Case Report: Acquisition of three spoken languages by a child with a cochlear implant

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ABSTRACT *There have been only two reports of multilingual cochlear implant users to date, and both of these were postlingually deafened adults. Here we report the case of a 6-year-old early-deafened child who is acquiring Cantonese, English and Mandarin in Hong Kong. He and two age-matched peers with similar educational backgrounds were tested using common, standardized tests of vocabulary and expressive and receptive language skills (Peabody Picture Vocabulary Test (Revised) and Reynell Developmental Language Scales version II). Results show that this child is acquiring Cantonese, English and Mandarin to a degree comparable to two classmates with normal hearing and similar educational and social backgrounds.*

Keywords: cochlear implant, bilingualism, multilingualism, early deafness, language acquisition

Introduction

As cochlear implant technology has become better at imparting adequate speech perceptual abilities, research has begun to focus on broader aspects of spoken language acquisition (e.g. Robbins et al., 1997). Similarly, cochlear implant technology is becoming increasingly available to clients from a broader range of linguistic and cultural backgrounds. As a result, research into the acquisition of multiple languages by cochlear implant users is both possible and increasingly necessary.

Two articles have documented the post-implant speech perceptual abilities of bilingual adults, one speaking Mandarin Chinese and English (Xu et al., 1987), and one speaking Welsh and English (Osborne et al., 1996). However, in both of these cases the patient became deaf after acquiring both spoken languages, and their primary concern was recovery of pre-existing capabilities. Both studies focused on basic speech perceptual capabilities, including word-length discrimination, closed-set vowel identification, and closed- and open-set segment and word identification. There is as yet little or no published information regarding the development of expressive and receptive linguistic abilities in more than one spoken language by an early-deafened child with a cochlear implant.

According to Grosjean (1982: vii), 'about half the world's population is bilingual ... and bilingualism is present in practically every country in the world'. As implant technology becomes more widespread, the proportion of young children using cochlear implants in multilingual communities must also rise. However, acquiring more than one language may prove to be particularly difficult for children with cochlear implants, who already have trouble developing and maintaining sufficiently distinct representations of the lexical items of a single language (Pisoni, 2000; Chin et al., 2000).

Similarly, the importance of cognitive factors such as attention and working memory capacity in language learning may be compounded by the use of cochlear implants (Pisoni, 2000) or hearing impairment in general. Rabbitt (1991) presented evidence that mild-to-moderate hearing loss reduces the ability to recall spoken words even when those words were correctly identified, and argued that perceptual deficits may reduce the accuracy of later recall by consuming cognitive resources that would otherwise be used in the storage and retrieval of items from memory (see also Schneider and Pichora-Fuller, 2000; Suprenant, 1999). If children with hearing impairment must divert resources from memory-encoding processes in favour of word identification, then the task of learning two or more languages, with distinct vocabularies, grammatical rules and pronunciations, may prove more difficult than for either monolingual hearing-impaired children or multilingual children with normal hearing.

Implants may even introduce difficulties for learning particular languages beyond those that result from hearing loss alone. For example, tone languages such as Cantonese can make lexical distinctions purely on the basis of differences in a syllable's fundamental frequency pattern, and results suggest that implantees have difficulty recognizing tonal differences (Ciocca et al., 2002; Lee et al., 1997, 2002). One reason for this may be that listeners using cochlear implants are likely to have difficulty perceiving the pitch of complex quasi-periodic sounds such as speech because they cannot resolve the low-numbered harmonics of sounds with fundamental frequencies within the typical range of speech (Faulkner et al., 2000). Cochlear implant users may be able to access pitch information from unresolved harmonics or from differences in the relative strength of stimulation across channels (Geurts and Wouters, 2001). However, even in listeners with normal cochlear function, periodicity information generates relatively weak, and sometimes ambiguous, pitch percepts, at least in some cases (Schouten et al., 1962). Although less is known about the ability to access pitch information from cross-channel level differences, it is likely that this source of pitch information is also not as easily accessed as resolved harmonics would be. Thus, the use of such 'secondary' cues for pitch perception may be more cognitively demanding than using primary cues such as resolved harmonics, leaving children with cochlear implants who are trying to learn a tone language with fewer cognitive resources to devote to higher-level cognitive processes involved in language learning.

