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The acquisition of Hong Kong Sign Language in deaf and hard-of-hearing children: A longitudinal study of sign language development in a bimodal bilingual co-enrollment programme

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ABSTRACT

This study followed the development of Hong Kong Sign Language (HKSL) proficiency in 31 deaf bimodal bilingual children (kindergarten through Primary 6) over two years. The Hong Kong Sign Language Elicitation Tool (HKSL-ET) was used at three time points to elicit the production of agreement, classifier, modal, negation, and wh-question structures. These were scored for accuracy based on specific language features, including classifier handshapes, non-manuals, phonological parameters, sign order, and use of space. Deaf children of hearing parents (dH children) showed significant improvements in accuracy for all structures and features, with most progress occurring between the first two assessments. By the third assessment, dH children showed similar performance to the deaf children of deaf parents (dD children) on most structures and features, but they were still significantly less accurate in their production of classifier constructions and use of space. This, along with an observed negative impact of later ages of acquisition on HKSL accuracy, underscores the importance of early exposure to sign language. Examining the relationship between signed and spoken language proficiency revealed a significant positive correlation between HKSL proficiency and Cantonese verbal expressive ability, suggesting that these languages may have mutually facilitative effects in terms of language development. Our findings highlight the utility of bimodal bilingual education in fostering linguistic development in deaf children.

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Introduction

Deaf children[1] often experience delayed development in oral language. Therefore, early intervention, utilising advanced assistive hearing technology like

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[1]In this paper, we use the term "deaf children" to cover children with a range of hearing loss, from no residual hearing to hard-of-hearing.

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cochlear implants or hearing aids, is the conventional approach to enhance their speech perception abilities. Meanwhile, there has been research examining the impact of sign language exposure on oral language acquisition. In terms of sign language acquisition, deaf children born to deaf parents begin to acquire sign language at birth and display a developmental trajectory similar to hearing children acquiring spoken languages (Lillo-Martin & Henner, 2021; Meier & Newport, 1990). The early introduction of sign language to deaf children, along with speech interventions, has the potential to foster bimodal bilingual language proficiency, meaning they have knowledge of both a signed and spoken language. However, almost 96% of deaf children are born to hearing parents (Mitchell & Karchmer, 2004), most of whom have no knowledge of sign language or connection with the Deaf community. Therefore, finding ways to help deaf children acquire sign language early in life, to support their language, literacy, and academic development, is crucial for parents and educators advocating for sign language in deaf education.

Little existing research has focused on the longitudinal development of sign language among deaf children educated in bimodal bilingual co-enrollment settings. We investigate the acquisition of Hong Kong Sign Language (HKSL) and its associated linguistic features among a group of deaf children studying in a co-enrollment education programme in Hong Kong, which provides a bimodal bilingual learning environment in Cantonese and Hong Kong Sign Language. The *Sign Bilingualism and Co-enrollment Education (SLCO) Programme*, launched in 2006, brings HKSL into mainstream education by incorporating a critical mass of deaf children into a regular classroom to study with hearing students (usually five to six deaf students and 25 to 30 hearing students). These classes adopt a co-teaching approach between a hearing teacher and a deaf or hearing teacher highly proficient in HKSL. In this pedagogical approach, deaf children predominantly utilise HKSL (which is generally presented in tandem with the hearing teacher's spoken Cantonese) to access classroom information. However, the extent to which they rely on HKSL may vary depending on the degree of their hearing loss and the efficacy of their hearing aids or cochlear implants. Around once per week, deaf students also receive around twenty minutes of additional, direct instruction in HKSL aimed at helping them improve their signing abilities.

This study aims to assess the development of deaf children's HKSL knowledge over two years of co-enrollment education. We analysed age-related changes in accuracy for HKSL grammatical structures and associated linguistic features among 26 deaf children of hearing parents (dH), who varied in their age of first exposure to HKSL. Their performance was also compared to a group of five deaf children of deaf parents (dD). Furthermore, we examined associations between HKSL proficiency and verbal comprehension (VC), verbal expression (VE), as well as age of HKSL acquisition (AoA) in order to better understand (1) the relationship between sign language and oral language

development and (2) how the timing of HKSL exposure affects sign language development in deaf children.

Importance of sign language for deaf children

When making decisions regarding modality of language input for their deaf children, parents must weigh a range of factors, including the potential benefits and variability of outcomes, associated with different approaches. While cochlear implants and hearing aids show promise for facilitating the development of spoken language in deaf children, outcomes are diverse and influenced by a range of factors, such as the age of implantation and the child's individual circumstances. In the case of cochlear implantation, initial successes in vocabulary and grammar (Duchesne et al., 2009), as well as spoken grammatical skills (Inscoe et al., 2009), have been reported. However, since the benefits of cochlear implantation reportedly vary in terms of speech recognition and language development, much research has focused on studying age of implantation and its long-term effects.

A meta-analysis of the language outcomes of implanted children in 21 studies conducted by Ruben (2018) concluded that the positive impacts of implantation before 12 months are high. After that age, effects diminish as the age of implantation increases. Hand et al. (2023) reported improved receptive and expressive English skills one to two years after implantation; however, children with an earlier switch-on age (age < 2) seemed to gain more advanced expressive skills than children with a switch-on age older than 2. After two years of implantation, the gap between the two groups widened in skills like understanding pronouns (e.g. *me, my, your*), quantification (e.g. *some, all, rest*), and combining words to form sentences.

A recent study by Wie et al. (2020) showed a diminishing long-term effect of cochlear implantation on deaf children's language development. Adopting a longitudinal approach over a period of six years, they tracked the development of Norwegian general language skills, vocabulary, and grammar in 19 congenitally deaf children who received even bilateral implantation between the ages of 5 and 18 months. During the first four years after implantation, these deaf children displayed similar general expressive and receptive language skills when compared with normal-hearing children. However, from four years to six years after implantation, gaps between the two groups in terms of expressive grammar skills and receptive vocabulary reemerged, possibly reflecting the increasing complexity of the semantics of words and grammar that the deaf children needed to acquire.

In the Hong Kong context, learning a tonal language like Cantonese poses a great challenge of a different nature to deaf children, since changes in tone, a suprasegmental feature of Cantonese, can lead to changes in word meanings. Holt et al. (2018) examined Cantonese word recognition and discrimination of

Cantonese tones by 41 implanted children and adolescents grouped into early and late (up to two years after birth) implant users. In their study, the implanted children's performance scores were significantly lower than those of the age-matched hearing comparison group. However, early implantation was associated with better performance than late implantation. Thus, it appears that while cochlear implantation enhances speech recognition, the perception and discrimination of tones still pose a great challenge to deaf children.

One potential danger of complete reliance on assistive hearing technology is language deprivation. It is difficult to estimate the effect brought about by the absence of language exposure until the time of implantation and switch-on. Furthermore, as outcomes can be unpredictable, cochlear implantation may have limited benefit for some deaf children, leaving them still unable to access spoken language phonology even with the use of a cochlear implant. Recently, researchers have advocated for sign language exposure for deaf children as early as possible as a potential safeguard against language deprivation (see Hall, 2017; Hall et al., 2019; Humphries et al., 2016). M. L. Hall et al. (2019) highlighted the importance of exposing deaf children to naturalistic sign language input, to "sensitize" them to the linguistic properties in acquisition.

