each stimulus by identifying the target tone from tone, vowel and consonant distractors which are represented in pictures. The test helps in the identification of specific tonal perception problems. Nonetheless, it takes about an hour to complete the test, or 30 minutes for the 30-item short version. Apparently, it may not be suitable for young children whose attention span is short. It will also be difficult to fit in the tight schedules of busy clinics. Although CanTIT is an excellent tool to illustrate a child's tone perception ability, such performance at monosyllabic word level does not represent one's ability to perceive spoken Cantonese.

The Cantonese Spoken Word Recognition Test (CanSWORT)[12] evaluates the word recognition ability for children aged three years or above. In the construction of CanSWORT, a series of stringent measurements of reliability and validity have been made. Unlike previous speech and language tests developed by use of the psychometric methods of classical test theory, CanSWORT is developed in accordance with item-response theory (IRT). Test items have been constructed within the lexical inventory of young children that remain applicable to the population with a whole spectrum of hearing sensitivity who use various hearing devices. The test consists of four equivalent lists of 20 disyllabic words. A child responds by verbally repeating the test item or expressing it by verbal description, gesture or drawing. CanSWORT allows clinical assessment of speech recognition, relevant to their daily communication needs, for very young children in quiet conditions and has been statistically proven to be valid and reliable. Furthermore, the fact that administration of a test list normally takes less than 10 minutes makes it clinically feasible and valuable.

In spite of these advantages, the difficulty that most children with hearing impairment have when listening in noise has not been addressed by this test. It is a well- known fact that the presence of noise may cause degradation in listening performance. The louder the noise, the more detrimental is the effect on speech perception.[13] In Hong Kong, many classrooms show unacceptably high average noise levels and exhibit insufficient acoustical treatments to provide significant noise reduction.[14] It was reported that the average speech level of teachers in typical classrooms was 60.1 dBA. The level for the most common activity, children sitting and working at their tables with some interactions among them, was 65 dBA in both primary and secondary school classrooms, resulting in a SNR of -5 dB.[15] The situation may be even worse for younger children in nurseries as the ambient noise level measured in occupied nursery rooms was around 75 dBA.[8,16] Therefore, test results obtained in a quiet test environment like CanSWORT may over-estimate the speech perception abilities of children with hearing impairment when compared to their actual performance in everyday listening scenarios.

In order to simulate a real life situation of hearing in noise, an attempt was made to add speech spectrum shaped noise[17] to the CanSWORT material, making CanSWORT in noise a tool of interest for this study. Our aim was to investigate whether the four word lists of CanSWORT 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. The ultimate goal was to determine if CanSWORT in noise was valid for use with our paediatric population and whether it could provide additional information beyond that coming from the traditional hearing tests.

Methods

Participants

Fifty-eight children with significant (moderate grade or worse) hearing impairment (31 males, 27 females), aged three to eight years, were recruited from the Child Assessment Service (CAS) of the Department of Health in Hong Kong. They were formally assessed by paediatricians for developmental disorders and, based on birth, medical and developmental history, they might also have been evaluated by clinical psychologists, speech therapists or other healthcare professionals. The children selected for inclusion in the study had no cognitive, physical or behavioural impairment reported by paediatricians. The participants were all previously diagnosed with sensorineural hearing loss at the CAS. Children were divided into four groups with reference to their degree of hearing impairment. According to Goodman's classification[18], the degree of hearing loss was categorized in 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) grade. In this study, pure tone averages were calculated from the mean of 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 their mean age at 5.29 years (SD = 1.26; range = 3.25 to 7.67 years). All participants were native Cantonese speakers. The participants were users of hearing aid, cochlear implant or auditory brainstem implant.

In addition to the above criteria, these children did not exhibit structural abnormalities of the ear, otologic pathologies, or impacted cerumen as revealed using otoscopy. They also possessed normal middle ear function, with tympanometric peak pressure measured between 100 and -150 daPa and static acoustic admittance between 0.2 and 1.8 ml.[19-20] They had sensorineural hearing impairment with no clinically significant difference (<10 dB) between air and bone conduction thresholds. If the loss was asymmetrical, pure tone average of the better hearing ear would be used to determine the degree of hearing loss of the concerned participants.

Children who met the above inclusion criteria would be assessed using the CanSWORT in noise. Participation in the study was voluntary. Verbal consent would be obtained from parents before an appointment was made on the telephone. They signed a consent form before the start of the test for their children. The project was approved by the Ethics Committee of the Department of Health, Hong Kong Special Administrative Region.

Equipment and speech material

The study was conducted in the Child Assessment Service. It is a service unit under the Department of Health in Hong Kong. It provides developmental assessment for paediatric population. 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. 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 analysers. 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 the four word lists of CanSWORT which were combined to form a list of 80 disyllabic words. The speech signals, presented by a recorded male voice at 65 dBA, were mixed with a Cantonese speech-spectrum shaped noise17 to create five noise conditions, namely SNRs of -8, -5, 0, +5dB and in quiet. The more difficult SNRs of -8 and -5dB were chosen as it was suggested by Keogh20 that classroom noise level might sometimes exceed a teacher's speech level. The range of SNRs for classrooms was approximately from +5 dB to -7 dB.7

The CanSWORT computer software was installed on a laptop computer being connected to a GSI 61 clinical audiometer to present speech material 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. A software program was utilised to ensure automatic randomization of item presentation order.

Procedure

The participants were seen by an audiologist in a sound-treated room at one of the child assessment centres mentioned above. Assessments were carried out following the procedures as described below.

Pure tone audiometry was carried out with air conduction thresholds for 250, 500, 1000, 2000, 4000 and 8000 Hz obtained in both ears using Hughson-Westlake procedures.[21] Bone conduction thresholds for 500, 1000, 2000 and 4000 Hz were established with narrow-band masking noise in the non-test ear when necessary.

Otoscopy and immittance audiometry were performed. Only children with normal middle ear function would proceed to testing with CanSWORT in noise. Those whose tympanometry results fell out of the normal ranges would be scheduled for a review in three months.

Standard verbal instructions would be given and training items presented until the child was familiar with the task. The more difficult test conditions would be presented first to minimise learning effects of the participants. Hence, they listened to the 80 items for five times in the SNR sequence of -8, -5, 0, +5dB and in quiet. After the presentation of each test item, the tester would pause to let the participants respond. They could express what had been heard by simply repeating the words exactly as heard, or by describing the meanings of the words, pointing to an object, using body gestures, drawing, etc. One point would be 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 the five different SNRs were analysed using ANOVA with within-subject factors (LIST and SNR) and between-subject factors (Hearing Status, Age of participants, Gender, Age of amplification, Amplification mode, Education level of participants, Education level of fathers, Education level of mothers).

An inter-list correlation study was done to evaluate the internal consistency of CanSWORT in noise. In addition, an inter-rater reliability test was performed. Two or three participants were randomly selected from each centre, giving a sum of 14 participants for this reliability study. Video recordings of the test sessions had been exchanged for scoring among other testers. Then the test scores would be compared with those obtained from the original testers using intra-class correlation coefficient (ICC) calculation. As content-related and construct-related evidence of validity of the 80-item lists had previously been supported by psychometric analyses,[22] validity study was not performed in this study.

Results

Pearson correlations ranged from 0.855 to 0.984, significant at the 0.01 level (2-tailed) across all conditions for the four lists, suggesting that they had high internal consistency. Moreover, the ICC (2,1) of the 80 items in five conditions was all between 0.931 and 0.999, indicating very high inter-rater reliability. As CanSWORT in noise showed good content validity as well as good reliability, all the test scores obtained in our study were used for data analysis.

The moderate 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 subjects, 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. 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.

Effect of LISTS

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 scores			
Noise conditions/ Lists	**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, $F(3, 148) = 12.36$, $p < 0.05$). However, the effect size was 0.186. According to Cohen[22], 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. They gradually increased from SNR-8 dB to the quiet condition.

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

	Mean test scores				
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

A paired samples test indicated significant differences in each of the groups across SNR with most groups reaching significance of $p < .01$.

Effect of HEARING STATUS

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

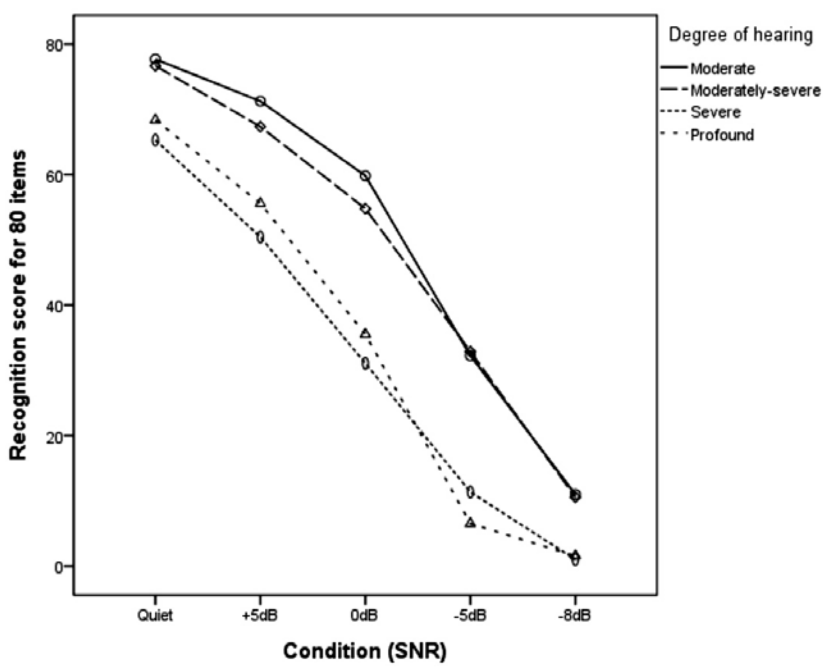


Fig.1. Comparison of mean test scores across the four hearing impaired groups

There was statistically significant difference in mean test scores according to degree of hearing impairment, $F(3, 54) = 7.966$, $p < .05$. Post hoc multiple comparisons revealed that there was a statistically significant difference in test scores between the moderate and severe hearing impaired groups, and between the moderate and profound hearing impaired groups, $p < .002$.

Effect of other variable factors

Other between-subject factors are shown in Table 3.