In the present article we focused on the ability of an early-deafened cochlear implant user to acquire more than one spoken language. We were primarily interested in the broader question of how well cochlear implants might support the development of spoken communication, rather than the more narrowly focused question of the degree to which cochlear implant-aided speech perception or production might approximate that of normally hearing listeners (cf. Geers, 1997; Pisoni, 2000; Robbins et al., 1997). Therefore, we employed commonly used, standardized developmental linguistic (rather than perceptual) tests and compared the cochlear implant user's scores to those of age-, gender- and education-matched classmates (cf. Miyamoto et al., 1997; Robbins et al., 1997).

Case report

In the present paper we report the case of a native speaker of Cantonese (here referred to as SC) aged 6 years and 10 months, who is also acquiring English and Mandarin. Hearing loss of unknown origin was first suspected at around 2 months of age, but not formally diagnosed until 6 months (0;6). SC's hearing was tested six times prior to implantation (at ages 0;6, 0;7, 1;0, 2;0, 2;5 and 3;0) using a variety of methods. Tests using open-sound field presentation of a variety of stimuli before age 1;0 suggested hearing thresholds in both ears around 80 dB HL. The results of more specific tests conducted between ages 2;0 and 3;0 are shown in Table 1. Overall, these test results suggest a pattern of increasingly severe hearing loss, greater at higher frequencies than lower, and starting from an already poor threshold at age 0;6. Auditory evoked potential (AEP) was also conducted at age 0;7 in the Audiology Clinic of Tung Wah Hospital. Results suggested profound sensorineural hearing loss with thresholds greater than 110 dB HL in both ears because absolute wave V latencies 'could not be traced or identified even at the maximum output level (110 dB) of the transducer'.

Between age 0;6 and about 3;0, hearing aids were used and SC developed a small vocabulary of a few hundred words (by maternal report) before continuing deterioration of hearing made cochlear implantation an option. Testing immediately prior to implantation (age 3;2) showed no responses at any frequency in either ear (audiometric limits of 110 dB HL). SC received a Clarion eight-channel implant in the left cochlea at the age of 3 years, 2 months (3;2) at the Queen Mary Hospital, Hong Kong (activated one month later). At age 6;4 (six months prior to testing) SC's implanted left ear audiogram

Table 1: SC's hearing test results between ages 2;0 and 3;0

Age	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
2;0	L: 85	R: 85	L: 105	R: 105	L: 100
	R: 105	L: >120	R: >120	L: >120	R: >120
2;5	L: 85	R: 100	L: 95	R: 110	L: 105
	R: 110	L: >110	R: >110	L: >110	R: >110
3;0	L: >105	R: >105	L: >120	R: >120	L: >120
	R: >120	L: >120	R: >120	L: >120	R: >120

Note: All thresholds are given in dB HL. L refers to left ear responses, R to right ear responses. A failure to respond at the limit of the stimulus delivery system is indicated with a > symbol before the system limit (e.g. >110 dB HL means that SC failed to respond to stimuli presented at 110 dB HL). Only pure tone audiometry (headphone presentation) results are presented here. Additional tests were conducted using sound field presentation methods (visual reinforcement/head-turn procedures) prior to age 2;0 but these results are not reported here.

showed a hearing threshold of 45 dB SPL at 250 Hz, 35 dB SPL at 500 Hz, 1000 Hz and 2000 Hz, and 30 dB SPL at 4000 Hz. The present testing was conducted when SC was 6 years, 10 months old (6;10).

SC's parents are native speakers of Cantonese (the dominant Chinese language in Hong Kong), and are fluent in both English and Mandarin Chinese (the dominant language of Mainland China and Taiwan). The primary language in the home is Cantonese, although since the age of about 5;6 SC has also spoken English with the family's domestic helper (who is herself a native speaker of Tagalog and who spoke non-fluent Cantonese to SC until he started learning English). SC also speaks both English and Mandarin with both parents on occasion. SC attended a kindergarten and primary school where the language of instruction was Cantonese, although English classes were taught in English and Mandarin classes were taught in Mandarin. Almost all of SC's classmates (all normally hearing) also speak Cantonese as a home language, so most or all of his non-instructional, school-related conversation is in Cantonese. This pattern of linguistic exposure is relatively typical in Hong Kong among families where one or both parents have had at least some tertiary education. In addition, SC has taken English lessons in school (one hour, five times per week) since the start of primary one (one year prior to testing), and Mandarin lessons (30 minutes, twice per week) for ten months prior to testing. His mother reads to him in the evenings in Mandarin for approximately the same time and duration. Prior to age 5;6 (one year, four months prior to testing) SC had little or no exposure to English or Mandarin.