Unfortunately, misconceptions about the nature of sign language and sign language acquisition can lead to biases and methodological issues in research that compares spoken language development in signing and non-signing children For example, in Geers et al.'s (2017) study on a group of implanted children, they defined signing children as those who learned any variety of signing at home, failing to differentiate between natural sign languages and artificial communication systems like sign supported speech and manually coded English. They compared the English skills of the signing children with those of a group of non-signing children—both immediately and three years after implantation. Based on their findings that the non-signing children consistently outperformed the signing children, they argued that listening and spoken language, but not sign language, are the two most crucial ingredients to support deaf children's optimal language development.

Upon closely scrutinising the data of Geers et al.'s (2017) study, Hall et al. (2019) found that roughly 75% of the non-signing children still fell below the 50th percentile, and the group as a whole did not show significant improvement in English skills three years after implantation. This under-par performance and language delay of the non-signing children come close to a characterisation of the potential danger of language deprivation based on their incomplete mastery of spoken language after three years of implantation. Even for the signing children, their poor performance in English could possibly be due to not only inadequate English but also lack of natural sign language exposure.

Meanwhile, there is growing evidence that bimodal bilingual deaf children's exposure to sign language does not negatively impact spoken language development and may even facilitate it. Davidson et al. (2014) compared five bimodal

bilingual deaf children with 20 KODAs (kids of deaf adults) and found nil significant differences in English vocabulary, syntax, and articulation. Goodwin and Lillo-Martin (2019) found a similar performance across most English grammatical morphemes (except plural *-s*) when comparing seven hearing and five implanted children of deaf parents, suggesting that the deaf children were at a roughly similar stage of morphosyntactic development at the time of testing. Goodwin et al. (2017) found that signing children (both hearing and deaf KODAs) did not omit English articles at a higher rate than non-signing implanted children. Tang et al. (2014) found that bimodal bilingual children with stronger HKSL skills also were stronger in both spoken and written language.

Effects of age of acquisition on sign language development

The initial age of sign language exposure for deaf children of hearing parents tends to be older than for their counterparts with deaf parents, who typically experience such exposure from birth. This onset of exposure is herein referred to as the age of acquisition (AoA). Research findings have consistently shown that, similar to children learning spoken language, deaf children with signing deaf parents develop language capabilities at a comparable pace and reach similar levels of ultimate language proficiency. Conversely, for deaf children of hearing parents, the timing of sign language exposure substantially impacts their language acquisition outcomes, leading to a broad range of proficiency levels.

Newport (1990) compared the sign language abilities of adults exposed to ASL either since birth, between the ages of 4–6 years, or at 12 years. While all three groups scored high on word order, subtle differences in terms of accuracy surfaced in other grammatical components such as ASL morphology as manifested in verb agreement, verbs of motion and location or classifiers, with native signers scoring the highest and early learners significantly lower and the late learners the lowest. Mayberry (2007) investigated the impact of AoA on ASL, concluding that delayed L1 exposure causes incomplete acquisition of all languages, with effects that spread across syntactic, phonological, and lexical levels. Regardless of modality, Mayberry argued that AoA strongly impacts L1 outcomes, but L2 outcomes depend more on early L1 acquisition, meaning that L1 and L2 development are interdependent and the timing of L1 exposure is key to positive ultimate attainment in any language of any modality.

Late language onset has been shown to have lasting impact on neural organisation for sign language processing. Mayberry, Chen, et al. (2011) found that native signers showed activation in classic language regions when exposed to language from infancy. However, when language acquisition was delayed, effects proportional to the length of the language deprivation period were

observed. For example, there was decreased activation in anterior areas for higher-level processing but increased activation in posterior areas for lower-level processing. These findings indicate language deprivation prevents full maturation of neural language systems.

More recent experimental studies have captured evidence of AoA effects in late signers as well. Language acquisition and aging have significant impacts on language processing abilities in deaf signers. Corina et al. (2020) found that deaf individuals' ability to repeat American Sign Language (ASL) sentences declined with age and that native signers exposed to sign language since birth outperformed those who acquired ASL early or late in life, showing evidence of the lasting impacts of initial language experiences. Similarly, Krebs et al. (2021) found that age of acquisition affected language processing in users of Austrian Sign Language. The age of acquisition, specifically within the range of 0 to 7 years, had a minimal impact on participants' grammatical acceptability ratings for certain structures. However, it significantly influenced syntactic processing for those acquiring language later in life. Late learners, for instance, typically favoured basic word order and struggled with complex structures, such as classifiers.

There are not many studies that examine AoA effects using a longitudinal approach. Berk (2004) examined two deaf children's ASL development over four years. These two children had no accessible linguistic input prior to entering a deaf school at around age 5–6 years. The children's late exposure to ASL resulted in their difficulty in acquiring how to use the signing space to denote grammatical properties. For instance, they did not improve in the use of space for person agreement even over the four years of observation. Another longitudinal study on ASL acquisition based on three filming sessions (roughly over a period of six years) by four late adolescent learners with no language experience prior to ASL exposure around the age of 14–15 years old (Cheng & Mayberry, 2019). Compared with child acquirers, these late learners showed a higher degree of conservatism towards canonical SV and VO word orders with longer exposure to ASL despite the initial production of variable word orders like OV or VS, which are also permitted in ASL and continued to be produced by native child acquirers. Moreover, the late adolescent learners tended to produce the OV order in verb agreement contexts while the child acquirers produced the same order in classifier constructions and other spatial inflections.

Sign language on literacy and academic achievement

As said, deaf students can face obstacles in subsequent literacy and academic achievement if they do not enter school with a strong first language or bimodal bilingual foundation (Mayberry, del Giudice, et al., 2011; Qi & Mitchell, 2011). Earlier research has shown that skilled deaf readers also tend to have strong signing abilities. Chamberlain and Mayberry (2008) found skilled deaf

adult readers had high ASL syntactic and narrative ability, supporting their English reading. Mayberry (2007) found that early ASL acquisition positively affects syntactic processing during reading. Deaf individuals with high sign language proficiency, typically beginning acquisition in infancy, had a post-high school reading level, while those with low proficiency read at a 3rd – 4th grade level. A recent study by Hoffmeister et al. (2022) investigated this sign-spoken relationship with a larger sample, where 517 bimodal bilingual students (ASL-English) aged 8–18, native and non-native, showed a positive correlation between ASL vocabulary and English syntax and reading comprehension and ASL syntax consistently predicted English syntax at all age levels. Last, the native signing participants acquiring ASL since birth outperformed the non-native ones in both ASL and English assessments.