Between subject factors	Groups	N
Age of participants	36-59 months	29
	60-83 months	18
	84 months or above	9
Age of amplification	0-6 months	19
	7-12 months	7
	13 months or above	30
Amplification mode	hearing aids	37
	cochlear implants	19
Education level of participants	K1- K3	44
	Primary 1 - Primary 3	12
Education level of mothers	below upper secondary	8
	upper secondary or above	48
Education level of fathers	below upper secondary	10
	upper secondary or above	46

Table 3. Details of between-subject variables

A summary of main effects is illustrated in Table 4.

Source	df	F	*p*	Partial Eta Squared
Between subject factors				
Age	2	3.013	0.059	0.116
Gender	1	0.031	0.862	0.001
Age of amplification	2	0.374	0.690	0.016
Amplification mode	1	3.727	0.060	0.075
Education level of participants	1	0.308	0.582	0.007
Education level of mothers	1	0.032	0.860	0.001
Education level of fathers	1	2.884	0.096	0.059

Table 4. ANOVA to examine the influence of the various factors on test scores

Our findings revealed that none of the above factors had significant effects on the test scores ($p > 0.05$). To sum up, only SNR and HEARING STATUS had an impact on the test scores.

Repeated measures were performed with two within-subject factors (SNR and LIST), and one between-subject factor (HEARING STATUS). A summary of the main effects and interactions of the factors is displayed in Table 5.

Table 5. Main effects and interaction effects in the repeated measures to examine the influence of the variable factors on CanSWORT scores

Source	df_1	df_2	F	*p*	Partial Eta Squared
Within subject factors					
LIST	3	148	12.36	0.000***	0.186
LIST * HEARING STATUS	8	148	2.06	0.042*	0.103
SNR	2	121	362.75	0.000***	0.870
SNR * HEARING STATUS	7	121	2.65	0.015*	0.128
LIST * SNR	9	491	2.02	0.034*	0.036
LIST* SNR * HEARING STATUS	27	491	1.67	0.019*	0.085
Between-subject					
HEARING STATUS	3	54	7.966	0.000***	0.307

Note: n= 58
* $p<0.05$; ** $p<0.01$; *** $p<0.001$

The results showed that there was a significant interaction effect, $F(7,121) = 2.65$, $p = 0.015$, for SNR * HEARING STATUS.

Relationship between audiometric thresholds and test scores

A Pearson product-moment correlation coefficient was used to investigate the relationship between pure tone thresholds of aided and unaided conditions and the speech perception scores under different noise conditions.

Test results are illustrated in Fig. 2a, 2b and Table 6.

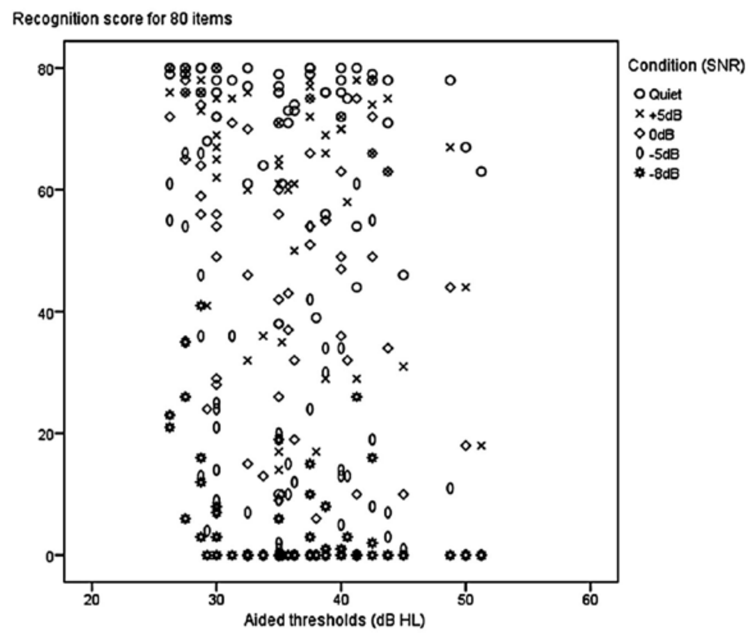


Fig. 2a. Relationship between aided thresholds and test scores

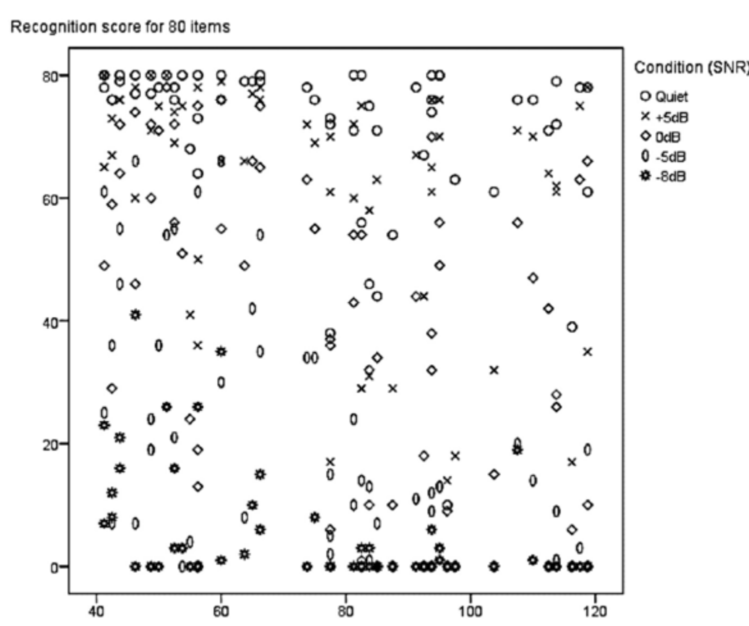


Fig. 2b. Relationship between unaided thresholds and test scores

Table 6. Relationship between pure tone thresholds and CanSWORT 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 in noise scores, suggesting better hearing thresholds, aided or unaided, were associated with higher CanSWORT in noise scores. However, the strength of correlation was weak, meaning that there was minimal relationship between them.

Discussion

Our findings has indicated that CanSWORT 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. The statistically significant group effect on test performance is consistent with findings of previous studies that show poorer speech understanding in children with more severe hearing loss.[5,23] An interesting finding of the present study is that a significant difference of mean scores was noted only between the moderate and severe groups, and between the moderate and profound groups. In other words, the performance of the moderately severe group was not statistically different compared to the moderate group, and similarly for the profound to severe group comparison. One of the important implications of this result may be that given appropriate amplification, children with moderately severe hearing impairment can achieve test scores comparable to those of children with moderate hearing impairment. However, for children with severe to profound hearing loss, no matter what kind of amplification device was used, performance remained significantly poorer than that of the moderate group.

The significant effect of SNR suggests that children with hearing loss using amplification benefit from an increase in SNR. According to the recommendations of the American Speech-Language-Hearing Association[24] and the British Association of Teachers of the Deaf[25], the noise levels in unoccupied classrooms should be 35 dBA or less and SNR should be +15 dBA or higher in occupied classrooms. The options of acoustic treatment, including use of double-glazing window or solid concrete barriers, help to reduce the incoming noise.[26] 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[5] that speech perception of Cantonese speaking children with hearing impairment cannot be predicted from their pure tone hearing thresholds. Heinrich et al.[27] explain 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 performance. Our test results further confirm that speech audiometry should be included as part of the test battery in order to provide more comprehensive audiological information for a child.

Clinical applications

CanSWORT 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 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 to minimise learning effect was made by letting the participants listen to the more difficult condition first, i.e. in the order of SNR -8dB, -5 dB, 0 dB, +5 dB and quiet, a learning effect for the test items could not be completely ruled out.

Furthermore, the test has 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 400 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 convenience 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 generalization of the speech test profiles to the entire paediatric population with significant hearing loss.

Because of the above factors, 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, reflect the word perception ability of the four hearing impaired groups. Nonetheless, the reference 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 not 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 as it involves grasping the ideas and facts presented in the connected discourse.[28] 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 essential that as a child with hearing impairment grows older, his/her speech understanding ability is further evaluated with other speech tests.

Future directions

It is important to further develop CanSWORT in noise applications with more reference 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 accomplished.

It is known that the combination of noise and reverberation may interfere with a child's acoustic-phonetic (bottom-up) processing and thus weakening their performance in word recognition.[4,7,29-31] In light of the reverberation factor, since its detrimental effect on speech recognition has not been depicted in our study, our CanSWORT in noise scores may still have over-estimated a child's word recognition ability. Future studies should bring more insights into a child's speech understanding across various acoustic environments e.g. noise-plus-reverberation, where real-world situations can be better simulated.

It is claimed that the evaluation of the ability to understand connected discourse has the highest face validity in predicting a child's ability to understand conversational speech[23] because it provides a true representation of the speech encountered in everyday life.[5,32] The University of Queensland Understanding Everyday Speech Test (UQUEST)[28] includes passages based on real-life situations that are familiar to school children. The test has been found to be sensitive to hearing deficits in children and adults.[20,33] A similar test, designed for Cantonese speaking children, would be a valuable tool for assessing older children.

Conclusion

With CanSWORT in noise, we can provide parents with clinical evidence of how their children respond to speech in noise. On counselling parents, emphasis should be put on improving the SNRs so that speech recognition can be better facilitated.

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 3 years of age.

Acknowledgements

We would like to thank Dr. Kathy Lee and her team from the Chinese University of Hong Kong and Dr. Bradley McPherson from the University of Hong Kong for their sincere help in data analyses and valuable comments on the study. We would also thank Dr. Iris Ng who has generously shared her experience of constructing CanSWORT and answered many of our queries. Special thanks also go to Mr. Gu Feng who has spent his valuable time on generating test material with noise for our use in this research project.

