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School Readiness, Cognitive, and Language Abilities of Six 6-Year-Old Malay Children with Cochlear Implants: A Case Series

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ABSTRACT

Cochlear implant is an electronic medical device that helps to restore hearing in children and adults with sensorineural hearing loss by replacing the function of the damaged parts of the cochlea and electrically providing sound signals to the brain. For school-aged children, the ability to hear is crucial as it enables them to acquire school readiness skills that are vital to their learning in mainstream schools alongside normal hearing children. This study described the school readiness of six 6-year-old Malay children with cochlear implants together with their cognitive and language abilities prior to their school entry. The school readiness of the children with cochlear implants was rated by their parents based on the Year One School Readiness Scale. Their cognitive abilities were measured using the Comprehensive Test of Nonverbal Intelligence, Second Edition (CTONI-2) while their language abilities were determined using the Malay Preschool Language Assessment Tool (MPLAT), the

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Malay Language Assessment, Remediation, and Screening Procedure (Malay-LARSP), and the Multilingual Phonological Test (MPT). All findings were compared with the normative values obtained from same-aged normal hearing children. Results determined that 5 of 6 children with cochlear implants were not ready for mainstream school, 4 of 6 children with cochlear implants had cognitive abilities that were below average of developmental norms, and all 6 children with cochlear implants had language abilities that were not commensurable with their chronological age.

Keywords: Cochlear implant, cognitive abilities, language abilities, Malay children, normal hearing, school readiness

INTRODUCTION

Cochlear implant is an electronic hearing device that could help alleviate sensorineural hearing loss in children by replacing the function of the damaged parts of the cochlea and electrically transmitting sound signals to the brain (Justice et al., 2009). By restoring their ability to sense sounds, the device in turn helps the children to acquire language skills (Chang, 2017). It was found that prelingual hearing-impaired infants who were at certain levels of deprivation of auditory input had longer detection time and less interest to speech stimuli compared to normal hearing infants (Jusczyk & Luce, 2002). By not paying attention to the ordering of speech sounds of the language, a hearing-impaired infant may not be able to develop normal sensitivities to language-specific properties such as phonotactic and rhythmic cues, thus is unable to segment words from fluent speech and acquire vocabulary like a normal hearing infant could. Attention to sound stimuli is therefore a prerequisite in the acquisition of language in children (Houston et al., 2003).

Early detection of hearing loss and implantation of cochlear implants, among other factors, are strongly associated with improved speech and language performance in deaf children (Meinzen-Derr et al., 2010). Several studies reported children who received cochlear implants by 24 months of age exhibited good spoken language outcomes (Spiric et al., 2016; Suh et al., 2009) and were likely to catch up academically to their hearing peers in school (Nicholas & Geers, 2007). Early detection of hearing loss is key as the earlier the cochlear implantation, the more likely it is for children to be school-ready and to make a successful transition into the mainstream education system (Nicholas & Geers, 2007).

School readiness is a multi-dimensional concept that measures the preparedness of a child cognitively, socially, and emotionally to adapt and thrive in school settings (Sabol & Pianta, 2017). It is measured through five distinct domains, which are physical well-being and appropriate motor development, emotional health and a positive approach to new experiences, age-appropriate social knowledge and competence, age-appropriate language skills, and age-appropriate general knowledge and cognitive skills (Janus & Offord, 2007). In the context of formal education, children would need to be equipped with basic literacy and numeracy skills in order to be considered school-ready (Wei & Hutagalung, 2014). The relationship between literacy skills and language skills are reciprocal as the engagement in literacy activities require a metalinguistic focus central to oral or written language (Justice, 2005). Similarly, language development is integral to the development of number representations and consequently in the learning of numeracy skills (Spaepen et al., 2011). These findings implicated the importance of language skills for children to develop other fundamental skills for school readiness.

In a study by Umat et al. (2018), children with cochlear implants were found to perform significantly lower in overall school readiness compared to their hearing peers and were rated to perform '*below average*' in the domains of civic, language and communication, and academic. The poor school readiness skills were expected as the children were implanted late at the mean age of 29.9 months. Similarly, Harrington et al. (2010) found that children who were implanted at the relatively late age of 24.3 months did not demonstrate the school readiness level expected of their chronological age. The poor school readiness of children with cochlear implants could be explained through the developmental psychobiological approach model, which suggested the children have not obtained the necessary self-regulation abilities to allow them to effectively engage in learning activities in school (Blair & Raver, 2015). These self-regulation abilities are embodied in, but not limited to, a child's ability to focus and maintain attention, regulate emotion and stress physiology, reflect on information and experience, and engage in sustained positive interactions with teachers and peers.

Cupples et al. (2018) noted there was a large degree of variability and individual factors in the success rate of children with cochlear implants in the acquisition of speech and language leading to school readiness. For one, the study determined the use of oral language and higher cognitive ability levels were indicative of higher language outcomes. Along with poor language skills, Umat et al. (2018) stated children with cochlear implants showed poor academic abilities. Furnham et al. (2009) deduced the biggest contributor to academic outcomes of school children was their cognitive abilities. This was substantiated by findings that cognitive abilities largely contributed to the school readiness skills of young children (Harrington et al., 2010). Mukari et al. (2007) reported while most Malaysian children with cochlear implants were enrolled into mainstream schools, the placements were not necessarily appropriate as they showed relatively poor academic performance. Thus, this present study aimed to report on the school readiness together with the cognitive and language abilities of children with cochlear implants at school-entry age through a case series of six 6-year-old Malay children with cochlear implants. Due to their late age of implantation, it was hypothesized the children in this study would not perform up to par with their hearing peers in overall school readiness, cognitive, and language skills. The evidence could be used to push for the implementation of policy for early implantation and intervention of deaf children in Malaysia in order to maximize their potential in school and beyond.