A strong first language also provides cognitive benefits for literacy. Hrastinski and Wilbur (2016) found deaf students with high ASL proficiency scored higher in reading, English, and math. Although both groups used ASL at school, the highly proficient group acquired ASL earlier and more extensively, developing greater fluency. ASL proficiency was the best predictor of scores, suggesting high proficiency in a first language aids academic achievement. Petitto et al. (2016) argue that proficiency in a natural sign language gives deaf children a strong semantic foundation to facilitate print-meaning connections. Studies show deaf readers activate signs when reading (Meade et al., 2017; Morford et al., 2011; Pan et al., 2015; Thierfelder et al., 2020b), indicating that sign language may support reading comprehension through print-sign associations (though speech-based phonology may play a role as well in some deaf signers, see Thierfelder et al., 2020a). Thierfelder and Stapleton (2016) found that adult deaf English learners from Hong Kong transfer lexical knowledge from both Chinese and HKSL to their written English. While such transfer can result in writing errors (as described by the authors), the presence of transfer errors indicates that deaf individuals are drawing on their linguistic repertoire (in this case, Chinese and HKSL) to support their acquisition of a new language, which underscores the cognitive benefits of bilingualism and the importance of a strong base in a first language.

In the Asian context, a recent study by Liu (2022) examined the relationship between Taiwanese Sign Language and Chinese reading comprehension, finding a positive outcome with a group of signing adults and children. The results showed that the number of years of learning TSL had a significant relationship with Chinese reading comprehension. In children aged 6–13 years, signed vocabulary size was a greater predictor the variance in Chinese reading comprehension. Liu argued that emerging bimodal bilingualism during childhood seems to count on TSL vocabulary to boost threshold reading in Chinese.

In summary, research shows early exposure to a natural sign language provides cognitive and linguistic benefits for deaf children that support their

later literacy and academic achievement. However, it is important to keep in mind that sign language is not invariably associated with academic success and there are a number of complex factors at play when it comes to literacy and academic ability in deaf students (see Marschark et al., 2015).

Co-enrollment education and language development

Tang (2017) discussed *sign-bilingualism* and *co-enrollment* against the emerging trend of mainstreaming deaf students within the general framework of integrative or inclusive education. Very often, these children experience isolation as they are probably the only deaf students in their respective classrooms. Even if sign interpretation is incorporated in the classroom, full participation of deaf students in classroom interactions and direct instruction from the teacher cannot be guaranteed (Winston, 1994). The concept of co-enrollment education for the deaf originated in Kirchner's (1994) "Tripod" Program to address many of the challenges these students may face when they enter general education classrooms to study a full curriculum with a majority of hearing classmates. Co-enrollment classrooms are characterised by three important features: (1) a class with a critical mass of deaf students to study with hearing students in the ratio of one deaf to three or four hearing students, (2) two teachers (one general, one specialising in deaf education) co-teach the class as a team, and (3) both sign and spoken languages are used in the classroom (Antia & Metz, 2014). Since the Tripod Program, co-enrollment education has spread to many countries in different forms of organisation while they converge on the importance of bimodal bilingual communication in the classroom (Marschark et al., 2019).

The SLCO Programme established in Hong Kong since 2006 has built a "through-train" education system for deaf students from kindergarten to senior secondary education. It emphasises a whole-school approach to educating both deaf and hearing children, exposing them to naturalistic bimodal bilingual input in the classroom environment. This is achieved by including Deaf signing teachers to bolster sign language acquisition and information accessibility in the pedagogical process.

To our knowledge, only one study has evaluated sign language development in dH co-enrollment students using a longitudinal approach. Martin et al. (2014) examined the development of spoken Spanish and Spanish Sign Language (LSE) skills in implanted children who were exposed to both languages early on in a co-enrollment preschool context. The children displayed considerable variability in spoken Spanish vocabulary development and atypical patterns in expressive and receptive vocabulary. In terms of sign language ability, the children's LSE development followed typical patterns when fully accessible, with receptive vocabulary outperforming expressive vocabulary. The researchers concluded that developing LSE simultaneously did not negatively impact spoken

Spanish growth, and bimodal bilingual children had larger conceptual vocabularies than monolingual peers.

For Hong Kong, during the process of developing SLCO programming, several studies were conducted to examine the language development of deaf children. Tang et al. (2014) assessed the grammatical knowledge of the signed and spoken languages of a group of severe to profound hearing loss children, some were implanted and some were prescribed hearing aids. The researchers found no interference in the children's learning of HKSL on their oral Cantonese and written Chinese development; instead, a consistently positive relationship was observed between the development of these languages. Where these children were exposed to HKSL since kindergarten roughly from age 3 to 6 onwards, Tang et al. (2015) designed a metalinguistic procedure with signed stimuli representing the grammar of either HKSL or Chinese to investigate the deaf children's ability of linguistic differentiation. The deaf children studying in this bimodal bilingual environment were able to separate the signed stimuli based on their knowledge of the two grammatical systems as young as 7 to 9 years old, suggesting that constant direct interactions between deaf/hearing peers as well as teachers allow opportunities for appreciating linguistic differences even if the grammar of the spoken language is represented in the signing mode, as in manually coded Chinese. In terms of oral Cantonese development, K. Lee et al. (2014) compared the oral Cantonese development of the SLCO deaf children and those deaf children in other mainstream settings. Using a standardised Hong Kong Cantonese Oral Language Assessment Scale (Tsou, 2012), the children were assessed for the first time at Primary 3 and again when they reached Primary 6. Since the backgrounds of both populations of deaf children were highly varied, statistical cluster analysis was adopted to identify 12 SLCO deaf children and 16 regular deaf children for the comparison. While both populations of deaf children indicated progress in oral Cantonese development measured in 2008 and again in 2010, repeated measures ANCOVA on the composite scores and sub-scores of the standardised test revealed greater improvement among the SLCO deaf children than the other deaf children, namely in the composite scores and sub-scores of Cantonese grammar, textual comprehension, lexical semantics, and story retelling. In other words, exposure to HKSL as in the SLCO school environment does not prevent deaf children from improving their oral Cantonese.

The last study to be reviewed here is the SLCO deaf children's written Chinese grammatical development. Tang et al. (2023) analysed the development of written Chinese grammar of 29 deaf children with severe to profound hearing loss (20 implanted, eight with hearing aids) and 176 hearing children who studied with the deaf children in the same SLCO classes. While the hearing children demonstrated significantly faster written Chinese development during Primary 1 and Primary 2, the deaf children's performance in most of the grammatical structures was not significantly different from their hearing peers by the

time they progressed to Primary 3. This finding suggests that, although the two groups of students progressed at different rates initially, the deaf children achieved a similar level of grammatical ability by the final assessment point. Some highly complex structures such as relative clauses and locative constructions continued to pose a challenge for the deaf students. However, the data suggested that their hearing peers also experienced difficulty with these structures, albeit to a lesser degree.