References

1. Roeser RJ, Downs MP. Auditory disorders in school children: the law, identification, remediation. 4th ed. New York: Thieme; 2004.
2. Festen JM, Plomp R. Effects of fluctuating noise and interfering speech on the speech-reception threshold for impaired and normal hearing. J Acoustic Soc Am. 1990;88:1725-1736.
3. Leek MR, Molis MR. Beyond Audibility: hearing loss and the perception of speech. The ASHA Leader. 2009;Nov 1. Available from: https://leader.pubs.asha.org/doi/10.1044/leader.FTR5.14142009.14
4. Finitzo-Hieber T,Tillman TW. Room acoustics effects on monosyllabic word discrimination ability for normal and hearing-impaired children. J Speech Hear Res. 1978;21:440-458.
5. Kei J, Smyth V. Measuring the ability of hearing impaired school-aged children to understand connected discourse using an intelligibility self-rating procedure. Australia Journal of Audiology. 1996;18:23-33.
6. Crandell CC, Smaldino JJ, Flexer, C. Speech perception in specific populations. In: Crandell C, Smaldino JJ, Flexer C, editors. Soundfield FM amplification: theory and practical applications. San Diego: Singular; 1995.
7. Crandell C, Smaldino J. Classroom acoustics for children with normal hearing and with hearing impairment. Language, Speech & hearing Services in schools. 2000;31:362-370.
8. Shield BM, Dockrell JE. The effects of noise on children at school. J. Building Acoustics. 2003;10(2):97-106.
9. Wong LL, Soli SD. Development of the Cantonese hearing in noise test (CHINT). Ear and Hearing. 2005;26(3):276-289.
10. Lee KYS. The Cantonese Basic Speech Perception Test (CBSPT). Hong Kong: Department of Surgery, the Chinese University of Hong Kong; 2006.
11. Lee KYS. Hong Kong Cantonese Tone Identification Test. Hong Kong: Division of Speech therapy, Department of Otorhinolaryngology, Head & Neck Surgery, The Chinese University of Hong Kong; 2012.
12. Ng IHY, Lee KYS, Lam JH, van Hasselt CA, Tong MC. An application item response theory and the Rasch model in speech recognition test materials. Am J Audiol. 2016;Jun 1;25(2):142-52.
13. Yang HM, Hsieh, YJ, Liang SJ. Speech recognition performance under noisy conditions of children with hearing loss. Clinical and Experimental Otorhinolaryngology. 2012;April 5(1):S73-S75.
14. Choi C, McPherson B. Noise levels in Hong Kong primary schools: implications for classroom listening. International Journal of Disability, Development and Education. 2005;52(4):345-360.
15. Picard M, Bradley JS. Revisiting speech interference in classrooms. Audiology. 2001;40:221-224.
16. Moodley A. Acoustic conditions in mainstream classrooms. Journal of British Association of Teachers of the Deaf. 1989;13(2):48-54.
17. Wong LLN, Ng EHN, Soli SD. Characterization of speech understanding in various types of noise. Journal of the Acoustical Society of America. 2012;132 (4):2642-2651.
18. Goodman, A. Reference zero levels for pure tone audiometers. ASHA. 1965;7:262-263.
19. Kei J, Hourigan A, Moore, K, Keogh, T, Driscoll, C. Tympanometric findings in children at school entry: a normative study. Australian and New Zealand Journal of Audiology. 2005;27(2):89-96.
20. Keogh T, Kei J, Driscoll C et al. Measuring the ability of school children with a history of otitis media to understand everyday speech. J Am Acad Audiol. 2005;16:303-313.

21. Carhart R, Jerger JF. Preferred method for clinical determination of pure-tone thresholds. J Speech Hear Disord. 1959;24:330-345.
22. Cohen, J. Statistical power analysis for the behavioural sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers; 1988.
23. Kei J, Murdoch B, Smyth V, McPherson B. Predicting the understanding of Cantonese connected discourse. Asia Pacific Journal of Speech, Language and Hearing. 1997;2:203-226.
24. American Speech-Language-Hearing Association. Position statement and guidelines for acoustics in educational settings. ASHA. 1995;37(Suppl.14):15-19.
25. British Association of Teachers of the Deaf. Classroom acoustics: recommended standards. BATOD Magazine. 2001;January. Available from: https://www.batod.org.uk/wp-content/uploads/2018/08/acoustic-standards.pdf
26. Chan, K, Li, C, Ma, E, Yiu, E, McPherson, B. Noise levels in an urban Asian school environment. Noise & Health; Mumbai. 2015;Jan-Feb:48-55.
27. Heinrich A, Henshaw H, Ferguson MA. The relationship of speech intelligibility with hearing sensitivity, cognition, and perceived hearing difficulties varies for different speech perception tests. Frontiers in Psychology. 2015;6:782.
28. Kei J, Smyth V, Burge E et al. Measuring the ability of children to understand everyday speech using computer technology: a normative study. Asia Pacific Journal of Speech, Language and Hearing. 2003;8:235-242.
29. Neuman, AC, Wróblewski, M, Hajicek, J, Rubinstein, A. Combined effects of noise and reverberation on speech recognition performance of normal-hearing children and adults. Ear and Hearing. 2010;31:336-344.
30. Wróblewski, M, Lewis, DE, Valente, DL, Stelmachowicz, PG. Effects of reverberation on speech recognition in stationary and modulated noise by school-aged children and young adults. Ear and Hearing. 2012;33:731-744.
31. Yang N, Bradley JS. Effects of room acoustics on the intelligibility of speech in classrooms for young children. The Journal of the Acoustical of America. 2009;125(2):922-933.
32. Giolas TG, Epstein A. Comparative intelligibility of word lists and continuous discourse. Journal of Speech and Hearing Research. 1963;6:349-358.
33. Keogh T, Kei J, Driscoll C, Khan A. Children with minimal conductive hearing impairment: speech comprehension in noise. Audiol Neurotol. 2010;15:27-35.

Paediatric Bimodal Fitting: The Queen Elizabeth Hospital Experience

Zoe YT CHAN, Vanessa SW CHAN, Dr Tsun Cheong CHU

Ear, Nose and Throat Department, Queen Elizabeth Hospital

Introduction

Paediatric Bimodal Fitting refers to paediatric patients (under 18 years old) using cochlear implant (CI) in one ear and hearing aid in the contralateral ear. In 2019, Education Bureau (EDB) commissioned designated Hospital Authority Cochlear Implant Centres (Prince of Wales Hospital, Queen Elizabeth Hospital and Queen Mary Hospital) to provide one-stop audiological management to paediatric bimodal users, and through-train audiological services to potential CI candidates. In Queen Elizabeth Hospital, one-stop audiological services are provided to paediatric bimodal users to ensure their hearing aids are optimally fitted with their cochlear implants, and will be discussed in this article.

Benefits of Bimodal Fitting

Unilateral CI users may find difficulties in sound localization and speech recognition in noisy environments. Bimodal fitting may provide binaural advantages to these patients. Numerous studies have shown that bimodal fitting result in better speech recognition in both quiet and noisy environments and better sound localization than using CI alone if there is residual hearing in the contralateral ear.[1-4] Additionally, patients with bimodal fitting reported better music appreciation and pitch perception, and better sound quality than using CI alone.[5-6] Hearing aids provide additional low frequency acoustic cues to bimodal users, which improve both musical and voice pitch perception.[5] Hearing aid works in synergy with CI to provide complementary information, thus enhancing and enriching hearing experience.

One-Stop Audiological Management of Paediatric Bimodal Cases

The following assessments and procedures are performed when paediatric CI users have hearing aid fitting in the contralateral ear:

1. Hearing Assessment

True hearing sensitivity across the frequency range must be obtained to provide appropriate gain for optimal hearing aid fitting. Assessing hearing sensitivity for young children is challenging; age and developmental appropriate tests (Distraction Test, Visual Reinforcement Audiometry, Play Audiometry, Pure Tone Audiometry) are selected accordingly, of which the ultimate goal is to obtain reliable behavioural responses to sound stimuli.

2. Tympanometry

Tympanometry is an objective test to assess the middle ear condition, which can help cross check the nature of hearing loss. Since otitis media is common among children, it is recommended to perform tympanometry in the paediatric population.

3. 3D Printing of Custom Ear Mould

Custom ear moulds must be made before hearing aids can be properly fitted. In Queen Elizabeth Hospital, ear moulds are produced with 3D printing technology. The ear impression is scanned (Figure 1) and transformed into stereolithography (STL) file, a file format compatible with 3D design software. The STL file is then modelled with Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) software (Figure 2) before it is sent to the 3D Printer for printing (Figure 3). Cleaning and finishing touches are made to the printed products before the final ear mould issue (Figure 4). 3D printing technology provides greater accuracy and efficiency in ear mould production, and this is especially advantageous in the paediatric population, where inaccurate ear mould fitting could affect hearing aid performance, and regular ear mould remake is necessary for the growing child.

Figure 1. Scanning of ear impression

Figure 2. Modelling of STL file using CAD/CAM software

Figure 3. 3D printing of ear moulds

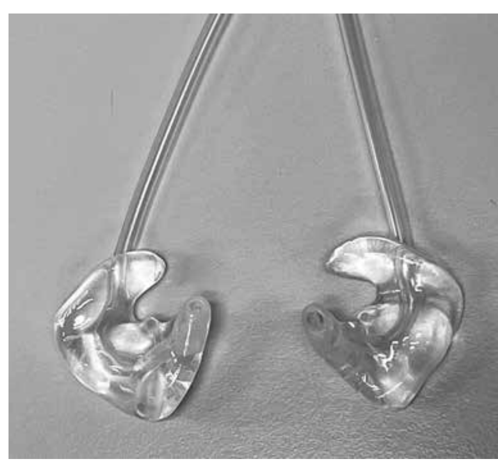


Figure 4. Paediatric ear moulds made by 3D printing

4. Hearing Aid Verification

The hearing aid will be initially tuned according to hearing levels across the frequency range. However, ear acoustic parameters vary among individuals, the sound pressure level (SPL) of the amplified signal measured at the ear canal near the eardrum will be different even for patients with similar hearing configurations. Real ear measurement (REM) is done to take this difference into account during hearing aid verification. Firstly, Real-ear-to-coupler-difference (RECD) is obtained by placing a probe tube into the ear canal to measure the actual SPL reaching the eardrum, thus noting the SPL difference between the actual measurement obtained within the ear canal and the measurement obtained via the 2cc coupler in hearing aid specifications. Secondly, the output of the hearing aid is fine-tuned and verified to ensure appropriate amplification via the Speech Mapping method. Speech Mapping can be performed on-ear (via placing probe tube into ear canal for measurement) or in the test box of the REM equipment. This method takes the ear acoustics (such as ear canal volume and ear canal resonance) into account during hearing aid fitting. Speech signals are used as stimuli, and the different intensity of speech signals can be used to meet the prescriptive targets (Figure 5). Instead of traditional pure tone or steady noise signals, speech signals are used to simulate real life situations more effectively.