Purpose of Study

Malaysia has documented a sizable number of cochlear implantation from two of its largest cochlear implant programmes, the Universiti Kebangsaan Malaysia (UKM) Cochlear Implant Programme (n=410) (Goh et al., 2018) and the National Cochlear Implant Programme under the Malaysian Ministry of Health (n=205) (Malaysian Ministry of Health, 2017). The average age of cochlear implantation of patients from the two programmes were relatively late at 39.8 months (Goh et al., 2018) and 41.5 months (Yusoff et al., 2017) respectively. Similarly, the children with CI in this study had a late average age of cochlear implantation at 39.8 months. It is important to report on the outcomes of the children with CI from this late age of cochlear implantation in hope of providing better insight to healthcare professionals in designing appropriate intervention strategies to help these children achieve optimum academic performance in school. To date, there are very few published studies in Malaysia reporting on the outcomes of patients post cochlear implantation, with only one study reporting on mainstream school readiness of paediatric cochlear implant recipients in Malaysia (Umat et al., 2018). This study adds on to the previous study by describing the school readiness together with the cognitive abilities and language abilities of six 6-year-old hearing-impaired Malay children with cochlear implants (CI) as compared to the normative data of same-aged normal hearing (NH) children.

MATERIALS AND METHODS

Research Design

This study employed the qualitative research design through descriptive case series reporting on the school readiness, cognitive abilities, and language abilities of six 6-year-old Malay children with CI.

Subjects

A total of six 6-year-old Malay children with CI and their respective parents were involved in the study. The children with CI were selected from the UKM and National CI Programmes based on five inclusion criteria: they need to be 1) 6 years old in 2017; 2) attending the final year of preschool in 2017; 3) of Malay ethnicity and the Malay language is their native language; 4) prelingually deaf prior to cochlear implantation; and 5) free from additional disabilities. Based on the inclusion criteria, 11 children with CI were invited to participate in the study but only six were consented by their respective parents to participate. Their age of cochlear implantation (the age between chronological date of birth and age during switch-on of CI) ranged from 2;1 (years;months) to 5;7

(Mean=39.83 months, SD=18.39 months). Table 1 reports the demographics of the six children with CI.

Table 1

Demographics of the six 6-year-old Malay children with CI

Subject	Gender	Chronological age (y;m)	Age of CI implantation (y;m)	Hearing age (y;m)	Type of CI fitting	Radiological findings
CI_1	Female	5;10	2;4	3;6	Unilateral	Normal
CI_2	Female	6;3	2;10	3;4	Bilateral	Normal
CI_3	Female	6;7	2;1	4;6	Bimodal	Normal
CI_4	Male	5;11	4;11	1;0	Bimodal	Bilateral cochlear anomaly and large endolymphatic sac
CI_5	Male	6;4	5;7	0;9	Bimodal	Large vestibular aqueduct
CI_6	Male	6;8	2;2	4;5	Bilateral	Normal

Footnote: (y;m)=(years;months)

Research Instruments

Year One School Readiness Scale (Majzub, 2009). The school readiness of the children with CI was rated by their respective parents using the Year One School Readiness Scale. The questionnaire assesses respondents' perception on the different domains of school readiness (A=academic, B=socio-emotional, C=gross motor abilities, D=fine motor abilities, E=self-help skills, F=language and communication, G=moral, H=aesthetic and creativity, and I=civic). The overall alpha value obtained for all domains of school readiness based on the sampling of 380 6–year-old NH children was very high at 0.96. This makes the questionnaire a reliable tool to gauge the school readiness of Malaysian children who are entering their first primary school year. The mean overall school readiness of each child with CI in this study was compared with the mean of the normative 380 6-year-old NH children. From the normative data, the following four categories were computed as benchmark for school readiness: '*not prepared*' (<25th percentile, Mean=<3.77), '*moderately prepared*' (25th to 50th percentile, Mean=3.77-4.24), '*prepared*' (51st to 75th percentile, Mean=4.25-4.68), and '*very prepared*' (>75th percentile, Mean=>4.68).

Comprehensive Test of Nonverbal Intelligence, 2nd Edition (CTONI-2) (Hammill et al., 2009). CTONI-2 was used to assess the cognitive abilities of the children with CI. The test uses nonverbal formats to measure the reasoning and problem solving skills of children and adults aged between 6 to 89 years old. CTONI-2 consists of six subtests, namely Pictorial Analogies (PA), Geometric Analogies (GA), Pictorial Categories (PC), Geometric Categories (GC), Pictorial Sequences (PS), and Geometric Sequences (GS). The tool measures analogical reasoning, categorical classification, and sequencing reasoning skills using picture stimuli. The CTONI-2 has demonstrated adequate reliability for individuals aged 6 years old. The present study utilized age-normed composite scores (M=100, SD=15) comprised of all six subtests (r=0.88 to 0.91) as a measure of nonverbal intelligence. The raw scores obtained at the end of all the six subtests of CTONI-2 were converted to sum of scaled scores and composite indexes based on the normative data of their chronological age group. The composite indexes served as the reference data for analysis and were compared to the following normative values of the age range 6;0 to 6;11: <70 ('*very poor*'), 70-79 ('*poor*'), 80-89 ('*below average*'), 90-110 ('*average*'), 111-120 ('*above average*'), 121-130 ('*superior*'), and >130 ('*very superior*'). A standard score of 2 SD below norm is considered developmentally of concern.

Malay Preschool Language Assessment Tool (MPLAT) (Razak et al., 2014). MPLAT is designed to measure the receptive and expressive use of language among preschool children of age 4;0 to 6;11. The test consists of five subtests: Picture Vocabulary (PV) and Grammatical Understanding (GU) to measure receptive language abilities; Referential Meaning (RefM), Relational Meaning (RelM), and Sentence Repetition (SR) to assess expressive language abilities. Three of the subtests (SR, GU, and RelM) had ceiling level score whereby ceiling effect is reached after five consecutive wrong responses or no response, after which the tests were immediately halted. Initial reliability measures were determined through the test-retest scores of MPLAT on a total of 101 typically developing children in the Klang Valley. The test-retest scores for subtests RefM, RelM, and SR showed high correlation coefficients of >0.80 while the PV and GU subtests showed acceptable reliability values of 0.78 and 0.77 respectively. The standard scores obtained from the children with CI were analysed based on the normative data of NH children (Mean=20, SD=4). A standard score of 2 SD below norm is considered developmentally of concern.