Grammatical properties of HKSL

HKSL is a natural variety of sign language used by the Deaf community of Hong Kong. According to a historical survey by Sze et al. (2013), two deaf schools were established in Hong Kong in 1948 and 1956 by deaf founders from Nanjing and Shanghai, China. These founders brought the sign language varieties of their hometowns with them to Hong Kong. Signs from these schools, as well as local signs already used among deaf people in Hong Kong, became integrated over time, resulting in the sign language variety we refer to as HKSL today. Therefore, HKSL can trace its origin to the sign language varieties of Nanjing and Shanghai, sharing around 66-68% of their lexicon (Woodward, 1993).

As the current paper analyses the developmental trajectory of the grammatical structures and linguistic features of HKSL, we will give a brief overview of these aspects of the language. Firstly, in terms of word order, HKSL differs substantially from oral Cantonese and written Chinese based on Mandarin Chinese grammar in surface structures and means of expression. While these varieties of Chinese have a relatively fixed SVO structure, word order is more variable in HKSL. Although HKSL's basic word order is also SVO, it permits variation, especially when incorporating functional elements like modals, negators, and classifiers, as well as verb inflections (Lam, 2003). HKSL modals like CAN and MUST, negators like NOT, NOT-HAVE, and NOT-YET, as well as other negative quantifiers and modals (e.g. CANNOT), consistently occur in a clause-final position (Fung & Tang, 2016; Tang, 2006), which differs from Cantonese and written Chinese, where these functional elements are generally preverbal.

Wh-questions are another example which demonstrate word order differences between HKSL and the two varieties of Chinese. In HKSL, wh-questions, especially adjunct wh-questions like HOW, WHY, WHEN, are generally clause-final but sometimes one may find in-situ argument wh-questions (Tang, 2006). This is unlike Cantonese and written Chinese where wh-questions are invariably in-situ.

Additionally, the use of space and simultaneous morphology manifested in two crucial morphosyntactic constructions in HKSL also leads to word order changes. Lam (2003) observed that agreement verbs like GIVE inflect for both subject and object. Consequently, the spatial loci allocated to the subject and object, along with the directional movement between them, enable these

components to be omitted yet comprehensible. This is facilitated by the person features and the corresponding spatial loci that function as discourse referents in the conversation. Transfer numerals in HKSL, which represent the movement or transfer of entities, can mark agreement between third-person referents using classifier handshapes attached to verb roots in neutral space (Koenders, 2022).

Classifier constructions, a distinct feature of HKSL, lack a direct equivalent in Cantonese or written Chinese grammar. They denote agreement between the handshapes and the entities they symbolise, employ spatial loci to assign positions to subjects and objects, and use movement to represent grammatical characteristics like location, transitive and causative predicates, as well as motion and directional predicates. The resulting morphosyntactic patterns typically take the form of either a sequence of subject-direct object-verb-indirect object in the case of agreement verbs, or a sequence of subject-object-verb or alternatively, object-subject-verb, in the case of classifier constructions (Lam, 2003). Thirdly, unlike Cantonese and written Chinese, the use of non-manuals to denote linguistic properties is a unique feature to all sign languages, which may be captured at the lexical, morphological, syntactic level and even prosodic level.

In summary, while HKSL shares some characteristics with Cantonese and written Chinese, such as a basic SVO word order (Matthews & Yip, 2013), it remains distinct in the realisation of many of its grammatical structures and linguistic features, as was outlined above.

The current study

The current study aims to address gaps in our understanding of how deaf children acquire HKSL over time. We focused on grammatical structures that reflect crucial linguistic features of sign language grammar, the realisation of which differs fundamentally from that of spoken languages that these children are exposed to, parallel to HKSL input. These consisted of agreement, classifier, modal, negation, and wh-question structures. We also singled out crucial linguistic features of HKSL as expressed in these structures for independent analysis. They are classifier handshapes, directionality, phonological forms, use of space, sign order, and non-manuals. By examining the development of these grammatical features of HKSL over two years of co-enrollment, the study offers insights into the effects of age of acquisition and crosslinguistic interaction on acquiring HKSL. Additional analysis will examine the associations between spoken language and signed language development.

Method

The current study uses HKSL production data collected across two consecutive years using The Hong Kong Sign Language Elicitation Tool (HKSL-ET; Lee et al.,

2011). The tool was designed to evaluate the development of deaf children's expressive grammar in HKSL by assessing their ability to produce phonologically and grammatically accurate sentences, specifically targeting key grammatical elements which are unique to sign languages. Ethics approval was granted by the university (ref: 6902145), and consent for participation was given by the children's parents or guardians.

Different elicitation methodologies using pictures were adopted. Picture description was employed to elicit productions of classifier (24 items) and negation (4 items) structures. Pictures were used to elicit productions of wh-questions (20 items). Meanwhile, story retelling served as a method for eliciting modal sentences (6 items) and agreement verbs (7 items). When coding agreement structures for accuracy, we focused on the use of directionality in using the sign GIVE. Classifier constructions were evaluated based on the accuracy of classifier handshapes for both dominant and non-dominant hands, sign order, and use of space. For the modal, negation, and wh-question structures, we examined the phonological forms of functional signs, sign order, and the use of non-manuals.

Each item was scored by an individual proficient in HKSL, either a native deaf signer or a sign linguist with a high level of fluency.[2] For each item, productions were evaluated based on predefined criteria (see Table 1 for scoring criteria) and given a binary score: "1" for an accurate production (i.e. produced in a manner consistent with the way an adult native deaf signer of HKSL would sign) and "0" for inaccurate production. We excluded cases where there was no production or the production was unrelated to the task (usually due to the participant becoming distracted from, misunderstanding, or forgetting the task) as these instances of unsuccessful production do not necessarily reflect linguistic competency.

At approximately the same three time points as the administration of the HKSL-ET, the Reynell Developmental Language Scales (RDLS; Au et al., 2004) were used to assess the receptive and expressive oral language skills of the deaf bimodal bilingual children. These assessments were carried out and scored by qualified speech therapists.

Participants

The final data set had a total of 31 deaf children who received education in the *Sign Bilingualism and Co-enrollment Programme* in Hong Kong (http://www.cslds.org/slco/en/). These children were formally enrolled into a SLCO kindergarten and promoted to a SLCO primary school three years later. At the time of testing, they were students from kindergarten to primary 6. Of these, two had mild hearing loss, four had moderately severe, six had severe, and 20 had

[2]When needed, sign linguists (who were hearing and not native signers) would ask native deaf signers to check and verify (or correct) their judgements with regards to scoring individual items.

Table 1. Structures, item count, features, and scoring criteria for the HKSL-ET.