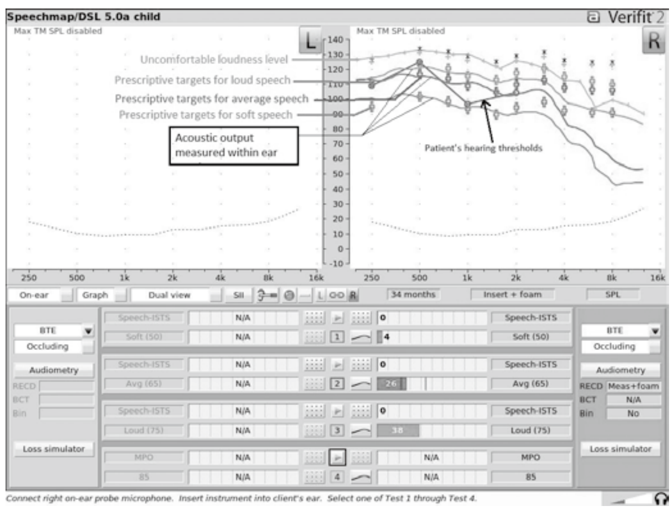


Figure 5. On-ear Speech Mapping: Fitting speech signals to prescriptive targets.
The hearing aid should be adjusted such that the green, purple and blue curves should meet the colour coded prescriptive targets of soft, average and loud speech levels respectively. The yellow curve should be below the uncomfortable loudness levels.

5. Hearing Aid Validation

Once the hearing aid fitting is verified, it must then be validated to ensure sufficient amplification is provided. Hearing aid fitting can be validated using the following methods: **Sound-field Aided Test** evaluates the aided performance of the hearing aid through obtaining behavioural responses to the softest frequency-modulated tones presented through a speaker in the free field (Figure 6).

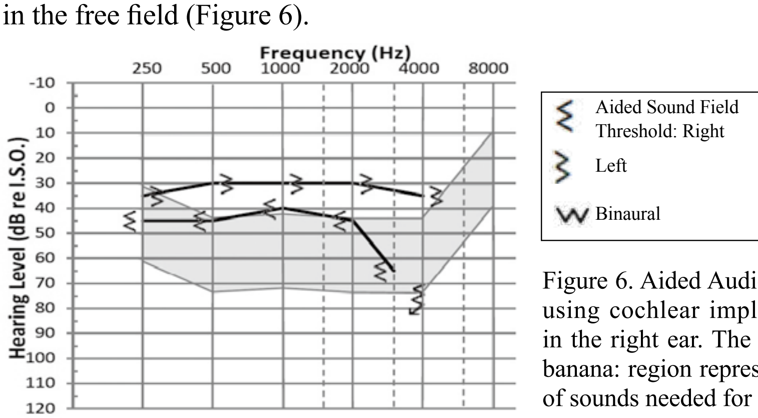
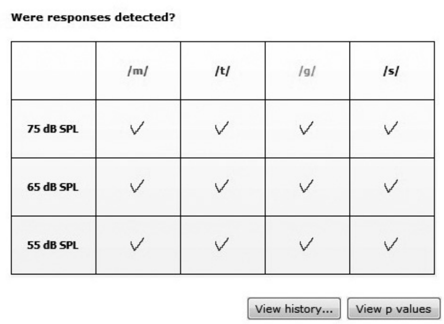


Figure 6. Aided Audiogram showing aided thresholds using cochlear implant in the left and hearing aid in the right ear. The shaded area denotes the speech banana: region representing frequencies and loudness of sounds needed for speech understanding.

Aided Cortical Auditory Evoked Potentials Assessment (ACA) is an electrophysiological test that evaluates the aided performance when reliable behavioural responses cannot be obtained. Speech stimuli (/m/, /g/, /t/, /s/) presented at 55, 65, 75 dB SPL are used to evoke cortical responses in the auditory cortex. ACA determines whether speech stimuli are detected at the cortical level (Figure 7). Hearing aids and cochlear implants may both be validated using the above methods.[7]



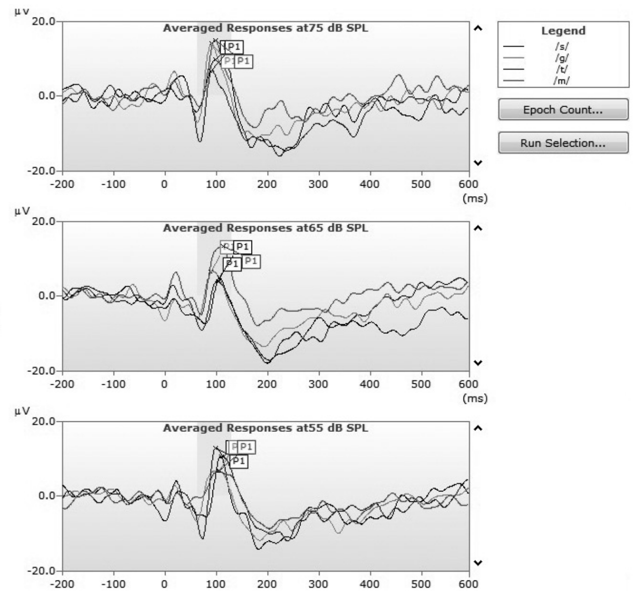


Figure 7. Aided Cortical Assessment showing responses obtained at 75, 65 and 55 dB SPL for stimuli /m/, /g/, /t/, /s/

Digitized versions of Paediatric Speech Perception Tests will be included in the near future as an additional validation tool for hearing aid and cochlear implant, as speech recognition ability is the ultimate outcome measure for all hearing device users.

6. Regular Review

There is not a single bimodal fitting approach that is universally accepted.[8] As the child grows, the ear canal volume will increase and the ear acoustic will change. Regular ear mould remake and review to fine tune the hearing aid is necessary. Further CI adjustment may also be necessary upon the bimodal child's speech and language developmental progress, according to their own or their care givers' feedbacks.

Conclusion

In Queen Elizabeth Hospital, one-stop audiological service manages hearing aid and cochlear implant fitting for paediatric bimodal users. Aided performances of CI and hearing aid are monitored regularly as well as speech and language development progress; CI and hearing aid adjustments are verified and validated, with ear mould remakes at regular intervals. Eventually, CI on the contralateral ear will be suggested if benefit of the hearing aid is limited. Queen Elizabeth Hospital Cochlear Implant Centre is devoted to providing through-train audiology service to newborns/infants diagnosed with bilateral severe to profound hearing loss. Once diagnosed, hearing aids are fitted promptly and we become their life partner on this long journey of rehabilitation. Whether they continue to use hearing aids, become unilateral CI users, bimodal users or eventually bilateral CI users, we ensure the best hearing experience for these children and let their true colour shine.

Reference

1. Ching, T. Y., Psarros, C., Hill, M., Dillon, H., & Incerti, P. (2001). Should children who use cochlear implants wear hearing aids in the opposite ear?. *Ear and hearing, 22*(5), 365-380.
2. Ching, T. Y., Incerti, P., Hill, M., & Van Wanrooy, E. (2006). An overview of binaural advantages for children and adults who use binaural/bimodal hearing devices. *Audiology and Neurotology, 11*(Suppl. 1), 6-11.
3. Dunn, C. C., Tyler, R. S., & Witt, S. A. (2005). Benefit of wearing a hearing aid on the unimplanted ear in adult users of a cochlear implant. Journal of Speech, Language, and Hearing Research.
4. Vroegop, J. L., Dingemanse, J. G., van der Schroeff, M. P., & Goedegebure, A. (2019). Comparing the effect of different hearing aid fitting methods in bimodal cochlear implant users. American Journal of Audiology, 28(1), 1-10.
5. Kong, Y. Y., Stickney, G. S., & Zeng, F. G. (2005). Speech and melody recognition in binaurally combined acoustic and electric hearing. *The Journal of the Acoustical Society of America, 117*(3), 1351-1361.
6. Sucher, C. M., & McDermott, H. J. (2009). Bimodal stimulation: benefits for music perception and sound quality. *Cochlear Implants International, 10*(S1), 96-99.
7. Choi, S. M., Wong, E. C., & McPherson, B. (2019). Aided cortical auditory evoked measures with cochlear implantees: the challenge of stimulus artefacts. Hearing, *Balance and Communication, 17*(3), 229-238.
8. Vroegop, J. L., Goedegebure, A., & van der Schroeff, M. P. (2018). How to optimally fit a hearing aid for bimodal cochlear implant users: *A systematic review. Ear and hearing, 39*(6), 1039-1045.

The Psychological Impact of Hearing Impairment: From Childhood to Adulthood

Kelly WY LAU
Child Assessment Service, Department of Health, Hong Kong

Hearing impairment (HI) refers to the reduced ability to perceive sounds that ranges from mild, moderate, moderate-severe, severe to profound, and it affects around 1-3 per 1000 infants at birth.[1] While deaf or hard-of-hearing (DHH) children are at risk of problems in language and communication that can have cascading impacts on their psychosocial development, studies have shown that their developmental outcomes vary considerably.[2] According to the bioecological model, it is not merely the hearing impairment per se, but the interplay between child characteristics and environmental contexts, that shapes a child's development.[4] Furthermore, individuals face unique tasks and challenges at each developmental stage in life.[5,6] As such, this paper explores the psychological impacts of hearing impairment with respect to risk and protective factors at different developmental stages.