Malay Language Assessment, Remediation, and Screening Procedure (Malay-LARSP) (Razak et al., 2016). Malay-LARSP was used to produce language profiles based on spontaneous speech of the children with CI in free conversations. It provides a comprehensive description of grammatical skills at the sentence, phrase, and word level. The extracted combinations were then profiled based on the various developmental stages of syntactic acquisition: stage 1 (one-word utterance level), stage 2 (two-word utterance level), stage 3 (three-word utterance level), stage 4 (4-word utterance level), stage 5 (inter-sentence level through the use of coordination, subordination, and embedding processes), stage 6 (complexity/error tabulation), and stage 7 (discourse level). Also, their mean length of utterance (MLU) was calculated. In this study, the Cohen's kappa inter-rater reliability on the analysis by the main researcher and two speech therapists who have had extensive experience with the assessment were very high at 0.85 and 0.88 respectively. The reliability scores indicated an almost perfect agreement (McHugh, 2012).

Multilingual Phonological Test (MPT) (Lim, 2010). MPT was used to assess the phonological development through consonant inventory of the children with CI. All 19 original Malay consonant sounds were tested at least once in the three positions within the word: initial, medial, and final. The test consists of 26-word items and five repeated word items to test for intra-word consistency of production. The overall production was scored using the formula for percentage of consonants correct [PCC = (Total consonants correct / total number of consonants) x 100]. Also, the stages of lexical acquisition, consistency of intra-word production, and inventory of consonants acquired by the children with CI were determined. The Cohen's kappa inter-rater reliability scores of the MPT analysis obtained in this study were very high at 0.85 and 0.92.

RESULTS

Year One School Readiness Scale

From the normative data of the questionnaire, it was determined only 25% (n=95) of the NH children were '*not prepared*' for mainstream school. As for the remainder of the NH children, 25.3% (n=96) were '*moderately prepared*', 11% (n=42) were '*prepared*', and 38.7% (n=147) were '*very prepared*'. In contrast, five of the six children with CI in this study were rated by their parents as '*not prepared*', which meant 83.3% of the study sample were not ready for mainstream schools. Only one child with CI (CI_6) was found to have achieved school readiness and was rated as '*prepared*'. Table 2 reports the school readiness scores of each of the six children with CI based on the normative cut-off scores of the NH children.

The majority of the children with CI were rated by their parents to be below the lower quartile (<25th percentile) in the domains of academic (5 out of 6), language and communication (5 out of 6), and civic (6 out of 6). Of the nine domains, CI_1 and CI_4 were rated to perform below the 25th percentile in four domains, CI_3 in five domains, CI_2 and CI_5 in seven domains, while CI_6 only in two domains. The individual performances of all six children

Table 2

The school readiness of the six 6-year-old Malay children with CI

Subject	School readiness scores [Mean (SD)]	Not prepared (<3.77)	Moderately prepared (3.77-4.24)	Prepared (4.25-4.68)	Very prepared (>4.68)
CI_1	3.19 (0.96)	✓	-	-	-
CI_2	3.16 (0.63)	✓	-	-	-
CI_3	3.66 (0.81)	✓	-	-	-
CI_4	3.68 (0.83)	✓	-	-	-
CI_5	3.15 (0.54)	✓	-	-	-
CI_6	4.25 (0.50)	-	-	✓	-

with CI on each domain of school readiness are reported in the boxplots in Figure 1.

Further analysis using Pearson's correlation coefficient (r) indicated the correlation between domain A (academic) and overall school readiness of the NH children was strong and positive (r=0.84, p<0.001). The large effect size (r^2) of 0.71 showed 70.6% of the variability in the NH children's overall school readiness can be predicted by the variability in their academic scores (domain A). Similarly, the correlation between domain F (language and communication) and overall school readiness of NH children was strong and positive (r=0.90, p<0.001). The large r^2 of 0.81 indicated 81% of the variability of NH children's overall school readiness could be predicted by the variability in their language scores (domain F).

For children with CI, domain A and overall school readiness indicated a non-significant correlation (r=0.73, p=0.10). There is however a strong and positive correlation between domain F and overall school readiness (r=0.93, p=0.007) with a large r^2 of 0.87. This indicated 86.5% of the variability in overall school readiness of children with CI could be predicted by the variability in their language scores (domain F).

CTONI-2

Analysis of CTONI-2 scores of the children with CI based on the normative age group 6;0 to 6;11 indicated two of them (CI_1 and CI_3) were in the range of '*poor*' nonverbal intelligence and another two (CI_4 and CI_5) were '*below average*'. Two children with CI were within or above the normal range for the same age group, with CI_2 being in the '*average*' nonverbal intelligence range and CI_6 in the '*above average*' range. The findings indicated four of six children with CI had nonverbal intelligence that did not commensurate with their chronological age. Despite the below average performance, none of the four children with CI demonstrated performance that was 2 SD below norm, clearing them