Structure	*N*	Features	Scoring Criteria
Agreement	7	Directionality	The signer uses the target agreement verbs, accurately marking the starting and ending points to indicate the grammatical relations between the subject and object.
Classifier	24	Classifier Handshapes	The signer uses classifier handshapes congruent with the arguments they refer to, subjects or objects, in classifier constructions.
		Sign order	The signer produces all words in an order consistent with the HKSL syntax.
		Use of Space	The signer systematically employs spatial referencing in classifier structures to articulate grammatical relationships.
Modal	6	Sign order	The signer produces all words in an order consistent with HKSL syntax. The modal is clause-final.
		Non-manuals	The signer incorporates the target non-manual features associated with the modal.
		Phonology	The signer accurately produces the handshape, location, movement, and orientation of the modal.
Negation	4	Sign order	The signer produces all words in an order consistent with HKSL syntax. The negator is clause-final.
		Non-manuals	The signer incorporates the target non-manual features for negation.
		Phonology	The signer accurately produces the handshape, location, movement, and orientation of the negator.
Wh-Question	20	Sign Order	The signer produces all signs in an order consistent with HKSL syntax. The wh-question word is clause-final.
		Non-manuals	The signer incorporates the target non-manual features for wh-questions.
		Phonology	The signer accurately produces the handshape, location, movement, and orientation of the wh-question sign.

Note: Table shows the target structures and the features on which their accuracy was evaluated. Scoring criteria describe an "accurate" production of the corresponding feature. N = number of target sentences items per structure.

profound hearing loss. In our primary analysis, we focused on 26 dH children whose ages of first exposure to HKSL ranged from 1.92 to 9.33 years old (M = 5.33 years, SD = 2.13).

We excluded five dD children from the primary analysis due to their early access to HKSL, which likely resulted in a different developmental timeline compared to dH children. However, we conducted a year-by-year comparison between the two groups to see how their trajectories may compare. During the first assessment period (T1), the ages of dD and dH children ranged from 5.74 to 12.33 years (M = 8.63, SD = 1.77). In the second assessment period (T2), ages ranged from 5.28 to 13.47 years (M = 9.23, SD = 2.01), and in the third assessment (T3), they ranged from 6.49 to 14.67 years (M = 10.46, SD = 2.02). The average time between assessments was 11.28 months (SD = 1.36) for T1 and T2, and 14.88 months (SD = 0.35) for T2 and T3 across participating children. Note that five students did not join the assessment until T2, so only 26 participated in the T1 assessment. A summary is provided in Table 2.

Analysis

To assess the overall accuracy of each HKSL structure (classifier, modal, negation, agreement, and wh-question structures) and linguistic feature (non-

Table 2. Summary statistics showing means for ages and language assessment scores.

Grade Range	Group	Age		RDLS-VC		RDLS-VE		HKSL-ET	
K3 – P2	dD	7.46	(0.56)	.69	(.11)	.88	(.10)	.43	(.50)
	dH	7.91	(1.36)	.69	(.20)	.79	(.16)	.35	(.48)
P3 – P4	dD	9.67	(0.59)	.86	(.08)	.92	(.07)	.67	(.47)
	dH	10.34	(0.99)	.77	(.19)	.91	(.10)	.49	(.50)
P5 – P6	dD	11.95	(0.67)	.95	(.02)	.96	(.00)	.87	(.34)
	dH	12.67	(1.15)	.70	(.19)	.86	(.10)	.70	(.46)

Note: Means for each grade range are calculated across all three time points. Standard deviations in parentheses. RDLS = Reynell Developmental Language Scales; VC = verbal comprehension; VE = verbal expression; HKSL-ET = Hong Kong Sign Language Elicitation Tool; K3 – P2 = Kindergarten to Primary 2; P3 – P4 = Primary 3 to Primary 4; P5 – P6 = Primary 5 to Primary 6.

manuals, classifier handshapes, phonology, sign order, and use of space), we conducted statistical analyses employing generalised linear mixed models (GLMMs) with a binomial distribution. These models were built using the glmmTMB package (Magnusson et al., 2017) in the R statistical environment (R Development Core Team, 2014). As verb agreement structures contained only one criterion—directionality—we excluded it from the linguistic feature analysis while retaining the agreement structure category in the analysis overall accuracy per structure.

For the dH group analysis, the full model included data from all three assessment periods (T1 to T3), with the binary assessment score (0 or 1) as the dependent variable. We built additional, separate models to examine the relationship between accuracy and age for each structure and feature from T1 to T2 and then from T2 to T3. Separate sets of models were built to look at (1) overall accuracy in producing the target structures and (2) accuracy in producing each of the target linguistic features across structures. Crossed fixed effects were specified for *structure* and *age* in the structure models and *feature* and *age* in the feature models.

We also sought to examine differences in performance across structures and features between dH and dD children at each testing period, rather than comparing their relative rates of progress. To achieve this, we introduced *group* and *time point* as additional crossed fixed effects in our analysis. However, due to the small sample size of the dD group compared to the dH group, results should be interpreted with caution. Further research with larger sample sizes is necessary to draw more robust conclusions about group differences.

Additional models were set up to examine the relationships between HKSL-ET scores and the variables of AoA, VC and VE, along with their interactions with age. Given that some students had either already attained the maximum score or could not complete one or both of the RDLS assessments, only cases where participants had both valid VC and VE scores at the corresponding time point were included. The resulting dataset included 26 students at T1, 29 at T2, and

13 from T3 (at which point many students have already achieved the maximum score for one or both of the assessments).

For all models, random intercepts for participants and items were included to account for individual differences and potential variations in item difficulty. Additionally, random slopes for *age* were specified to account for varying rates of change across individuals and items. For the analyses of AoA, VC, and VE effects, these factors were included in addition to age as random slopes for participants.

Considering the relatively large number of tests required due to the inclusion of structure, feature and three time points in the models, we used the `emmeans` package to calculate estimated marginal means for interactions and pairwise comparisons. To account for multiple testing and reduce the likelihood of false positive findings (Type I errors), we applied false discovery rate (FDR) corrections. Continuous variables (age, AoA, VC score, and VE score) were all centred and scaled. Detailed statistics and structures for all models can be found in Tables 5–9. Summaries of raw data are available in Tables 3 and 4.

Table 3. Summary statistics showing mean accuracy rates per structure.

Structure	Group	K3 – P2		P3 – P4		P5 – P6	
Agreement	dD	.70	(.47)	.74	(.45)	.88	(.33)
	dH	.63	(.49)	.74	(.44)	.66	(.48)
Classifier	dD	.29	(.45)	.67	(.47)	.93	(.25)
	dH	.17	(.37)	.38	(.49)	.73	(.44)
Modal	dD	.73	(.45)	.91	(.29)	1.00	(.00)
	dH	.60	(.49)	.81	(.40)	.84	(.37)
Negation	dD	.61	(.49)	.67	(.48)	.83	(.38)
	dH	.52	(.50)	.59	(.49)	.65	(.48)
Wh-Question	dD	.50	(.50)	.61	(.49)	.77	(.42)
	dH	.46	(.50)	.51	(.50)	.64	(.48)

Note: Means for each grade range are calculated across all three time points. Standard deviations in parentheses. K3 – P2 = Kindergarten to Primary 2; P3 – P4 = Primary 3 to Primary 4; P5 – P6 = Primary 5 to Primary 6.

Table 4. Summary statistics showing mean accuracy rates per feature.