SC has received supplementary speech and listening training, primarily using the techniques of auditory/verbal (A/V) therapy (Estabrooks, 1994) as well as one-on-one conversations with language tutors. He began A/V-style therapy once per week in Cantonese and in English (alternating weeks in each language) approximately one year and four months prior to testing. He had additional English conversational practice with a native speaker twice per week for about 40 bi-weekly sessions during this time. Approximately eight months prior to testing he began supplemental Mandarin tutoring twice per week with a native speaker from Beijing. Three months prior to testing SC completed 13 sessions of A/V therapy in Mandarin at the Children's Hearing Foundation in Taiwan.

Testing was also conducted on two of SC's classmates in order to provide a baseline for what might be expected of normally hearing children from similar linguistic and cultural backgrounds. These two children were 7;02 (HC) and 7;03 (CK) years old at the time of testing, and had been in the same pre-school and primary school classes as SC during the previous two years. CK's family also has a domestic helper whose native language is Tagalog but who speaks with the family (including CK) in English. CK began taking supplementary (extra-scholastic) English lessons once per week just prior to testing, and had completed two lessons at the time of testing. HC had no experience with English or Mandarin outside of school at the time of testing.

Method

All children were tested with commonly used, standardized instruments for assessing communicative competence. In English, we used the Revised Peabody Picture Vocabulary Test (PPVT-R) (Dunn and Dunn, 1981) Form L and the Reynell Developmental Language Scales version II (Reynell and Huntley, 1987) for both receptive and expressive language. In Cantonese, we used the Hong Kong Cantonese Receptive Vocabulary Test (HKCRVT) (Lee et al., 1996), which is comparable in format and scoring to the English PPVT-R, and the Cantonese version of the Reynell Developmental Language Scales version II (C-RDLS II) (Reynell, 1977/87) for both receptive and expressive language. In Mandarin, we used a Mandarin (Taiwanese) translation of the PPVT-R (Lu and Liu, 1994).

Although all the tests we used were selected to be highly similar across languages in terms of the linguistic knowledge they test, the non-English tests vary in the degree to which they are based on the materials and specific test items of the English tests to which they correspond. The HKCRVT follows a similar format to the English PPVT-R, but uses a different set of pictures. Both tests are progressive, such that later-occurring items are more difficult than earlier ones. However, in developing the Cantonese test, both phonetic and semantic similarity was taken into account for determining targets and distractors. Furthermore, while the PPVT-R has a maximum age equivalence of 33;8 (extending well into the range of normal adulthood), the HKCRVT was only normed for children, based on a population of 609 normally developing children (322 boys, 287 girls) between the ages of 1;10 and 6;1. Overall mean score for age 6;0 was 61.26 (out of 65), with a standard deviation of 3.59.

The Cantonese version of the Reynell Developmental Language Scales is largely derived from the English language version, although during the development of the test some items were changed to better reflect the environment of Hong Kong children. For example, in part 4 of the receptive test, a Chinese cooking pot was used instead of a frying pan, while in the expressive component the theme and context of the pictures were changed to be more compatible with Hong Kong children's experience. Rather than setting the table, shopping in a store and gardening, the Cantonese version of the Reynell shows pictures of cleaning the house, eating dinner, shopping in a marketplace and playing on the beach. Other aspects of the pictures were also changed (e.g. hair colour, furniture styles, etc.). In addition, during test development some late-occurring items were found to be easier than earlier-occurring ones, and therefore a number of items were reordered to preserve the progressive nature of the test. For example, part 6 of the English Reynell (relating attributes to objects) was found to be easier for Cantonese-speaking children than parts 4 and 5 (recognition of animated objects, relating two verbal concepts) so the orders of these were reversed in the Cantonese version. Finally, some new items were added to better assess linguistic constructions that are significant in Cantonese but not necessarily important (or difficult to learn) in English. For example, in the expressive component of the test, six new items were added: (1) two-word sentences (verb-object constructions which are common in Cantonese); (2) appropriate use of adjectives; (3) appropriate use of numeral classifiers; (4) appropriate use of the perfective aspect marker; (5) appropriate use of the progressive aspect marker; and (6) the appropriate use of prepositions or adverbs to indicate position and direction in time and space. The Cantonese version of the RDLS was normed on the basis of scores from 1081 children (537 boys, 544 girls) ages 1;0 to 7;0. The mean score for the receptive language scale at age 7;0 was 61.7, with a standard deviation of 2.9 (at age 6;9 the mean was 61.1, SD of 2.9). On the expressive language scale the mean score at age 7;0 was 64.0, with a standard deviation of 5.1 (at age 6;9 the mean was 63.2, SD of 5.2).