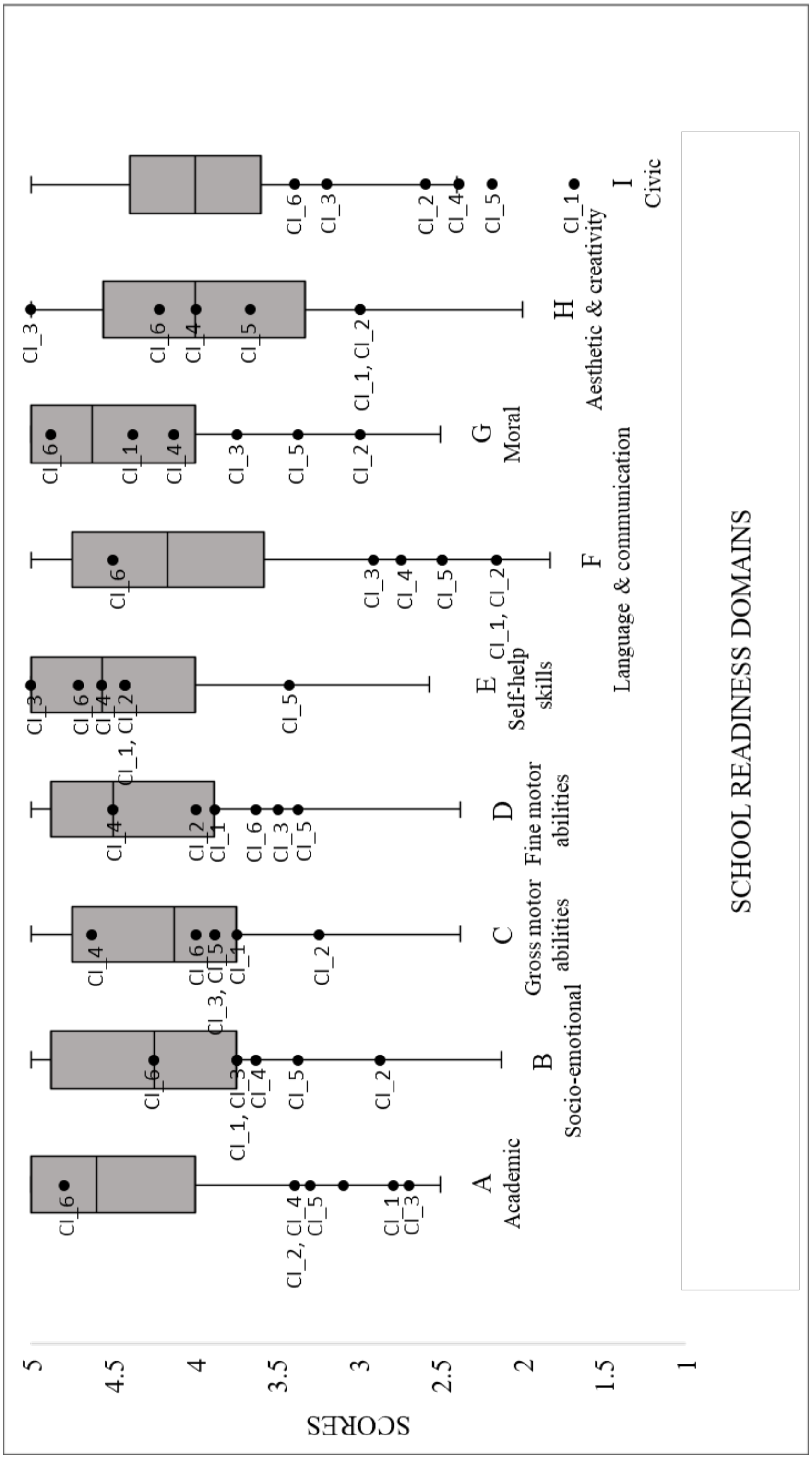

Figure 1. Performance on individual domains of school readiness of the six 6-year-old Malay children with CI as compared to the normative data of NH children

of developmental delay (Harvill, 1991). Figure 2 below illustrates the nonverbal intelligence level of each of the six children with CI.

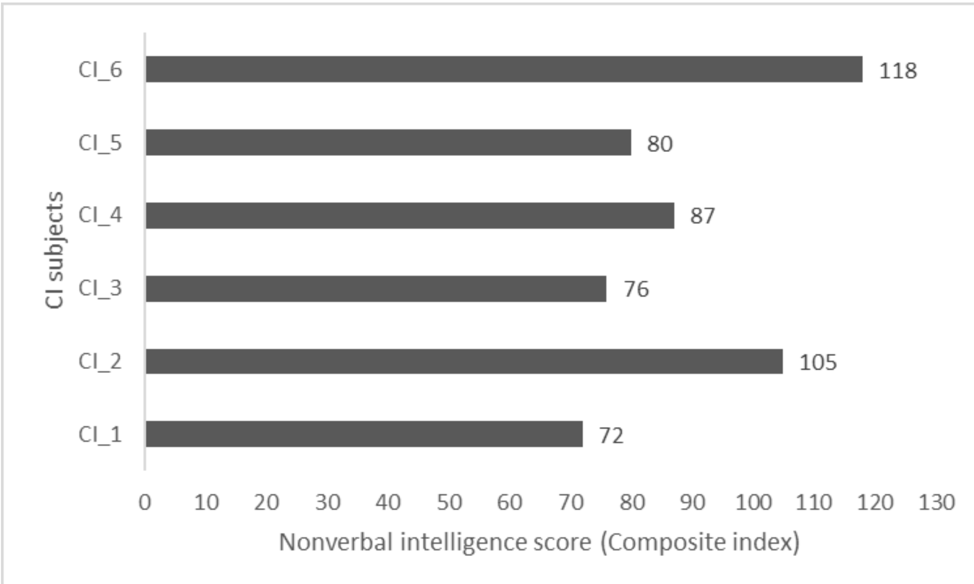

Figure 2. Nonverbal intelligence scores of the six 6-year-old Malay children with CI

Footnotes: Range of composite index and their corresponding descriptive nonverbal IQ terms (Hammill et al., 2009); <70=*very poor,* 70-79=*poor,* 80-89=*below average,* 90-110=*average,* 111-120=*above average,* 121-130=*superior,* >130=*very superior.*

MPLAT

Findings in MPLAT determined three of the children with CI (CI_2, CI_3, and CI_5) performed below the minimum range of the language age 4;0-4;5 while two (CI_1 and CI_4) were within the range of scores for the same age group, and one child (CI_6) performed above mean for the language age of 5;6-5;11. The children with CI showed better performance in their receptive language skills compared to their expressive language skills (refer to Figure 3). However, only CI_3 was presented to have delayed receptive language (over 2 SD below mean) while five of the six children with CI, except for CI_1, showed delayed expressive language abilities based on their respective language age groups (Razak et al., 2014). Overall, the language abilities of the six children with CI were considered to be delayed as they did not perform as expected of their chronological age.