Infancy and toddlerhood

The first few years of a child's life is a critical time for forming attachment.[7] This early bonding provides an interactional context in which a child acquires language, social knowledge, sense of self, and self-regulatory abilities.[8,9] Hence, sensitive and reciprocal parent-child interaction in early years is essential for secure attachment and growth, whereas disruption of such can negatively affect attachment quality and subsequent linguistic, cognitive, and socio-emotional otcomes.[10,11]

Approximately 90–95% of DHH children are born to hearing parents, who do not expect a DHH child and have limited understanding of HI.[12] Parents' reaction to the diagnosis is often grief and shock.[13] The mismatch between parent's and child's communication modalities puts DHH children at risk of early interactional difficulties and delayed development.[11] Infants miss out verbal cues from hearing parents, reciprocate fewer communicative attempts, and have reduced access to language and socio-emotional learning.[14,15] Hearing parents often have limited means to communicate and are under high stress.[16,17] They may sometimes resort to overprotective, or intrusive parenting strategies that inadvertently compromise their child's psychosocial development.[18,19] By contrast, deaf parents with competence to communicate via non-vocal modalities, are more able to facilitate their child's attachment and development.[20,21] They provide early and shared access to language by signing[22], and foster better coping and independence more readily, which result in more favourable socio-emotional development.[23,24]

Given most deaf children are born to hearing parents, early access to support and services is crucial to enhance parents' coping skills and prevent the cascading impacts of language deprivation on children's development.[25] Typically, early family-based intervention improves parent-child interactions by increasing parental responsiveness and incorporating the use of total communication strategies.[26] The latter employs a full range of spoken and/or visual modalities to facilitate children's comprehension and expression of language.[27] These early interventions have been shown effective in improving interaction quality and enhancing children's language outcomes.[28,29]

In addition, with the advent of universal newborn hearing screening, diagnosis of HI can be made as early as the first month of life.[30] Increasing research suggested that infants receiving cochlear implants (CI) before 12 months of age frequently catch up with their typically developing peers.[31,32] As such, early detection, coupled with early fitting of hearing devices, represents another path to enhance language and functional performance outcomes of DHH children during this critical period.[33,34]

Childhood

With the start of schooling, academic abilities and peer relationships assume greater importance for the development of self-concept and sense of competence during childhood.[5] In general, DHH children with additional disabilities, lower intelligence, older age of implantation of CI, and more severe language delays, are more likely to be disadvantaged in academic and psychosocial development.[35-37]

DHH children are prone to early auditory deprivation and reduced exposure to language, putting them at greater risk of language delays.[38,39] As language competence is often associated with learning, social interaction and abstract thinking, early language deficits can have wide-ranging impacts in various domains.[40,41] Academically, DHH children are often weak in vocabulary, grammar, sentence structures, and phonological processing[42], leaving them vulnerable to difficulties in reading and comprehension and thus academic underachievement.[43] DHH children may also miss out opportunities for incidental learning due to difficulties in communication or perceiving conversations in noisy environment, thus limiting their acquisition of social knowledge or pragmatic language skills.[14,44] Socially, DHH children often encounter difficulties in developing peer relationships due to language barriers and potential stigma.[45] As a result, they experience greater feelings of social isolation, especially when they are the only deaf student in the mainstream classroom.[46] As such, these psychosocial difficulties, combined with academic challenges, may contribute to low self-esteem and subsequent risks for developing emotional and behavioural difficulties.[43,47,48]

Support from educational settings, parents and peers helps to alleviate DHH children's difficulties in learning and psychosocial adjustment.[23] Early literacy intervention can offset risks of accumulating academic disparities between DHH and typically developing students.[49] Moreover, explicit teaching of emotional literacy and social skills, encouraging expressions regarding thoughts and feelings and increasing opportunities to practise problem-solving skills by parents or teachers help strengthen DHH children's communication and socio-emotional capacities.[25] Optimism and positive feedback from significant others contribute to these children's learning motivation and aspirations for themselves.[50] Having an accepting and non-victimizing peer group is also beneficial for socio-emotional development of DHH children in facilitating their social learning and interpersonal skills.[51,52]

While findings comparing outcomes of special and mainstream education are inconclusive, a better understanding of the special needs of HI, an inclusive and accepting environment, and the promotion of positive interaction are active ingredients contributing to students' psychosocial well-being regardless of educational settings.[23,53,54] Co-enrollment programs, characterized by a balanced intake of DHH and hearing students and co-teaching, co-learning practices in the context of bilingualism (sign and oral language), is seen as a promising 'third way' practice that draws upon the academic benefits of mainstream school and social benefits of special education.[55] Appropriate choice of educational settings should take into consideration of individual factors such as severity of HI, speech intelligibility, adaptive functioning, and learning abilities.[56]

Adolescence

As a transition from childhood to adulthood, adolescence is a critical period for forming identity and developing a sense of direction in life.[5] It is also a time with great importance attached to intimate relationships, conformity to peer groups, and sensitivity about one's place in relation to a wider social environment.[57] As such, adolescence may be a particularly difficult period for DHH individuals who struggle with increased feelings of self-consciousness of their HI status.[58] DHH adolescents may feel different from the majority because of their observable hearing aids, use of sign language, or distinct intonations of their speech.[59] Some adolescents, particularly those studying in mainstream settings or born to hearing families, struggle to fit in the hearing world.[60] They may end up with marginalized identities and a confused attitude toward their HI status, worrying over their future place in the world.[58,61] This sense of social alienation is detrimental to their self-esteem and mental health.[62]

Numerous studies on acculturation styles have highlighted the protective role of having a bicultural or deaf identity, both of which share a positive acceptance of hearing loss).[63,64] Specifically, bicultural identity contributes to good psychosocial adjustment through the dexterity in navigating both deaf and hearing world[63] whereas deaf identity contributes to well-being through a sense of belonging to Deaf community and a positive attitude toward deafness and Deaf culture.[64] Research suggested the choice of language, school placement, and relationships with deaf or hearing peers are important factors contributing to identity development of DHH adolescents.[65] Particularly, contact with DHH peers or positive role models in Deaf community is beneficial for developing a positive identity and socio-emotional well-being.[66] In addition, close social networks of family and friends are also conducive to adolescents' sense of being part of the larger social circle and positive self-concept.[67] The availability of social networking sites enables adolescents to engage in social interactions online where HI is not identified and poses little barrier to communication.[68] These social capitals are valuable in helping DHH adolescents to buffer stress and establish positive identity.

Adulthood

As individuals enter adulthood, they face the developmental task of moving toward an independent life and establishing autonomy.[69] Many seek to gain financial freedom, obtain employment, develop intimate relationships, and have families of their own.[70] However, ‘transition shock’ often arises at the beginning of adulthood when DHH people leave the supportive school environments and enter the adult hearing world.[71] Language competence and social environment are major factors affecting their psychosocial adjustment.[4] Poor language skills put them at a disadvantage in the labour market and compromise their quality of life.[4,72] Social discrimination is also commonly seen, particularly those who use only sign language.[73] DHH people are thus at risk for various suboptimal outcomes, including educational achievement[74], employment opportunities[75], working conditions[76], health literacy[77] and mental health[4]. They are also more vulnerable to intimate partner violence and other abusive experiences.[78] All these experiences may undercut their overall sense of control and satisfaction in life.

While DHH individuals typically face more challenges to adapt to adulthood, various factors and sources of support prove to be protective of their well-being.[70] Personal resources, such as life optimism, coping skills and self-efficacy, helps to alleviate stress and problem-solve ongoing challenges in life.[64,79] Moreover, positive relations with family and friends continue to be another source of resilience, offering individuals a sense of relatedness and essential access to social resources in face of challenges. In particular, involvement in a Deaf community gives them a shared identity and enables them to make meaning from their common experiences, fostering a better sense of purpose and direction in life.[50] Advocacy and community participation are also empowering factors. As DHH individuals take an active role to negotiate for appropriate accommodations to their needs, self-determination and environmental mastery are fostered.[80]

Conclusion

While hearing impairment is developmentally linked with greater likelihood of a range of suboptimal outcomes, research suggested that it is the familial, social, and institutional contexts in which HI is perceived and handled that subsequently determine the psychosocial outcomes of DHH individuals.[81] The fact that many DHH people are mentally healthy and live fulfilling lives, highlights the importance of factors that promote their resilience and adaptation.[82] Throughout different stages, family, teachers or peers adjust to the needs, communicate warmth and care, and foster communication with DHH individuals, help promote better psychosocial adjustment).[67] Despite these promising findings, social and institutional discrimination are continually in place, limiting their developmental potential. As such, it is vital that more future efforts be dedicated on how to better promote resilience-building of DHH individuals.

References

1. Seifert E, Brosch S, Dinnesen AG, Keilmann A, Neuschaefer-Rube C, Goldschmidt O, et al. [Peripheral hearing disorders in childhood. Results of an evidenced based consensus conference]. HNO. 2005 Apr;53(4):376–82.
2. Kral A, O’Donoghue GM. Profound deafness in childhood. N Engl J Med. 2010 Oct 7;363(15):1438–50.
3. Bronfenbrenner U. Environments in developmental perspective: Theoretical and operational models. In: Friedman SL, Wachs TD, editors. Measuring environment across the life span: Emerging methods and concepts [Internet]. Washington: American Psychological Association; 1999 [cited 2022 Mar 29]. p. 3–28. Available from: http://content.apa.org/books/10317-001
4. Fellinger J, Holzinger D, Pollard R. Mental health of deaf people. Lancet. 2012 Mar 17;379(9820):1037–44.
5. Erikson EH. [Growth and crises of the healthy personality]. Psyche (Stuttg). 1953 Apr;7(1):1–31.