The Mandarin version of the PPVT-R uses the same items as the English PPVT-R with some exceptions, and with revised norming and standardization. There are two sets of test pictures (A and B) (similar to English PPVT-R, Form L and M). We used the Test A (similar to Form L of the English PPVT-R). This test was originally piloted on 656 children, age 3;0 to 12;0, and then standardized using 886 children (454 boys and 432 girls, also 3–12 years old). This test does not provide age-equivalence information, but *z*-score normalized scores can be given a percentile rank based on the original standardization results for each age group.

It should be noted that the children who participated in this study are chronologically at the uppermost end of the age range for which most of these tests are intended, and our results will show that they did indeed perform at or close to ceiling in Cantonese. These tests were chosen for two principal reasons. First, the use of standard instruments that are widely available in a variety of languages increases the likelihood that our results can be compared and extended across multilingual participants from a range of language backgrounds, and we were interested in developing a broadly applicable method for assessing the effectiveness of remediation (in general) in multilingual children with the possibility of delayed or disordered language development. Second, these particular tests were chosen to provide a broad range of assessment from very poor to age-appropriate performance. Prior to carrying out this study, it was expected that a child with a cochlear implant who received the implant after age three and who had been using that implant for less than four years would likely be performing below his chronological age, and well within the intended range of the Cantonese Reynell and HKCRVT. Furthermore, none of the participating children was a 'balanced' bilingual. That is, they all had considerably more exposure to, and experience with, Cantonese as opposed to either English or Mandarin. Thus, it was expected that, regardless of their Cantonese abilities, their Mandarin and English language performance would be well within the intended range of the tests used for those two languages. See Romaine (1989) for a discussion of the difficulties and dangers of trying to classify multilingual individuals in terms of the relative dominance of each language. Factors that must be considered include the role each language plays in the individual's society and family, and the amount and nature of the exposure to each language that the individual receives. In the present case, ethnically Chinese children in Hong Kong are typically exposed to far more Cantonese than Mandarin or English in their daily life. Although over the course of a child's education, English, and to a lesser extent Mandarin (primarily in its written form), play an increasingly important role, in these and almost all other cases Cantonese remains the primary medium for daily communication. It is possible that, given a more balanced exposure to English or Mandarin, SC (and, indeed, his normally hearing peers) might show a more balanced pattern of test results across these languages. However, given the pattern of language exposure that is typical for this population, the pattern of linguistic capabilities shown by all three children is not unexpected.

Results

Cantonese

All three children scored extremely well on the Cantonese Receptive Vocabulary Test, as shown in the first row of Table 2. While the fact that all three children scored at or near ceiling might suggest that this test was inappropriate for children of this age, our goal was to employ a uniform set of tests across all languages. Using a more age-appropriate test in the children's first language might well have resulted in a floor effect when testing subsequent languages.

Results for the Reynell Developmental Language Scales are shown in Figure 1. From this figure it can be seen that SC's scores were comparable to his peers

Table 2: Results of vocabulary tests in three languages

	HC	SC	CK
Cantonese score	>6;1 65	5;11–6;0 62	>6;1 65
English score	2;5 14	2;5 13	2;3 10
Mandarin score	21st percentile 44	18th percentile 38	12th percentile 38