Malay-LARSP

Language samples collected from five of the six children with CI (CI_1, CI_2, CI_4, CI_5, and CI_6) were analysed and described based on the stages of Malay-LARSP. CI_3 produced only two impromptu utterances and was thus excluded from the assessment

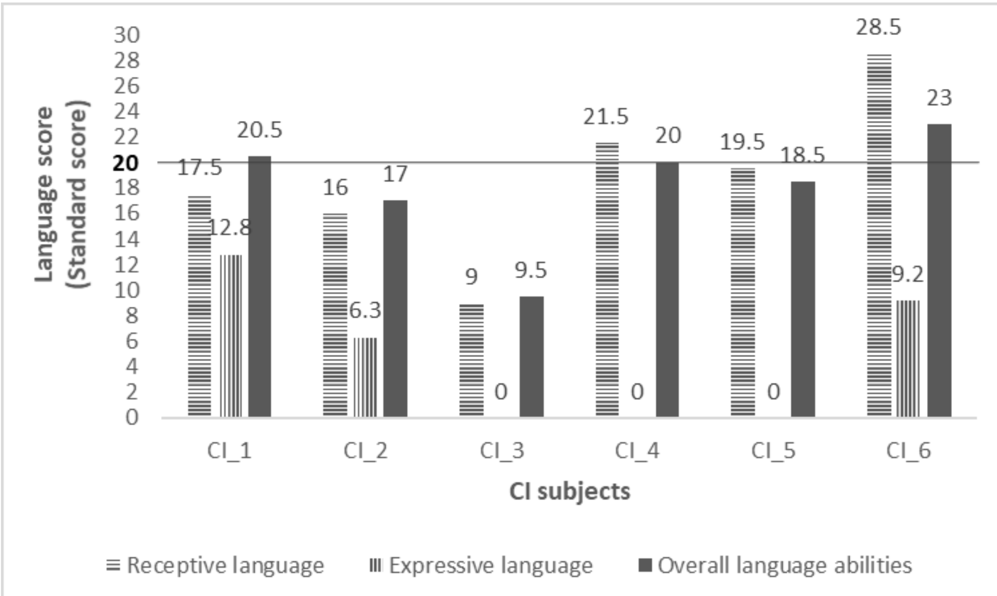

Figure 3. Standard scores of receptive, expressive, and overall language performance of the six 6-year-old Malay children with CI in MPLAT

Keynotes:

1. Receptive language [Picture Vocabulary (PV) and Grammatical Understanding (GU)]
2. Expressive language [Sentence Repetition (SR), Referential Meaning (RefM), and Relational Meaning (RelM)]

Footnotes:

1. CI_1 to CI_5: Based on the normative data of language age 4;0 to 4;5
2. CI_6: Based on the normative data of language age 5;6 to 5;11
3. Normative average for all language age groups is the standard score of 20, SD=4 (Razak et al., 2014)
4. Standard score of zero is given when the child could not answer any of the three tests for expressive language before reaching the ceiling effect. This result, however, does not indicate the absence of expressive language in the child as MPLAT tests pre-selected language structures of children within the age range of 4;0 to 6;11. This indicated that CI_3, CI_4, and CI_5 might have had expressive language abilities that were below the age of 4;0

as a minimum of 50 utterances is required for a representative language sample (Boehm et al., 2005). The expressive language of CI_2, CI_4, and CI_5 corresponded to the language age of 1;0 to 2;2 (Brown, 1973) and their utterances were most dominant in stage I. This corresponded to their MLU of 1.78, 1.41, and 1.41 respectively. They however could not produce complex sentence structures through the expansion of phrases. They also demonstrated errors such as omission and order reversal of elements. Of the three children with CI, CI_2 made the most error [omission (n=6) and order reversal (n=2)] compared to CI_4 [omission (n=1)] and CI_5 [omission (n=2)]. This indicated CI_2 might be actively combining elements to produce longer sentences, which explained why the child's MLU was higher than that of CI_4 and CI_5.

CI_1 and CI_6 had higher expressive language frequency that corresponded to the age range of 2;3 to 2;6 and 2;11 to 3;4 respectively. CI_1 produced utterances with highest concentration in stages I and II. The child was also able to produce expansion of phrases at stage III (n=5) and at stage IV (n=3), and also produced errors [omission (n=5) and order reversal (n=7)], which contributed to the high MLU of 2.33. On the other hand, CI_6 produced utterances with highest concentration in stages II and III. The child was also able to produce expansion of phrases at stage III (n=8) and complex structures at stage IV (n=2). CI_6 also produced many errors in utterances [omission (n=10) and order reversal (n=3)]. These activities contributed to CI_6's high MLU of 3.21. One common finding across all the five language samples was the omission of words by the children with CI in their utterances. This indicated the limited and small vocabulary inventory, as well as the possibility of slow vocabulary growth amongst the children with CI. Table 3 below describes the findings of Malay-LARSP based on the respective language samples of the five children with CI.

Table 3
Malay-LARSP findings of the five 6-year-old Malay children with CI

Subject	CI_1	CI_2	CI_4	CI_5	CI_6
Syntactic stages of utterances produced (%)	Stage I (30.1%)	Stage I (49.3%)	Stage I (66.4%)	Stage I (59.3%)	Stage I (15.7%)
	Stage II (45.9%)	Stage II (28.2%)	Stage II (16.4%)	Stage II (18.6%)	Stage II (48.7%)
	Stage III (14.3%)	Stage III (11.9%)	Stage III (9.1%)	Stage III (18.6%)	Stage III (25.1%)
	Stage IV (9.7%)	Stage IV (10.6%)	Stage IV (6.4%)	Stage IV (3.5%)	Stage IV (6.8%)
			Stage V (1.7%)		Stage V (3.7%)

Table 3 *(Continued)*

Subject	CI_1	CI_2	CI_4	CI_5	CI_6
Expansion of phrases (n)	Stage III: X+V:VP (4) X+A:AP (1) Stage IV: XY+O:NP (1) XY+A:AP (2)	None	None	None	Stage III: X+S:NP (4) X+V:VP (1) X+O:NP (1) X+A:AP (2) Stage IV: XY+V:VP (1) XY+A:AP (1)
Errors made (n)	Ø (5) ↔ (7)	Ø (6) ↔ (2)	Ø (1)	Ø (2)	Ø (10) ↔ (3)
MLU	2.33	1.78	1.41	1.41	3.21
Highest concentration of structures	Stage II (2;3 to 2;6)	Stage I (1;0 to 2;2)	Stage I (1;0 to 2;2)	Stage I (1;0 to 2;2)	Stage III (2;11 to 3;4)