Feature	Group	K3 – P2		P3 – P4		P5 – P6	
Classifier Handshapes	dD	.42	(.50)	.73	(.44)	.90	(.31)
	dH	.27	(.44)	.45	(.50)	.76	(.43)
Non-Manuals	dD	.70	(.47)	.74	(.45)	.88	(.33)
	dH	.63	(.49)	.74	(.44)	.66	(.48)
Phonology	dD	.32	(.47)	.44	(.50)	.49	(.50)
	dH	.30	(.46)	.37	(.48)	.42	(.49)
Sign Order	dD	.75	(.44)	.89	(.32)	.93	(.26)
	dH	.60	(.49)	.77	(.42)	.86	(.35)
Use of Space	dD	.40	(.49)	.63	(.48)	.94	(.23)
	dH	.35	(.48)	.45	(.50)	.70	(.46)

Note: Means for each grade range are calculated across all three time points. Standard deviations in parentheses. K3 – P2 = Kindergarten to Primary 2; P3 – P4 = Primary 3 to Primary 4; P5 – P6 = Primary 5 to Primary 6.

Table 5. Interaction effects of age and HKSL structures from T1 – T2, T2 – T3, and T1 – T3

	T1 – T2				T2 – T3				T1 – T3			
	β	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*
Age × Agreement	0.64	0.28	2.32	**.021**	-0.15	0.24	-0.63	.787	0.03	0.20	0.14	.891
Age × Classifier	1.44	0.18	8.14	**.000**	0.63	0.18	3.44	**.003**	1.00	0.14	7.20	**.000**
Age × Modal	0.99	0.21	4.60	**.000**	0.13	0.20	0.64	.787	0.59	0.17	3.54	**.001**
Age × Negation	0.49	0.21	2.37	**.021**	0.04	0.21	0.18	.859	0.25	0.17	1.48	.174
Age × Wh-Question	0.59	0.18	3.37	**.001**	0.09	0.18	0.48	.787	0.38	0.14	2.75	**.010**

Note: For each age-structure interaction at each time point, the β (estimated coefficient), SE (standard error), z-score, and *p*-value are listed. Significant *p*-values are indicated in bold. These values are derived from the fitted GLMM models. Model structure: HKSL Score ~ Age × Structure + (1 + Age | Participant) + (1 + Age | Item).

Table 6. Interaction effects of age and HKSL features from T1 – T2, T2 – T3, and T1 – T3

	T1 – T2				T2 – T3				T1 – T3			
	β	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*
Age × Classifier Handshapes	0.75	0.23	3.18	**.002**	0.14	0.22	0.64	.520	0.58	0.18	3.28	**.001**
Age × Non-Manuals	1.08	0.24	4.56	**.000**	0.28	0.22	1.30	.241	0.63	0.18	3.52	**.001**
Age × Phonology	2.03	0.25	8.15	**.000**	0.73	0.22	3.28	**.005**	1.06	0.18	5.81	**.000**
Age × Sign Order	1.13	0.22	5.07	**.000**	0.47	0.21	2.27	**.039**	0.85	0.17	5.00	**.000**
Age × Use of Space	1.30	0.26	5.09	**.000**	0.61	0.23	2.65	**.020**	0.95	0.19	5.00	**.000**

Note: For each age-feature interaction at each time point, the β (estimated coefficient), SE (standard error), *z*-score, and *p*-value are listed. Significant *p*-values are indicated in bold. These values are derived from the fitted GLMM models. Model structure: HKSL Score ~ Age × Feature + (1 + Age | Participant) + (1 + Age | Item).

Results

dH group

From T1 to T2, dH children's accuracy significantly increased with age for all target HKSL structures (agreement, classifier, modal, negation, and wh-question structures). From T2 to T3, their accuracy only significantly increased for classifier constructions, while overall performance on other structures remained similar. When examining all three time points, significant improvements were seen in the children's accuracy in producing classifier, modal, and wh-question structures. However, no significant improvement was observed in their ability to produce agreement and negation structures.

From T1 to T2, dH children's accuracy rates increased with age for all features (classifier handshapes, non-manuals, phonology, use of space and sign order). From T2 to T3, they showed significantly increased accuracy in phonology, use of space, and sign order. However, there were no significant changes in accuracy rates for classifier handshapes and non-manuals. Across all time points, accuracy increased with age for classifier handshapes, non-manuals, phonology, use of space, and sign order. Model output is presented in Tables 5 and 6. Interactions between age and accuracy for each feature within each target structure are visualised in Figure 1.

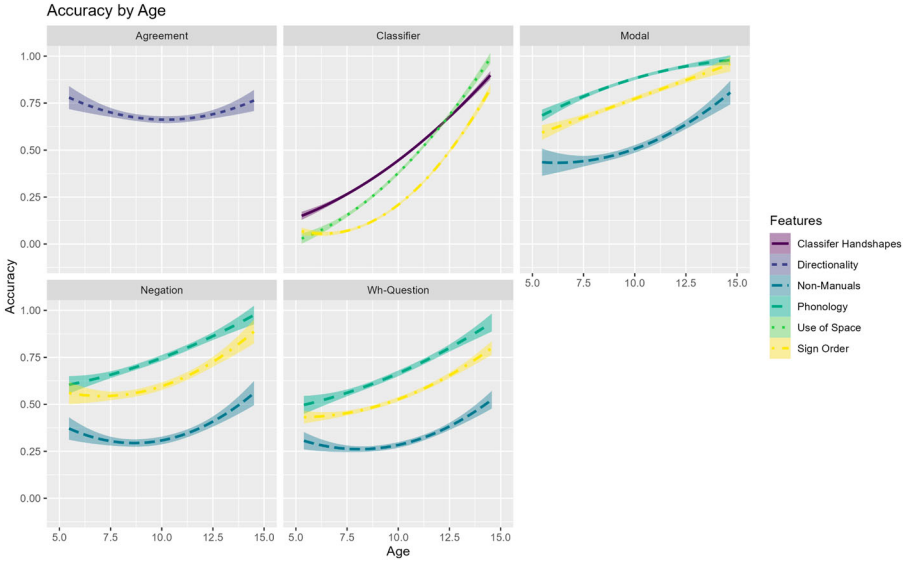


Figure 1. Accuracy for each structure and feature as a function of age for dH children from T1 to T3.

Note: Plots show changes in mean accuracy rates for each of the evaluated linguistic features within each structure type.

Table 7. Interaction effects of group (dD and dH) and HKSL structures at three time points.

	T1				T2				T3			
	β	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*
dD – dH × Agreement	−0.42	0.84	−0.50	.616	0.51	0.76	0.67	.502	2.59	1.25	2.07	.096
dD – dH × Classifier	2.36	0.46	5.17	**.000**	2.53	0.43	5.91	**.000**	1.13	0.38	2.95	**.016**
dD – dH × Modal	9.04	10.53	0.86	.488	1.68	0.74	2.25	**.040**	1.28	0.68	1.88	.100
dD – dH × Negation	1.17	0.63	1.87	.103	1.05	0.53	2.00	.057	0.52	0.50	1.04	.371
dD – dH × Wh-Question	1.67	0.46	3.64	**.001**	0.97	0.40	2.43	**.038**	0.25	0.38	0.66	.508

Note: For each group-structure interaction at each time point, the β (estimated coefficient), SE (standard error), z-score, and *p*-value are listed. Significant *p*-values are indicated in bold. These values are derived from the fitted GLMM models. Model structure: HKSL Score ∼ Group × Structure × Age + (1 + Age | Participant) + (1 + Age | Item).