Note: HC, SC and CK refer to the three children tested, matched on age, gender and education. SC has a cochlear implant, the other two children have normal hearing. Cantonese score indicates age equivalence and raw point score on the Cantonese Receptive Vocabulary Test (Lee et al., 1996). English score indicates age equivalence and raw points score on the Revised Peabody Picture Vocabulary Test (PPVT-R) (Dunn and Dunn, 1981). Mandarin score indicates percentile ranking within age group and raw points score on the Mandarin version of the PPVT-R (Lu and Liu, 1994). Ranking within age group means that SC's score of 38 puts him in a higher percentile than that of CK, with an identical score, because SC was tested at age 6;10 (within the 6;6–6;11 age range) while CK was tested at age 7;2 (within the 7;0–7;5 age range).

in both the production and perception of Cantonese, and he even shows a slight advantage over them in language production. On the receptive portion of the test, SC scored 63/67, while HC scored 61/67and CK scored 66/67. On the expressive portion of the test SC scored better than the other children (72/73 versus 64/73 and 69/73). Also, on the expressive portion of the test SC had a higher content subscale score (24/24) than the other two boys (19/24 and 20/24). It must be noted that the children's near-ceiling performance means that it is not possible to state definitively that all three children have equivalent levels of expertise with Cantonese vocabulary. These tests are simply not sufficiently sensitive at this level of expertise to differentiate between the three children, and thus undetected differences may still exist. However, these results do demonstrate that all three children have achieved at least age-appropriate performance on both Cantonese language tests.

English

Scores on the English Peabody Picture Vocabulary Test (PPVT) were considerably lower than in Cantonese, but again all three children achieved roughly equal scores, as shown in the second row of Table 1. Note that, although the children scored much lower than their chronological ages, they had only started formal English instruction in the previous year.

Figure 2 shows the results of the Reynell Developmental Language Scales in English. Again, SC's scores were indistinguishable from his peers, although in

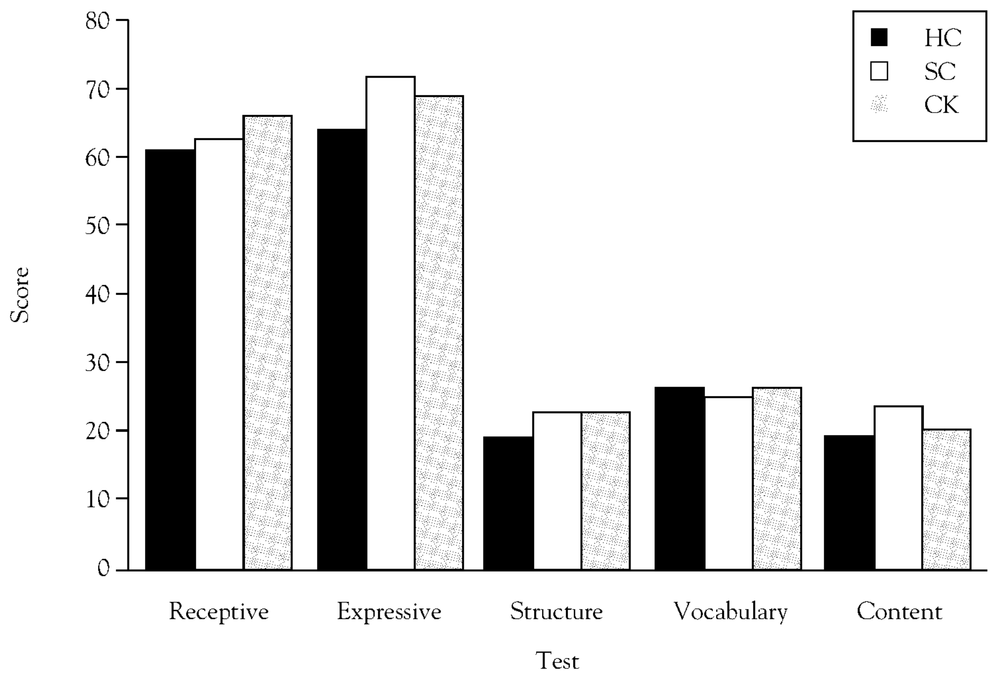

Figure 1: Performance of three children (HC, SC and CK) on the Reynell Developmental Language Scales version II, Cantonese (Hong Kong) version. SC uses a cochlear implant. HC and CK have normal hearing. Scores shown by subscale.

this case he was the only one of the three boys who scored better on the expressive portion of the test than on the receptive section. As in Cantonese, he achieved a much higher score on the content subscale (16/24) as compared with 5/24 and 8/24 for the other two boys.