Footnotes:
1. X+V:VP=Element + Verb: Verb Phrase
2. X+A:AP=Element + Adverb: Adverb Phrase
3. X+S: NP=Element + Subject: Noun Phrase
4. X+O: NP=Element + Object: Noun Phrase
5. XY+O: NP=Elements + Object: Noun Phrase
6. XY+A: AP=Elements + Adverb: Adverb Phrase
7. XY+V: VP=Elements + Verb: Verb Phrase
8. Ø=Omission of elements
9. ↔=Order reversal of elements

MPT

Analysis of findings in MPT determined all of the children with CI scored less than 94.2% of consonants correct, which was below the average percentage expected of children aged 4;0 and above (Lim, 2010). Only one child with CI (CI_6) scored near the average of the age group, with 93.6% of consonants correct. Similarly, only CI_6 was found to have acquired all 19 Malay consonant sounds. The remaining five children with CI had yet to fully acquire all the consonant sounds, indicating they had delayed phonological inventories as all the sounds were supposed to be acquired by the age of 4;0 to 4;5 (Lim, 2010). Table 4 below reports the PCC and the corresponding degree of severity, intra-word production consistency, and acquired and missing consonant sounds of each of the six children with CI.

Table 4

MPT findings of the six 6-year-old Malay children with CI

Subject	CI_1	CI_2	CI_3	CI_4	CI_5	CI_6
PCC	61.3%	46.8%	8.1%	75.8%	51.6%	93.6%
*Degree of severity	Moderate-severe	Severe	Severe	Mild-moderate	Moderate-severe	Mild
Intra-word production consistency	3/5	2/5	3/5	4/5	3/5	5/5
Acquired consonants	p, b, t, d, ʔ, t͡ʃ, d͡ʒ, m, n, ɲ, ŋ, l, w, j	p, b, t, d, ʔ, s, h, t͡ʃ, m, n, ɲ, ŋ, l, r, w, j	h, t͡ʃ, m	p, b, t, d, k, g, ʔ, h, t͡ʃ, d͡ʒ, m, n, ɲ, ŋ, l, r, w, j	p, b, t, d, g, ʔ, t͡ʃ, d͡ʒ, m, n, ɲ, l, w, j	p, b, t, d, k, g, ʔ, s, h, t͡ʃ, d͡ʒ, m, n, ɲ, ŋ, l, r, w, j
Missing consonants	k, g, s, h, r	k, g, d͡ʒ	p, b, t, d, k, g, ʔ, s, d͡ʒ, n, ɲ, ŋ, l, r, w, j	s	k, s, h, ŋ, r	None

Footnotes:
*Degrees of severity based on PCC index values (Wertzner et al., 2005):
1. Mild (>85%)
2. Mild-moderate (85% to 65%)
3. Moderate-severe (50% to 65%)
4. Severe (<50%)

Triangulation of Results from Cognitive and Language Assessments

CI_6 consistently performed the best out of the six children with CI in all language assessments. The child performed above mean of the language age 5;6 to 5;11 in MPLAT with the standard score of 23, which was better than expected of the child's hearing age of 4;5 and only about a year delayed from the child's chronological age of 6;8. CI_6 also had the highest MLU of 3.21 in Malay-LARSP and the child was able to produce complex utterances as part of developing language repertoire. CI_6's relatively good language performance could be explained through MPT results which determined the child had a complete speech sound inventory and obtained an acceptable PCC of 93.6%. Like the child's language scores, CI_6 obtained the highest cognitive score among the six children (composite index=118). The score indicated the child's nonverbal intelligence was '*above average*' based on his age group. In contrast, CI_3 showed the second poorest cognitive score (composite index=76) and was categorically under the '*poor*' range of the same age group. Furthermore, CI_3 obtained the lowest scores on the language assessments, performing significantly below the age of 4;0 to 4;5 in MPLAT with the standard score of 9.5. This indicated a performance that was delayed based on both the child's hearing age of 4;6 and chronological age of 6;7. Malay-LARSP analysis could not be completed for CI_3 due to limited expressive language and the child's MPT results confirmed a low PCC of 8.1% and a low speech sound inventory as the child had yet to acquire most of the consonant sounds, limiting the child's vocabulary production.

CI_1 and CI_4 obtained similar standard scores of 20.5 and 20 respectively, which were within mean of the language age 4;0 to 4;5 in MPLAT. Their findings in Malay-LARSP however varied as CI_1 obtained a higher MLU of 2.33 compared to CI_4's 1.41, which was due to CI_1's ability to produce complex sentence structures. While the language performance was below expected of their chronological age of 5;10 (CI_1) and 5;11 (CI_4), they performed better than expected of their hearing age of 3;6 (CI_1) and 1;0 (CI_4). Both CI_1 and CI_4 had obtained most of the speech sounds but the incomplete inventory resulted in their low PCC of 61.3% and 75.8% respectively. Despite the similar language scores, CI_1 and CI_4 showed differing cognitive performances. CI_4 who was categorized under the '*below average*' cognitive range (composite index=87) performed better than CI_1 under the '*poor*' range (composite index=72). Both their scores ultimately indicated the cognitive performance of below average of their age group, but are not developmentally delayed.

CI_2 and CI_5 performed about 1 SD below mean of age group 4;0 to 4;5 in MPLAT with the standard scores of 17 and 18.5 respectively, which were indicative of their respective hearing ages of 3;4 (CI_2) and 0;9 (CI_5). Their performance was however delayed from their chronological age of 6;3 (CI_2) and 6;4 (CI_5). Their performance in Malay-LARSP was also similar with the MLU of 1.78 (CI_2) and 1.41 (CI_5). The low MLU was the result of their incomplete speech sound inventory and low PCC of 46.8% (CI_2) and 51.6% (CI_5), inhibiting them from forming larger number of words and longer sentences. Their cognitive scores however indicated different performances. CI_2 obtained the second highest score (composite index=105) among the children and was categorically under the '*average*' range of nonverbal intelligence. On the other hand, CI_5 obtained '*below average*' score (composite index=80) and was categorically under the '*below average*' range of the same age group.