6. Piaget J. Piaget's Theory. In: Inhelder B, Chipman HH, Zwingmann C, editors. Piaget and His School [Internet]. Berlin, Heidelberg: Springer Berlin Heidelberg; 1976 [cited 2022 Mar 29]. p. 11–23. Available from: http://link.springer.com/10.1007/978-3-642-46323-5_2
7. Bowlby J. Attachment and loss. 1: Attachment. 2. ed. New York: Basic Books; 2003. 425 p.
8. Chapman RS. Children's language learning: an interactionist perspective. J Child Psychol Psychiatry. 2000 Jan;41(1):33–54.
9. Kochanska G, Coy KC, Murray KT. The development of self-regulation in the first four years of life. Child Dev. 2001 Aug;72(4):1091–111.
10. Holmes J. Attachment theory: a biological basis for psychotherapy? Br J Psychiatry. 1993 Oct;163:430–8.
11. Morgan G, Curtin M, Botting N. The interplay between early social interaction, language and executive function development in deaf and hearing infants. Infant Behav Dev. 2021 Aug;64:101591.
12. Albertini JA. Deafness and Hearing Loss. In: Weiner IB, Craighead WE, editors. The Corsini Encyclopedia of Psychology [Internet]. Hoboken, NJ, USA: John Wiley & Sons, Inc.; 2010 [cited 2022 Mar 29]. p. corpsy0251. Available from: https://onlinelibrary.wiley.com/doi/10.1002/9780470479216.corpsy0251
13. Gilbey P. Qualitative analysis of parents' experience with receiving the news of the detection of their child's hearing loss. Int J Pediatr Otorhinolaryngol. 2010 Mar;74(3):265–70.
14. Calderon R, Greenberg MT. Social and Emotional Development of Deaf Children: Family, School, and Program Effects [Internet]. Oxford University Press; 2011 [cited 2022 Mar 29]. Available from: http://oxfordhandbooks.com/view/10.1093/oxfordhb/9780199750986.001.0001/oxfordhb-9780199750986-e-013
15. Kelly C, Morgan G, Bannard C, Matthews D. Early Pragmatics in Deaf and Hard of Hearing Infants. Pediatrics. 2020 Nov;146(Suppl 3):S262–9.
16. Lederberg AR, Schick B, Spencer PE. Language and literacy development of deaf and hard-of-hearing children: successes and challenges. Dev Psychol. 2013 Jan;49(1):15–30.
17. Hintermair M. Parental resources, parental stress, and socioemotional development of deaf and hard of hearing children. J Deaf Stud Deaf Educ. 2006;11(4):493–513.
18. Meadow-Orlans KP, Spencer PE, Koester LS. The World of Deaf Infants [Internet]. Oxford University Press; 2004 [cited 2022 Mar 31]. Available from: http://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780195147902.001.0001/acprof-9780195147902
19. Fagan MK, Bergeson TR, Morris KJ. Synchrony, complexity and directiveness in mothers' interactions with infants pre- and post-cochlear implantation. Infant Behav Dev. 2014 Aug;37(3):249–57.
20. Koester LS, McCray N. Deaf Parents as Sources of Positive Development and Resilience for Deaf Infants. In: Zand DH, Pierce KJ, editors. Resilience in Deaf Children [Internet]. New York, NY: Springer New York; 2011 [cited 2022 Mar 29]. p. 65–86. Available from: http://link.springer.com/10.1007/978-1-4419-7796-0_3
21. Traci M, Koester LS. Parent–Infant Interactions: A Transactional Approach to Understanding the Development of Deaf Infants [Internet]. Oxford University Press; 2011 [cited 2022 Mar 29]. Available from: http://oxfordhandbooks.com/view/10.1093/oxfordhb/9780199750986.001.0001/oxfordhb-9780199750986-e-014
22. Humphries T, Kushalnagar P, Mathur G, Napoli DJ, Padden C, Rathmann C, et al. Language acquisition for deaf children: Reducing the harms of zero tolerance to the use of alternative approaches. Harm Reduct J. 2012 Apr 2;9:16.
23. Polat F. Factors Affecting Psychosocial Adjustment of Deaf Students. J Deaf Stud Deaf Educ. 2003;8(3):325–39.
24. Harris M. Early Communication in Sign and Speech [Internet]. Oxford University Press; 2010 [cited 2022 Mar 29]. Available from: http://oxfordhandbooks.com/view/10.1093/oxfordhb/9780195390032.001.0001/oxfordhb-9780195390032-e-021
25. Mental Health in Deaf Children [Internet]. ACAMH; 2020 May [cited 2022 Mar 29]. Available from: https://www.acamh.org/research-digest/mental-health-in-deaf-children/
26. Moeller MP, Carr G, Seaver L, Stredler-Brown A, Holzinger D. Best practices in family-centered early intervention for children who are deaf or hard of hearing: an international consensus statement. J Deaf Stud Deaf Educ. 2013 Oct;18(4):429–45.
27. Mayer C. Rethinking Total Communication [Internet]. Marschark M, Spencer PE, editors. Oxford University Press; 2015 [cited 2022 Mar 29]. Available from: http://oxfordhandbooks.com/view/10.1093/oxfordhb/9780190241414.001.0001/oxfordhb-9780190241414-e-3

28. Roberts MY. Parent-Implemented Communication Treatment for Infants and Toddlers With Hearing Loss: A Randomized Pilot Trial. J Speech Lang Hear Res. 2019 Jan 30;62(1):143–52.
29. Nicastri M, Giallini I, Amicucci M, Mariani L, de Vincentiis M, Greco A, et al. Variables influencing executive functioning in preschool hearing-impaired children implanted within 24 months of age: an observational cohort study. Eur Arch Otorhinolaryngol. 2021 Aug;278(8):2733–43.
30. McCann DC, Worsfold S, Law CM, Mullee M, Petrou S, Stevenson J, et al. Reading and communication skills after universal newborn screening for permanent childhood hearing impairment. Archives of Disease in Childhood. 2009 Apr 1;94(4):293–7.
31. Miyamoto RT, Colson B, Henning S, Pisoni D. Cochlear implantation in infants below 12 months of age. World J Otorhinolaryngol Head Neck Surg. 2017 Dec;3(4):214–8.
32. Cuda D, Murri A, Guerzoni L, Fabrizi E, Mariani V. Pre-school children have better spoken language when early implanted. Int J Pediatr Otorhinolaryngol. 2014 Aug;78(8):1327–31.
33. Nelson HD, Bougatsos C, Nygren P, 2001 US Preventive Services Task Force. Universal newborn hearing screening: systematic review to update the 2001 US Preventive Services Task Force Recommendation. Pediatrics. 2008 Jul;122(1):e266-276.
34. Ching TYC, Dillon H, Button L, Seeto M, Van Buynder P, Marnane V, et al. Age at Intervention for Permanent Hearing Loss and 5-Year Language Outcomes. Pediatrics. 2017 Sep;140(3):e20164274.
35. Dammeyer J. Psychosocial development in a Danish population of children with cochlear implants and deaf and hard-of-hearing children. J Deaf Stud Deaf Educ. 2010;15(1):50–8.
36. Porter H, Sladen DP, Ampah SB, Rothpletz A, Bess FH. Developmental outcomes in early school-age children with minimal hearing loss. Am J Audiol. 2013 Dec;22(2):263–70.
37. Theunissen SCPM, Rieffe C, Kouwenberg M, De Raeve LJI, Soede W, Briaire JJ, et al. Behavioral problems in school-aged hearing-impaired children: the influence of sociodemographic, linguistic, and medical factors. Eur Child Adolesc Psychiatry. 2014 Apr;23(4):187–96.
38. Werker JF, Hensch TK. Critical periods in speech perception: new directions. Annu Rev Psychol. 2015 Jan 3;66:173–96.
39. Hall WC. What You Don’t Know Can Hurt You: The Risk of Language Deprivation by Impairing Sign Language Development in Deaf Children. Matern Child Health J. 2017 May;21(5):961–5.
40. Edwards L, Crocker S. Psychological processes in deaf children with complex needs: an evidence-based practical guide. 1. publ. London: Kingsley; 2008. 204 p.
41. Hintermair M. The Role of Language in Deaf and Hard-of-Hearing Children’s Social-Emotional Development [Internet]. Marschark M, Spencer PE, editors. Oxford University Press; 2015 [cited 2022 Mar 29]. Available from: http://oxfordhandbooks.com/view/10.1093/oxfordhb/9780190241414.001.0001/oxfordhb-9780190241414-e-5
42. Spencer PE, Marschark M. Evidence-based practice in educating deaf and hard-of-hearing students. Oxford New York: Oxford University Press; 2010. 244 p. (Professional Perspectives On Deafness: Evidence and Applications).
43. Most T, Aram D, Andorn T. Early Literacy in Children with Hearing Loss: A Comparison between Two Educational Systems. Volta Review. 2006 Jan 1;106.
44. Svirsky MA, Teoh SW, Neuburger H. Development of language and speech perception in congenitally, profoundly deaf children as a function of age at cochlear implantation. Audiol Neurootol. 2004 Aug;9(4):224–33.
45. Keating E, Mirus G. Examining Interactions across Language Modalities: Deaf Children and Hearing Peers at School. Anthropology & Education Quarterly. 2003;34(2):115–35.
46. Kluwin TN. Social Processes and Outcomes of In-School Contact Between Deaf and Hearing Peers. Journal of Deaf Studies and Deaf Education. 2002 Jun 1;7(3):200–13.
47. Hogan A, Shipley M, Strazdins L, Purcell A, Baker E. Communication and behavioural disorders among children with hearing loss increases risk of mental health disorders. Aust N Z J Public Health. 2011 Aug;35(4):377–83.
48. Hintermair M. Psychosocial Development in Deaf and Hard-of-Hearing Children in the Twenty-first Century. In: Marschark M, Tang G, Knoors H, editors. Bilingualism and Bilingual Deaf Education [Internet]. Oxford University Press; 2014 [cited 2022 Mar 29]. p. 152–86. Available from: https://oxford.universitypressscholarship.com/view/10.1093/acprof:oso/9780199371815.001.0001/acprof-9780199371815-chapter-7