Mandarin

Because all three children have the least amount of experience in Mandarin, it was expected that their performance would be poorest in this language, and only a vocabulary test, not a grammar test, was administered. As shown in row three of Table 2, SC again achieved a score comparable to that of his normally hearing peers.

Discussion

The results presented here suggest that it is possible for an early-deafened child with a cochlear implant to acquire more than one spoken language to a degree approximating that of his normally hearing peers. Although only preliminary, these results have implications for aural habilitation of children from multilingual backgrounds who use cochlear implants, and provide a basis for identifying areas of future research.

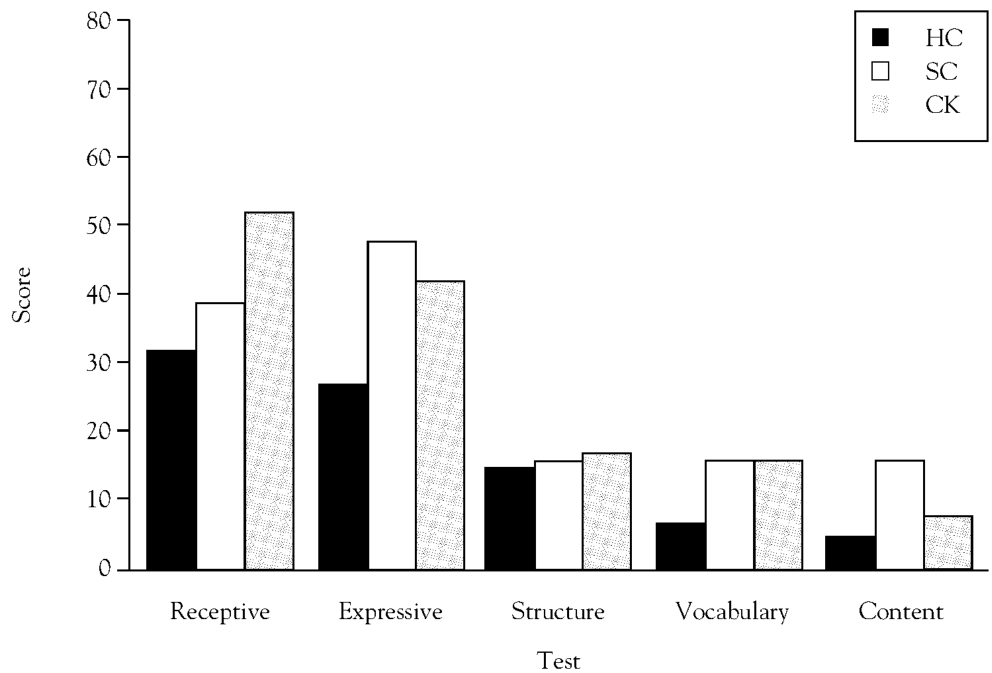

Figure 2: Performance of three children (HC, SC and CK) on the Reynell Developmental Language Scales version II (English language version). SC uses a cochlear implant. HC and CK have normal hearing. Scores shown by subscale.

Most people in the world speak more than one language, and in many countries multilingualism is the norm (Romaine, 1989). Anecdotal evidence suggests that some audiologists and speech therapists may consider learning more than one language to be 'too difficult' for children with cochlear implants. Consideration must be taken of the possibility that using a cochlear implant might in itself impose considerable demands on attention and working memory. Nonetheless, the results of the present study suggest that, at least for some children, it is possible to acquire more than one language at a peer-equivalent level despite using a cochlear implant.

A number of factors may have contributed to SC's particular linguistic abilities. First, Cantonese and Mandarin are closely related languages, and share a great deal of lexical and grammatical patterns (Norman, 1988). Although the two languages are typically considered to be mutually unintelligible, and many words are pronounced quite differently between the two languages, an examination of the items on the HKCRVT and Mandarin PPVT suggests that an age-appropriate vocabulary in Cantonese could improve performance on the Mandarin test even if the child only answered in Cantonese. For example, the Mandarin test item [t^{h}iao^{4} ʂuei^{3}] 'jump (into the) water' sounds quite similar to the equivalent Cantonese phrase [t^{h}iu^{3} sœi^{2}], while Mandarin [ji^{1} kuei^{4}] is similar to Cantonese [ji^{1} k^{w}ai^{6}] 'clothes cupboard'. This similarity may improve transfer of abilities from one well-learned language (e.g. Cantonese) to a subsequent language (e.g. Mandarin), a phenomenon known as 'positive transfer'. (Transcriptions are in standard IPA format (Pullum and Ladusaw, 1986), except for tones, for which standard tone numbers are used. For Mandarin these are 1, high level; 2, rising; 3, falling-rising; 4, falling (Chao, 1948). For Cantonese these are 1, high level; 2, high rising; 3, mid-level; 4, low falling; 5, low rising; 6, low level (Chao, 1947).)