DISCUSSION

Findings showed five of the six 6-year-old Malay children with CI in this study were rated by their parents to be not prepared to enrol into mainstream schools. Their poor scores on overall school readiness were attributed to their poor performance (below 25th percentile of normative data) in skills required for them to thrive in mainstream education setting. In contrast, Majzub and

Rashid (2012) found there were generally high levels of school readiness in typically-developing NH children. This indicated that at six years old, the NH children had obtained the necessary self-regulation abilities that allowed them to effectively engage in learning activities, which were pivotal to the adjustment into mainstream schools (Blair & Raver, 2015). Umat et al. (2018) found that compared to NH children, hearing-impaired children had less optimum auditory experience, which might have negatively impacted their self-regulation abilities at biological and behavioural levels. This consequently affects their overall readiness to school, as evidenced in this study. Parents of the five children with CI felt that their children had yet to acquire all the important skills underlying school readiness, resulting in them being rated as unprepared. CI_6 on the other hand, was rated to show commensurable performance with NH peers in most of the domains, which was why the child was deemed ready to be placed in mainstream schools alongside normal hearing peers.

Findings of cognitive abilities determined two of the six children with CI performed comparably to NH peers aged 6;0 to 6;11. This is consistent with findings in literature that children with prelingual deafness showed age-typical level of performance on nonverbal cognitive tasks (Cejas et al., 2018; Karpicke et al., 2011; Lee et al., 2015) as the tests measure skills such as perceptual organization, abstract reasoning, and problem solving without the influence of the children's language abilities or lack thereof (Barbosa et al., 2013). In contrast to the previous studies, four of the six children with CI in this study had nonverbal intelligence scores that did not commensurate with their chronological age. Even though below average of their age group, their cognitive scores were not developmentally of concern as all the scores were not more than 2 SD below norm of the age group. Emmett et al. (2015) suggested demographic and socioeconomic factors were strongly associated with higher nonverbal intelligence scores in hearing-impaired children. Unique child factors, such as genetic, environmental, and lifestyle factors (Oommen, 2014) could have influenced the varied outcome of cognitive performance of the children with CI. This could explain why a significant association was not established between domain A (academic), which was the biggest contributor to cognitive abilities (Furnham et al., 2009), and overall school readiness of the children with CI in this study ($r=0.73$, $p=0.10$). It is therefore imperative the assessment of nonverbal cognitive abilities is not carried out in isolation to the demographic and socioeconomic variables in hearing-impaired children with CI.

Findings of language assessments determined all six children with CI did not demonstrate language performance that was commensurable with their chronological age. Bavelier et al. (2008) attributed the relatively poor language performance in hearing-impaired children to the delayed development of their vocabulary, which was why children were encouraged to build on their vocabulary inventory in order to increase the likeliness of successful integration into school (Weitzman & Greenberg, 2010). Khoramian and Soleymani (2018) stated the development of vocabulary was directly linked to components of the Baddeley and Hitch's (1974) working memory model, specifically the central executive and phonological loop. The central executive controls all attention and processing activities and regulates the flow of information in the processing system while the phonological loop is involved in the temporary storage of phonological memory codes. Young children were found to exhibit a dramatic increase in their ability to remember phonological information, which was attributed to the increase in their working memory capacity and its processing efficiency, resulting in dramatic improvements in their speech and language skills (Cowan et al., 2012). The abilities however decline with age. In this study, all the six children with CI had missed the early opportunity for normal language learning as they were implanted relatively late and only started hearing after the age of 2;0 (Nicholas & Geers, 2007). It is therefore suggested their below-average language performance might stem from their shorter memory spans leading to slower vocabulary growth as compared to age-matched typically developing children (Pisoni & Cleary, 2003).

The Malay-LARSP profiles of the children with CI evidenced their low vocabulary repertoire, inhibiting them from forming longer sentences. They produced mostly utterances in stages I and II when they should be producing utterances at stage V at their age (Brown, 1973). The lack of vocabulary was further explained through their performance in MPT whereby all of them produced PCC below the normal percentage of 94.2% for children aged 4;0 and above (Lim, 2010). The finding suggested weak phonological awareness had resulted in the children's difficulty to learn vocabulary (Baddeley & Gathercole, 1990). Weaknesses in phonological awareness have been similarly described in previous literature as a basis for weak vocabulary skills in children (Estes & Bowen, 2013; Hu & Schuele, 2005; Ravenska & Hidajat, 2011). Phonological awareness is defined as the sensitivity to the unit of sound of oral language, including the awareness of sentences, words, syllables, and phonemes (Ziolkowski & Goldstein, 2015). Phonological awareness is central to phonological acquisition and subsequently word learning in children (Carey & Bartlett, 1978; Grech & Dodd, 2008). Therefore, based on the low sound production correctness and the incomplete phonological acquisition of five of the children with CI in this study, their small vocabulary inventory was explained. The relatively commensurable performance of CI_6 in MPT as compared to NH peers thus explained the child's ability to perform better than the other five children with CI in language assessments. This could have resulted in the child being rated as prepared for mainstream schools because good language skill is one of the key indicators of a student's academic success and effective participation in class learning (Sprenger, 2013). The finding on the positive correlation between domain F (language and communication) and overall school readiness (r=0.93, p=0.007), as well as the large r^2 of 0.87 in this study further supported the predictability of children's performance in school through their language skills.