49. Lederberg AR, Miller EM, Easterbrooks SR, Connor CM. Foundations for Literacy: An Early Literacy Intervention for Deaf and Hard-of-Hearing Children. Journal of Deaf Studies and Deaf Education. 2014 Oct 1;19(4):438–55.
50. Listman JD, Kurz KB. Lived Experience: Deaf Professionals' Stories of Resilience and Risks. The Journal of Deaf Studies and Deaf Education. 2020 Apr 5;25(2):239–49.
51. Parker J, Gottman J. Social and emotional development in a relational context: Friendship interaction from early childhood to adolescence. TJ Berndt and GW Ladd (eds) Peer Relationships in Child Development. 1989 Jan 1;
52. Newcomb AF, Bagwell CL. The developmental significance of children's friendship relations. In: The company they keep: Friendship in childhood and adolescence. New York, NY, US: Cambridge University Press; 1996. p. 289–321. (Cambridge studies in social and emotional development.).
53. van Gurp S. Self-Concept of Deaf Secondary School Students in Different Educational Settings. Journal of Deaf Studies and Deaf Education. 2001;6(1):54–69.
54. Leigh IW, Maxwell-McCaw D, Bat-Chava Y, Christiansen JB. Correlates of psychosocial adjustment in deaf adolescents with and without cochlear implants: a preliminary investigation. J Deaf Stud Deaf Educ. 2009;14(2):244–59.
55. Yiu K man C, Tang G. Social Integration of Deaf and Hard-of-Hearing Students in a Sign Bilingual and Co-enrollment Environment. In: Marschark M, Tang G, Knoors H, editors. Bilingualism and Bilingual Deaf Education [Internet]. Oxford University Press; 2014 [cited 2022 Mar 29]. p. 342–67. Available from: https://oxford.universitypressscholarship.com/view/10.1093/acprof:oso/9780199371815.001.0001/acprof-9780199371815-chapter-14
56. Keilmann A, Limberger A, Mann WJ. Psychological and physical well-being in hearing-impaired children. Int J Pediatr Otorhinolaryngol. 2007 Nov;71(11):1747–52.
57. Eder D, Nenga SK. Socialization in adolescence. In: Handbook of social psychology. New York, NY, US: Kluwer Academic/Plenum Publishers; 2003. p. 157–82. (Handbooks of sociology and social research.).
58. Punch R, Hyde M. Social participation of children and adolescents with cochlear implants: a qualitative analysis of parent, teacher, and child interviews. J Deaf Stud Deaf Educ. 2011;16(4):474–93.
59. Weiner MT, Day SJ, Galvan D. Deaf and Hard of Hearing Students' Perspectives on Bullying and School Climate. American Annals of the Deaf. 2013;158(3):334–43.
60. Punch R, Hyde M. Children with cochlear implants in Australia: educational settings, supports, and outcomes. J Deaf Stud Deaf Educ. 2010;15(4):405–21.
61. Mckee RL. The Construction of Deaf Children as Marginal Bilinguals in the Mainstream. International Journal of Bilingual Education and Bilingualism. 2008 Sep;11(5):519–40.
62. van Gent T, Goedhart AW, Treffers PDA. Self-concept and psychopathology in deaf adolescents: preliminary support for moderating effects of deafness-related characteristics and peer problems. J Child Psychol Psychiatry. 2011 Jun;52(6):720–8.
63. Bat-Chava Y. Diversity of deaf identities. Am Ann Deaf. 2000 Dec;145(5):420–8.
64. Hintermair M. Self-esteem and satisfaction with life of deaf and hard-of-hearing people--a resource-oriented approach to identity work. J Deaf Stud Deaf Educ. 2008;13(2):278–300.
65. Brice PJ, Strauss G. Deaf adolescents in a hearing world: a review of factors affecting psychosocial adaptation. Adolesc Health Med Ther. 2016;7:67–76.
66. Cawthon SW, Johnson PM, Garberoglio CL, Schoffstall SJ. Role Models as Facilitators of Social Capital for Deaf Individuals: A Research Synthesis. Am Ann Deaf. 2016;161(2):115–27.
67. Byatt TJ, Dally K, Duncan J. Systematic Review of Literature: Social Capital and Adolescents who are Deaf or Hard of Hearing. J Deaf Stud Deaf Educ. 2019 Oct 1;24(4):319–32.
68. Terlektsi E, Kreppner J, Mahon M, Worsfold S, Kennedy CR. Peer Relationship Experiences Of Deaf And Hard-Of-Hearing Adolescents. The Journal of Deaf Studies and Deaf Education. 2020 Apr 5;25(2):153–66.
69. Arnett JJ. Emerging adulthood. A theory of development from the late teens through the twenties. Am Psychol. 2000 May;55(5):469–80.
70. Meyer J, Kashubeck-West S. Psychological well-being in emerging adults who are deaf. In: Resilience in deaf children: Adaptation through emerging adulthood. New York, NY, US: Springer Science + Business Media; 2011. p. 359–74.

71. Valentine G, Skelton T. Re-Defining 'Norms': D/Deaf Young People's Transitions to Independence. The Sociological Review. 2007 Feb;55(1):104–23.
72. Schroedel JG, Geyer PD. Long-term career attainments of deaf and hard of hearing college graduates: results from a 15-year follow-up survey. Am Ann Deaf. 2000 Oct;145(4):303–14.
73. Mousley VL, Chaudoir SR. Deaf Stigma: Links Between Stigma and Well-Being Among Deaf Emerging Adults1. The Journal of Deaf Studies and Deaf Education. 2018 Oct 1;23(4):341–50.
74. Boutin D. Occupational Outcomes for Vocational Rehabilitation Consumers with Hearing Impairments. Journal of rehabilitation. 2010 Jul 20;76:40–6.
75. Kim EJ, Byrne B, Parish SL. Deaf people and economic well-being: findings from the Life Opportunities Survey. Disability & Society. 2018 Mar 16;33(3):374–91.
76. Woodcock K, Pole JD. Educational attainment, labour force status and injury: a comparison of Canadians with and without deafness and hearing loss. Int J Rehabil Res. 2008 Dec;31(4):297–304.
77. McKee MM, Paasche-Orlow MK, Winters PC, Fiscella K, Zazove P, Sen A, et al. Assessing Health Literacy in Deaf American Sign Language Users. J Health Commun. 2015;20 Suppl 2:92–100.
78. Wakeland E, Austen S, Rose J. What is the prevalence of abuse in the deaf/hard of hearing population? The Journal of Forensic Psychiatry & Psychology. 2018 May 4;29(3):434–54.
79. Ryff CD, Love GD, Essex MJ, Singer B. Resilience in Adulthood and Later Life. In: Lomranz J, editor. Handbook of Aging and Mental Health [Internet]. Boston, MA: Springer US; 1998 [cited 2022 Mar 29]. p. 69–96. Available from: http://link.springer.com/10.1007/978-1-4899-0098-2_4
80. Luckner, John L.; Becker, Sharon J. Fostering Skills in Self-Advocacy: A Key to Access in School and Beyond. Odyssey: New Directions in Deaf Education. 2013;14:34–8.
81. Young A, Rogers KD, Green L, Daniels S. Critical Issues in the Application of Resilience Frameworks to the Experiences of Deaf Children and Young People. In: Zand DH, Pierce KJ, editors. Resilience in Deaf Children [Internet]. New York, NY: Springer New York; 2011 [cited 2022 Mar 29]. p. 3–24. Available from: http://link.springer.com/10.1007/978-1-4419-7796-0_1
82. Leigh IW, Pollard Jr. RQ. Mental health and deaf adults. In: The Oxford handbook of deaf studies, language, and education, Vol 1, 2nd ed. New York, NY, US: Oxford University Press; 2011. p. 214–26. (Oxford library of psychology.).

「香港唯一聽障特殊學校」—— 路德會啟聾學校

許加恩校長

香港的聽障兒童教育始於1935年，英國聖公會於香港開辦第一間聽障兒童教育特殊學校。其後因應社會對聽障兒童教育有迫切需要，由1935年至1973年期間香港先後有9間聽障兒童學校成立。香港路德會亦於1968年成立路德會啟聾學校（啟聾學校）。

啟聾學校是一所資助特殊學校，亦是現時香港唯一提供小一至中六聽障兒童教育的特殊學校。學校的服務對象可分為兩類：在學校就讀中、小學的聽障學生及參與「聽障學生增強支援服務」的普通學校之聽障學生。啟聾學校提供六年小學基礎課程、四年初中和三年高中，共十三年的主流課程，更為有其他弱能/殘疾的學生提供調適課程。

啟聾學校深信每位學生都是獨特的，因此引入多元化課程，提供均衡優質教育，致力推動學生生涯規劃，激發他們無限的潛能，並促進他們身心的發展，自強不息而融入社會。學校設施完備，讓學生可在一個理想的學習環境中全面發展，奠定終身學習的基礎。學校靠賴上帝的引導、全體教師的努力及家長的認同支持，同心協力為聽障學童提供基督化全人教育，貫徹香港路德會的辦學宗旨，實踐學校「聾人得恩」的校訓，匡扶孩子的成長。

啟聾學校自1968年創立至今，歷經50多載，由借用別校校舍發展至選址新界葵涌興盛路地段，於1990年落成一所完整之獨立新校舍，過程間不斷優化和完善校內設備，2018年9月更啟動宿舍服務，為聽障學童提供更全面性、更適切性和更優質的教育服務。

教育局跟隨香港康復計劃方案(RPP)及世界衛生組織(WHO)的建議，劃分聽障缺損程度為四個等級：輕度聽障26-40分貝、中度聽障41-60分貝、嚴重聽障61-80分貝，深度聽障81分貝以上。而由2021年9月1日開始，建議缺損61分貝以上的嚴重聽障的學童入讀啓聾學校。學校現時的收生人數為61名，推行小學、初中、高中的分班和分組教學。除教師外，並透過專業團隊的支援，包括專職支援言語治療師、聽覺技師、社工、護士、職業治療師及助理、教育心理學家、舍監、宿舍職員，全面照顧和支援學生成長需要。

1977年，政府發表白皮書提倡特殊兒童融合教育政策並分階段推行，讓殘障兒童在主流學校接受教育。在1997年，政府開始制定融合教育政策。本校於1992年起支援主流學校的聽障學生，透過課後支援及到校為聽障學生提供輔導，時至今天，本校共有五個支援中心包括九龍中心、將軍澳中心、葵涌中心、沙田中心和屯門中心，為全港在主流學校就讀的聽障學生提供服務，幫助他們掌握學習策略、提升語文能力及增進言語溝通技巧，從而融入學校生活，發揮潛能。

在教學方面，本校採用綜合溝通法–手語、口語及書面語三方面，以協助聽障學生在最少障礙的環境中學習，按學生能力需要跨班、跨級分組學習；一班分為兩組進行教學或兩班合併為一組進行教學，例如小學部的視覺藝術科、音樂科、體育科、手語科及中學部的體育科。

在課程設計方面，「幼小銜接」課程的設計為期四個月，以四個主題（大家好、愉快的校園、我們的生活環境、共渡佳節）貫通各學科的學習內容，從社交、情緒及心理的關顧和已有學習經歷的理解及認知能力的銜接，幫助學生適應新的學習階段。

小學部提供主流、調適（智障組）和非華語課程，科目包括中文、英文、數學、常識、聖經、視覺藝術、音樂、電腦和體育，並設有言語治療(ST)、導修課、手語課、多元活動課和午間輔導課，於高小時推行STEM「知」旅和生涯教育課。