Table 8. Interaction effects of group (dD and dH) and HKSL features at three time points.

	T1				T2				T3			
	β	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*
dD – dH × Classifier Handshapes	2.13	0.56	3.84	**.000**	2.41	0.51	4.73	**.000**	0.76	0.46	1.63	.141
dD – dH × Non-Manuals	1.32	0.57	2.31	**.021**	0.71	0.49	1.45	.149	0.33	0.48	0.67	.501
dD – dH × Phonology	2.84	1.06	2.67	**.009**	1.11	0.57	1.95	.064	1.06	0.51	2.06	.099
dD – dH × Sign order	2.49	0.54	4.58	**.000**	1.82	0.48	3.83	**.000**	0.72	0.45	1.59	.141
dD – dH × Use of Space	2.46	0.64	3.84	**.000**	3.09	0.84	3.66	**.000**	1.43	0.50	2.84	**.023**

Note: For each group-feature interaction at each time point, the β (estimated coefficient), SE (standard error), z-score, and *p*-value are listed. Significant *p*-values are indicated in bold. These values are derived from the fitted GLMM models. Model structure: HKSL Score ~ Group × Feature × Age + (1 + Age | Participant) + (1 + Age | Item).

Table 9. GLMMs for the effects of age, age of acquisition (AoA), verbal comprehension (VC), and verbal expression (VE) on HKSL scores.

	β	*SE*	*z*	*p*		*β*	*SE*	*z*	*p*		*β*	*SE*	*z*	*p*
(Intercept)	0.02	0.19	0.10	.922	(Intercept)	0.12	0.25	0.48	.633	(Intercept)	−0.08	0.18	−0.42	.676
Age	0.62	0.15	4.24	**.000**	Age	0.78	0.16	4.84	**.000**	Age	0.77	0.18	4.29	**.000**
AoA	−0.29	0.13	−2.22	**.027**	VC	0.20	0.15	1.32	.187	VE	0.28	0.14	2.09	**.037**
Age × AoA	0.05	0.11	0.41	.679	Age × VC	−0.24	0.13	−1.84	.066	Age × VE	−0.22	0.14	−1.57	.117

Note: Each row represents a different variable or interaction, and the columns display the estimated coefficient (β), standard error (SE), z-score, and *p*-value for each. Significant *p*-values are indicated in bold. Model 1 structure: HKSL Score ~ AoA × Age + (1 + Age + AoA | Participant) + (1 + Age | Item); Model 2 structure: HKSL Score ~ VC Score × Age + (1 + Age + VC Score | Participant) + (1 + Age | Item); Model 3 structure: HKSL Score ~ VE Score × Age + (1 + Age + VE Score | Participant) + (1 + Age | Item).

dD and dH group comparison

At T1, dD children were significantly more accurate in their production of classifier and wh-question structures in comparison to dH children. At T2, while the dD children were significantly more accurate than dH children in producing classifier constructions and wh-questions, no significant differences were observed between the two groups in their production of agreement, modal, and negation structures. At T3, dD children were significantly more accurate than dH children only in their production of classifier structures. Yet, when it came to agreement, modal, negation, and wh-question structures, the two groups did not differ significantly.

Comparing their performance on linguistic features, at T1, dD children had significantly higher accuracy than dH children across all of the evaluated features, which included classifier handshapes, non-manuals, phonology, use of space, and sign order. At T2, while dD children still exhibited a higher accuracy rate in classifier handshapes, use of space, and sign order, the two groups no longer differed significantly in non-manuals and phonology. At the final time point, T3, the dD children had significantly higher accuracy than the dH children in their use of space, but there were no significant differences between the two groups in their accuracy on classifier handshapes, non-manuals, phonology, and sign order. Model output is presented in Tables 3 and 4.

AoA and RDLS scores

There was a significant effect of age on HKSL-ET scores, indicating an overall increase in accuracy across all items with age. There was a significant effect of AoA, indicating an association between later HKSL exposure and lower overall HKSL-ET accuracy. Examining the RDLS scores, a significant positive correlation was observed between VE scores and accuracy in the HKSL-ET, suggesting that higher VE scores are associated with overall higher HKSL-ET accuracy. There were no significant effects associated with VC scores. Model output is presented in Table 5.

Discussion

In this study, we evaluated HKSL proficiency among bimodal bilingual deaf children. The assessment data was gathered over a span of two years, across three distinct time points, employing picture description and story-retelling tasks from the Hong Kong Sign Language Elicitation Tool (HKSL-ET). Our analysis focused on the accuracy rates of five target structures (agreement, classifier, modal, negation, and wh-question structures) and five target language features (classifier handshapes to refer to specific arguments, non-manual features, phonological parameters of functional signs, word order, and use of space). We used statistical analysis to identify correlations between accuracy rates and age,

which we take to be indicative of changes in the productive proficiency of dH children in the target structures and language features over time. Through additional analyses, we looked at how age of acquisition influences the development of HKSL proficiency, as well as the relationship between HKSL ability and the development of Cantonese verbal expression and comprehension.

For structures, based on the T1 and T2 assessments, we saw that dH children improved in their overall ability to accurately produce agreement, classifier, modal, negation, and wh-question structures. At T3, they only showed further improvement in their production of classifier constructions. A significant trend of sustained improvement across all three assessments was found for classifier, modal, and wh-question structures, but not for agreement or negation structures. For features, across the first year, the T1 and T2 assessments showed improved accuracy across all target features, which included classifier handshapes, non-manual features, phonological parameters, sign order, and use of space. Between T2 and T3, they showed further increases in accuracy for phonology, sign order, and use of space. Across all three assessments, we saw sustained improvements in all features.

As language acquisition does not adhere to a linear trajectory, we can expect variation in the rates at which dH children gain proficiency in different grammatical structures of HKSL. We saw an initial increase in accuracy across all structures among the dH children, but further improvement was found only in their production of classifier constructions by the last assessment at T3. Post-hoc tests showed that accuracy rates for classifier constructions were significantly lower than those of other tested structures across all time points ($b = -1.03$, $SE = 0.14$, $p < .001$). This indicates that these structures were particularly difficult for dH children to acquire and therefore require a longer time before reaching adult-like competence. Consequently, in contrast to their production of less complex structures, dH children showed continuous improvements in their production of classifier constructions, not only from T1 to T2 but also from T2 to T3.