While slow vocabulary development due to late age of cochlear implantation has been determined to be the probable cause of weak language skills in the children with CI in this study, the basis of differing language skills could not be determined based on other demographics. For example, CI_2 and CI_6 were both bilaterally implanted with CI, yet showed very different language performances. Only CI_6's performance was consistent with the hypothesis that bilateral implantation is more beneficial in distinguishing words and sentences compared to unilateral implantation, leading to better language performance (Dunn et al., 2008). CI_2 even showed poorer language performance compared to CI_1 (unilateral user), as well as CI_4 and CI_5 (bimodal users). On the other hand, bimodal user CI_3 performed the lowest in the language assessments despite having been hearing the longest (4;6) out of the six children. This was inconsistent with the assumption that longer duration of hearing equates better language performance (Campos et al., 2018; Dunn et al., 2014). However, the assumption was found true for CI_6 and CI_1 who have been hearing for 4;5 and 3;6 respectively and were respectively the top two performers in language assessments. Aside from that, there was no indication of a connection between hearing age and language performance. This was apparent with the similar performance of CI_1 (3;6) and CI_4 (1;0), as well as between CI_2 (3;4) and CI_5 (0;9). It was also noted CI_4 and CI_5 had abnormal radiological findings but a previous research has reported normal findings of speech perception in patients with inner ear malformations as the limitations were confined to the inner ear and did not affect the operation of the auditory nerve and central auditory pathway, which are vital to the functioning of CI (Wu et al., 2008). These findings suggested there are other underlying factors in the differing success rate of language learning in children with CI that should be considered in their language assessments.

Findings from this study suggest important implications for the inclusion of hearing-impaired children in mainstream school in Malaysia. First and foremost, school readiness screening should be made compulsory to preschool children with CI much prior to their first primary school year. This is to ensure those who are at high risk of possibly not performing in school could be identified for 'bridging' interventions as early as possible. Maluleke et al. (2019) found that deaf children who were identified late and consequently received delayed initiation of intervention, demonstrated poorer attention, communication abilities, concept knowledge, and early literacy skills compared to children who obtained intervention at earlier ages. As the optimum age for the most rapid growth in children's self-regulation abilities is within birth to the age of five (Bates et al., 2006), it is suggested early intervention is carried out within this critical period. This suggestion goes hand in hand with the push for early cochlear implantation as ultimately, deaf children could only come to acquire other school readiness skills once the foundation for language is laid (Pace et al., 2018). Language findings from this study revealed the main problem area for the children with CI was their limited vocabulary, which manifested from their low speech sound inventory. Therefore, the planning of intervention modules and strategies for children with CI should focus on behavioural treatment of speech disorders, which include the practice of coordinating movements of oral structures (lips, tongue, and soft palate) to improve speech production (Williams et al., 2010). This will help them to increase their vocabulary repertoire as a basis to improve on their grammatical abilities and overall language abilities. With good language as a precursor for good academic abilities, the chances of the children with CI entering mainstream schools is further enhanced.

CONCLUSION

The majority of the children with CI in this study were found to have poor scores on school readiness skills and performed poorly in both their cognitive and language skills. While their cognitive abilities probably differed due to varying child factors, their poor language performance appeared to be due to issues in speech sound acquisition and consequently learning of vocabulary, which was hindered by their relatively late age of cochlear implantation. This detailed analyses of the language abilities of the six 6-year old Malay children with CI could shed some light at micro level on the difficulties faced by these children when enrolled into formal, mainstream education settings.

Limitations

One of the limitations faced in this study was the variation in the rating of school readiness by parents for the children with CI and by teachers for the normative data of NH children. Despite the high Cronbach's alpha value for ratings by parents in this study (0.96), Umat et al. (2018) explained there was poor inter-rater agreement between the two groups as teachers tended to rate their students lower than parents in their school readiness. However, teachers were found to be the most reliable evaluators of overall school readiness as they do not adopt strictly academic perception of school readiness, but rather view the model of readiness as self-regulation that facilitate teaching and learning activities in classrooms (Blair & Raver, 2015). This makes their rating an appropriate reference for a child's preparedness for school considering school readiness is a multi-faceted concept. Despite the strong reference point, results from this study must be taken with caution due to the possible discrepancy between the evaluation by teachers and by parents.

Another limitation is the relatively small sample size of 6-year-old Malay children in this study. Despite having the children recruited from two of the largest CI programmes in Malaysia, only 11 children were determined and only six were later consented by their parents to join the study. Based on the quantity alone, this study could not be generalized to all 6-year-old Malay children with CI in Malaysia. The same limitation extends to the design of the study, which is the case study design. As case studies typically deal with individual cases that might not fit standard categories, there are concerns with external validity and generalizability of findings to the wider population. On top of that, qualitative studies such as this could not rely on statistical support to deduce findings and each case is analysed on an individual basis. This, again, brings about concerns of generalizability and the findings must therefore be interpreted with caution.

A limitation was also found in one of the three language assessments employed, the Malay Preschool Language Assessment Tool (MPLAT). Due to the high floor scores, three of the children with CI did not manage to score any of the expressive language subtests (RefM, RelM, and SR). The floor effect inferred the expressive language subtests might have been too difficult for the children with hearing loss whose expressive language was expected to be impaired. This was why MPLAT was supplemented with the expressive language test Malay-LARSP to yield a more accurate analysis of the expressive language performance of children with CI.

Suggestions for Future Research

One of the aspects that should be properly considered in studies involving children with CI is the heterogeneity of their background. In this study, CI_3 appeared to be an outlier in all the language assessments despite fulfilling the selection criteria to join the study, suggesting unique child factors, such as genetic, environmental, and lifestyle factors could have influenced the language outcomes of the children with CI. Therefore, it is strongly suggested future assessments on the abilities of hearing-impaired children with CI is carried out in consideration of potentially influencing demographic and socioeconomic variables.

A larger sample size is also highly suggested for future studies as it could provide more concrete evidence on the outcome of school readiness in hearing-impaired children that might not have been established in this study, such as the association between cognitive abilities and overall school readiness. With a large enough sample, statistical evidence could be generated to further strengthen the justifications of the findings on the abilities of children with CI.

Aside that, there also needs to be participants from varied racial backgrounds to allow for the generalizability of the findings to the general population. In this study, the inclusion criterion was to include only children of Malay ethnicity who spoke

Malay as a first language. The criterion was appropriate for this study as all three of the language assessment tools were specifically designed to assess structures of the Malay language. Further studies on participants of different ethnicities and languages using corresponding assessment tools are required to generate a better picture on the abilities of children with CI in Malaysia, which is a multi-cultural country.

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