而小學課程是中學教育的基礎，打穩基礎便容易迎接中學新里程。透過建立中小溝通平台，如：中小科組銜接課程會議、小六、升中交接會議、中小銜接家長會，以幫助學生順利過渡學習。

中學部亦按照教育局的指引推展新高中學制，提供主流、調適（智障組）和非華語課程，包括體育、設計與工藝、音樂、言語溝通、科學、電腦、聖經/生命教育、生活與科技、中國歷史、其他學習經歷、生涯規劃教育、獨立生活的中學文憑考試科目。

透過不同的閱讀活動，例如「中英文廣泛閱讀計劃」、「早讀計劃」、「好書介紹活動」等，推廣校內的閱讀文化，培養學生閱讀興趣及提升閱讀技巧，達致終身學習的目標。

為了讓學生有更多的學習經歷，本校著重學生跑出課室，利用社區不同的資源，進行戶外學習，豐富學生的學習。通過各級進行本科或跨學科專題研習，例如參觀、訪問、實地考查、匯報等，推動學生自主學習，幫助學生透過多元化的學習經歷，建構各方面的知識。學生在蒐集、整理及綜合資料的過程中，發展共通能力。

本校致力應用資訊科技資源，以促進學生學習。除了電腦室外，禮堂、圖書館，特別室及所有課室均裝置了電腦及投影機。老師除自行設計電子教材外，亦可使用電子課本進行教學，透過不同的學習活動，加強學生運用資訊科技的能力。

配合教育局的課程改革，推行德育及公民教育。以學生為中心，著重培養學生五種價值觀和態度：國民身分的認同、積極、堅毅、尊重他人及對社會和國家的責任承擔。透過各項參觀、講座及不同的活動，培養學生成為負責任、守紀律及具有正確價值觀的公民。同步把正向教育心理學的理念應用於學校環境中，強化學生的個人內在能力，建立正向思維及品格，並使他們以積極的態度面對生活中的壓力及挑戰，學習轉化負面情緒，即使身處困難或挫折仍然抱有積極的信念及盼望。因此，本校為每位學生建立個人學習計劃(IEP)，關顧每位學生的成長。計劃內容針對每位同學的情緒、自理、社交、生活態度等獨特需要，為他們訂立長、短期目標、內容及成功準則，繼而使用不同的教學策略或獎勵計劃，並透過定時之跟進會議檢視進展成效，鼓勵學生努力達標。

啟聾學校朝著七大方針，包括(一)創意科技訓練思維、(二)生涯規劃展翅高飛、(三)多元課程完善生活、(四)體藝發展啟發潛能、(五)正向人生文化承傳、(六)為鹽為光回饋社會、(七)前人分享規劃未來，以助提升學與教的效能和配合學生的生涯規劃發展，完善校園環境設施。

創意科技 訓練思維

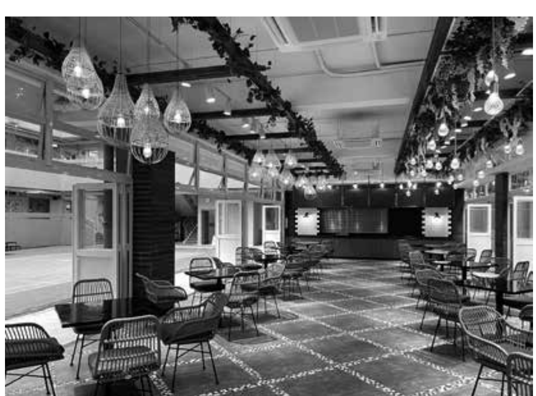
隨著STEM 教育發展，學校以整體而連貫的方式去培養創科人才，利用創意探知室及創意科技室作為小學和中學學生的STEM 活動基地，從小開始改善學生感知及小手肌的協調能力，循序漸進地開發他們對STEM 的認知;升中後更鼓勵學生參與不同的比賽，讓他們更深入了解設計與科技科，訓練思維。

生涯規劃 展翅高飛

新落成的「許明堅牧師伉儷多用途圖書館」是校長與師生以耳朵外型為概念而共同設計的，其將現代風與工業風相結合，營造出充裕的空間感和優雅的環境，以提升閱讀氣氛。新圖書館內置了花店Lutheran florist 及有機無土綠牆，用作開拓花藝手工創作和場景佈置的訓練課程，旨在培養聽障學生日後成為此領域的專才，並藉著學習花藝和植物維護，教導學生生命、品德和環保等正向教育，幫助學生發展創作和審美能力，懂得欣賞藝術和大自然；同時藉著舉辦相關工作坊，提供更多家校合作和親子共融的機會。同時，本校為關顧學生需要及配合活動發展，於有蓋空地（學生飯堂）加設空調和強化玻璃鋁質摺門，作為「學生飯堂/多用途學生活動中心」之用，並打造出如同餐廳的場景，除了給學生提供一個舒適的用餐環境外，亦給予他們一個可用於工作實習體驗及舉辦多用途活動的場地。此外，本校重視家校合作，為了與家長及學生一起攜手構建未來，本校構思了「夢想啟航親子積木壁畫拼砌活動」，壁畫內容是我們學生未來的發展願景，透過家長與學生一起共建，別具意義。

圖書館內設有 LutheranFlorist


許明堅牧師伉儷多用途圖書館


學生飯堂及多用途
學生活動中心

多元課程　完善生活

小學設多元活動課、中學設其他學習經歷OLE，擴闊學生的學習經歷，啟發潛能，提升學習信心。按學生的能力、興趣和需要舉辦不同興趣小組(學術性、體育性、藝術性、興趣性及服務性)參觀活動和生涯規劃活動。著重提升綜合溝通能力，新增小學手語堂、言語治療服務、聽覺支援服務、ASL 美式手語課程、外國宣教士駐校計劃和與屬會持續進修部協商英語ESL 及ASL 美式手語課程，探索與海外大學在港開辦遙距課程。而手語輔助教學資源中心和啟聾手語視像字典能夠幫助學校在學與教層面建立一套有系統的溝通和教學語言，讓學生在手語、口語及書面語三方面都能得到均衡發展，提升聽障學童的溝通效能和自信;而與總會合作開發的「聾健同行」應用程式則可方便大眾有效地學習手語，推動共融。

體藝發展　啟發潛能

本校十分關注學生身心健康，發展他們的體藝潛能，特意將大禮堂的木摺門和小禮堂的鋁門改裝為強化鏡面玻璃鋁質摺門，並在大禮堂左右兩側加上扶手，使大禮堂能兼成舞蹈室，讓學生親身體驗不同種類的運動項目如各項球類運動、跳繩及舞蹈等；新建成的「感覺統合健身室/多用途活動中心」配合生涯規劃課程，向學生提供不同的專業訓練，以提升他們的體適能表現及公開考試成績，拓展畢業出路。

多用途大禮堂

夢想啟航親子積木壁畫

感覺統合健身室 / 多用途活動中心

正向人生　文化承傳

學校於2017年獲優質教育基金資助，推行「好心情積極愛校園計劃」。計劃內容分別涉獵學生、家長及教職員三方面，透過班級經營、週會、小息午膳活動建立學生的正面情緒和良好的人際關係，在校內全方位發展個人的「品格強項」，例如中、小學部設立「大哥哥大姐姐小組」，由學兄學姐帶領低年班同學進行各類型活動，輪流分享及推廣健康正面訊息，不但能加強學生與人溝通的能力，從中亦學習到關心別人的需要，承傳啟聾的關愛文化。「午間心靈打氣站」及「鬆一zone」小組活動在午飯時段舉行，學生可以在繁忙的學習生活上，騰出一個小空間與同學互相交往分享，建立正面的互助氣氛。家長方面，計劃為家長提供親職講座及小組活動，促進了家長與學校的互動，提升家校關愛。而為了提升教師對處理學生的情緒技巧，計劃包涵精神健康急救課程，全校96%教師完成了相關課程，學習處理精神健康急救重點，對日常教學工作有頗大的裨益。此外，學校為配合國民教育發展和宣揚中國傳統文化，定期舉行升旗儀式和中華文化日，更特設中華文化教學資源室，室內佈置充滿中華文化元素，古樸典雅，學生在室中學習中國傳統文化及國家相關知識，仿如置身中國各朝各代，大大提升其學習興趣，學習事半功倍。

為鹽為光　回饋社會

啟聾學校啟動全新多功能網上平台「藏聾計劃」，藉此連繫「社、福、校」界別，創造「社區資本」以回饋社區，推動聾健共融。計劃致力培訓聽障學童及畢業生擔任「社區導師」，舉辦多元化共融體驗工作坊和義工協作服務：烘焙、花藝、咖啡、體育活動等；招募社區人士、家長義工、校友、慈善團預約參加，達至聾健共融，助人自助。此外平台設有預訂學生作品及藝廊，向公眾展示學生學習成果，讓公眾人士了解和欣賞本校學生的非凡才能，幫助他們自我確立和對生涯規劃的認識，提高聽障人士日後更多就業機會，以達致宣傳和教育公眾的目的，與外界攜手共建和諧全納的社會。

前人分享　規劃未來

本校與基督教家庭服務中心主辦的賽馬會躍動啟航計劃香港輔助專業人員計劃合作，該計劃網羅了擁有專業牌照及專業知識的退休人士，為本校的學生提供技能傳授的師友配對，亦透過師友定期的面見，分享人生經驗和價值觀。有關的技能種類多元化，例如資訊科技、工程牌照、攝影、護理、健體藝術等。

啟聾學校的硬件設施及課程設計均緊扣學生生涯規劃和價值教育，希望學生除了能獲取書本上的知識，亦能嘗試貼近社會的生活，逐步協助他們由校園生活過渡到獨立生活，並學會勇於面對困難，在神的引領下，為鹽為光，盡展所長，回饋社會，砥礪前行。

藏聾計劃」Deaf Treasure	http://www.deaftreasure.org
新設施奉獻禮花絮	https://www.lsd.edu.hk/content/files/files/movie/%E6%96%B0%E8%A8%AD%E6%96%BD%E5%A5%89%E7%8D%BB%E7%A6%AE%E8%8A%B1%E7%B5%AE.mp4