While dH students showed continuous progress across assessments in their development of all target features, accuracy rates for sign order and non-manual features were revealed by post-hoc tests to be lower than those of other features (non-manuals: $b = -1.55$ $SE = 0.06$, $p < .001$; sign order: $b = -0.27$, $SE = 0.04$, $p < .001$). As the accuracy rates were especially low for non-manuals, we further examined the data to see what patterns exist in the non-target productions. We found that the most common type of non-target production was the use of Cantonese mouthings ($N = 533$) not commonly used by adult deaf signers, followed by the lack of any non-manual (i.e. a neutral facial expression) in obligatory contexts ($N = 325$; e.g. the absence of brow furrowing when producing a wh-question). In the literature, non-manuals are observed to be developmentally late (Reilly, 2005), so the persistence of non-adult-like production of non-manuals in dH and dD children is not atypical.

Sign order errors primarily involve the production of Chinese-like sign order—for example, producing functional signs like CAN in a pre-verbal position, in line with written Chinese and oral Cantonese, rather than the clause-final position standard in natural HKSL. Notably, the non-target productions in both non-manual features and sign order show the influence oral Cantonese and/or written Chinese in their performance, which is likely due to the high level of exposure to these languages that the deaf bimodal bilingual children receive in the co-enrollment setting through text, as well as their oral-language interactions with hearing teachers and classmates. This finding mirrors other studies, which have noted that HKSL-Cantonese bimodal bilingual children often employ code blending and code switching (Fung & Tang, 2016; Tang et al., 2015).

Comparing dD and dH children's overall scores on each structure at each time point, we found that dD children had higher accuracy in classifier and wh-question structures at T1. At T2, dD children were more accurate in their production of classifier, modal, and wh-question structures, and at T3, they had higher accuracy rates only in their production of classifier structures. Comparing dD and dH children on their accuracy in producing the target language features at T1, dD children had higher accuracy in their production of all features, which included classifier handshapes, non-manuals, phonological parameters, sign order, and use of space. At T2, dD children showed higher accuracy in their production of classifier handshapes, sign order, and use of space, but not in their non-manual features or phonology. By T3, dD children showed significantly higher accuracy than dH children only in their use of space.

Based on these comparisons, we see a notable pattern emerge: dD children show persistently higher accuracy in their production of classifier constructions and their use of space. In our analysis of interactions between assessment scores and AoA, we saw not only that later acquisition of HKSL correlates with lower overall HKSL accuracy, but also that children who start learning HKSL later in life experienced slower improvements in their signing abilities over time. This echoes the pattern we saw in the statistical comparison dD and dH children, wherein despite making continuous improvements in classifier constructions and the associated target language features (i.e. sign order, use of space, and classifier handshapes), there remained a gap between the two groups, particularly in their ability to use space in classifier constructions. This finding highlights the importance of early exposure to natural sign language in fostering the acquisition of grammatical structures and linguistic elements crucial for HKSL. As found in Mayberry (1993, 2007), delayed L1 acquisition impacts fluency and native-like mastery.

While it is rarely possible for hearing parents of deaf children to provide their children with robust exposure to sign language from the earliest stages, it is important to emphasise that dH children can achieve relatively strong signing skills if they are given adequate exposure to natural sign language in the

school setting. Investigating a different cohort of bimodal bilingual dH children, Tang and Li (2018) found that despite dH children's initial difficulties in producing classifier constructions, wherein they would often replace classifier verbs with lexical verbs, with continued exposure to HKSL, they eventually learned to accurately produce classifier constructions by the end of their primary education. The authors concluded that consistent exposure to HKSL in a bimodal bilingual co-enrollment setting can compensate, to some degree, for late sign language exposure, although the acquisition process may be longer for dH than for dD children. In the current study, while the dH children did not achieve the same level of accuracy in classifier constructions and use of space as the dD children, they did show a consistent positive trend in accuracy, indicating steady improvement over time. A future study would be needed to evaluate whether this trend continued long enough to close the gap between the two groups.

In this study, we also found a significant positive relationship between verbal expression in oral Cantonese and accuracy in the HKSL assessment among both dH and dD children. While there was a weak positive correlation between degree of hearing loss and HKSL accuracy [$r(87) = 0.35$, $p < .001$], suggesting that deaf children with higher degrees of hearing loss tended to be stronger signers, verbal expression scores did not significantly correlate with degree of hearing loss ($ps > .1$), indicating that this language ability may be more directly related to HKSL proficiency than to the degree of hearing loss. In line with previous studies on bimodal bilingual language development, these findings suggest that HKSL proficiency and oral language ability may be mutually supportive and that stronger abilities in verbal expression in Cantonese may enhance HKSL proficiency, and vice versa, regardless of the degree of hearing loss.

Translanguaging, as conceptualised by García and Wei (2015) is the fluid and dynamic process by which multilinguals utilise the entirety of their linguistic repertoire for communication. Wong et al. (2022), in their research on the same bimodal bilingual co-enrollment programme examined in our study, found that deaf bimodal bilingual students utilise translanguaging strategies, flexibly oscillating between oral Cantonese and HKSL. Wong et al. (2022) suggest that this practice facilitates bimodal bilingual students' access to multiple languages and promotes the development of their linguistic skills. Our findings indicate a tendency among dH children to exhibit cross-linguistic interaction through incorporating Chinese syntactic patterns and Cantonese mouthing into their signed productions. While this results in inaccuracies when evaluated against the standard of natural HKSL as used by deaf adults, these tendencies appear to diminish over time. This is underscored by the fact that bimodal bilingual deaf children can eventually demonstrate the ability to differentiate between manually coded Chinese and natural HKSL (Tang et al., 2015). In other words, the interactions between these languages prove to be beneficial,

as reflected in our findings, with HKSL and oral Cantonese developing in a mutually facilitative manner. Thus, the incorporation of both languages enriches the linguistic resources available to deaf children and enhances their communicative abilities.

Conclusion

Our study provides empirical insights into the development of HKSL proficiency within a population of deaf bimodal bilingual children and the complex relationship between HKSL and Cantonese in the bimodal bilingual co-enrollment context. We found that, while deaf children of hearing parents (dH children) who acquired HKSL later in life demonstrated slower progress and lower overall accuracy in certain HKSL structures and features, they did exhibit consistent improvement over time.

Notably, our findings showed that dH children, despite showing improved accuracy at each assessment point, continued to experience difficulty in accurately producing classifier constructions and the use of space compared to their deaf peers who had deaf parents (dD children). This underscores the importance of early and sustained exposure to natural sign language for acquiring the complex linguistic features unique to natural sign languages.

Furthermore, we found a positive correlation between HKSL and oral Cantonese proficiency, suggesting that bimodal bilingual communication practices (e.g. translanguaging, code blending, and code switching) commonly employed in the co-enrollment setting support the development of both the spoken and signed language. Although the initial effects of these cross-linguistic interactions may lead to non-target productions in the HKSL assessment, we observed a diminishing trend of these inaccuracies over time, indicating a growing ability in dH children to differentiate between the two languages. In sum, our study contributes to the growing body of research on sign language acquisition in bimodal bilingual co-enrollment settings, emphasising the importance of early and substantial exposure to a natural sign language for optimal linguistic development in deaf children. Looking forward, it would be beneficial for future research to investigate the final attainment in HKSL proficiency bimodal bilingual dD and dH adults who have graduated from the co-enrollment programme.

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