However, similarities between languages can also be misleading (leading to 'interference' or 'negative transfer', cf. Romaine, 1989: 51–52). For example, the Cantonese word [ji^6] 'two' sounds quite similar to the Mandarin word [ji^1] 'one', which may cause considerable confusion, especially if one cannot accurately perceive pitch (the Mandarin tone 1 is a high-level tone, while the Cantonese tone 6 is a low-level tone). Furthermore, positive transfer cannot account as easily for SC's English performance, or that of his peers, as English and Cantonese are phonologically, lexically and grammatically quite different from one another. If we are to account for SC's skills in particular (as compared with the initial assumption that a child with a cochlear implant would not be able to achieve linguistic parity in more than one language with normally hearing children), we might better look at features particular to SC himself.

For example, SC and his family have spent a considerable amount of time and energy on supplementary language experience, including both therapy specific to children with cochlear implants, and also more traditional language tutoring. While it is common for Hong Kong children to receive extra-scholastic tutoring in English and/or Mandarin, SC has still received considerably more tutoring than his peers, and much of this has been in the context of targeted oral/aural training. Such supplementary training likely contributed strongly to his language development, perhaps especially with respect to expressive language (cf. Robbins et al., 1997).

Another factor that may contribute to SC's abilities is the observation that he may have benefited from early residual hearing. While children such as SC who become deaf before three years of age seem to pattern with those who were born deaf with respect to their ability to acquire basic speech perceptual skills (Osberger et al., 1991), it is possible that even the relatively small amount of early hearing demonstrated by SC could have facilitated his subsequent acquisition of spoken language understanding.

General cognitive factors may have contributed to SC's abilities in other ways as well. Although it is only possible to speculate in the most general terms without quantitative data (e.g. on digit span recall; cf. Pisoni and Geers, 2000), it should be noted that SC is extremely extroverted and quite intelligent (exhibiting an IQ of approximately 121 on the Hong Kong Wechsler Intelligence Scale for Children (Psychological Corporation, 1981) at the age of 5;08). Rabbitt (1991) argued that individuals with higher IQs may be better at coming up with correct interpretations of poorly perceived words because they are able to employ information-processing strategies more quickly to compensate for missing acoustic information (in this case, perhaps including missing pitch information for tone language perception). Thus, it seems plausible that high levels of general cognitive skills, combined with strong internal motivations, may contribute significantly to success in acquiring any spoken language via cochlear implant. It may be noted that SC did not make an unusually high number of tone-related errors on any of the Cantonese or Mandarin receptive tests, suggesting that he was able to compensate for any lack of pitch information provided by his implant, either by means of higher-level word-finding strategies as suggested by Rabbit's (1991) argument, or by devoting more cognitive resources to using secondary acoustic cues to pitch, as suggested in the introduction.

All of these possibilities, however, must remain in the realm of speculation pending the outcome of further research. In particular, it is important to identify other children from multilingual environments who receive cochlear implants, with the goal of documenting and further investigating additional cases of multiple spoken language acquisition. There is of course an obvious paradox involved in such research. Parents, audiologists and speech therapists are less likely to choose to encourage children with cochlear implants to acquire more than one language until it can be shown that it can be done by most or all children. However, without further research, such a claim cannot be made. While multilingual children with cochlear implants are likely to remain rare in the near future, it is to be hoped that the increasing numbers of cochlear implantees in traditionally multilingual regions and cultures will contribute to the identification of more successes such as that of SC. Furthermore, it is important to investigate the role in language acquisition of physiological variables such as duration and degree of early auditory experience, and also more general cognitive factors such as attentional capacity and short-term memory, as well as the ways in which these factors interact with the acquisition of multiple languages.

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