

# **Perception of Lexical Tone and Its Effect on Sentence Recognition in Children Using Cochlear Implants**

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Pitch variations, often referred as tones, are used to convey lexical meanings in tone languages such as Mandarin Chinese. However, current cochlear implants provide only limited information about voice fundamental frequency ( $f_0$ ). Here we report on three experiments investigating the perception and use of tone in syllables and sentences in Mandarin speaking children using cochlear implants, and in normal-hearing controls using acoustic simulations. Experiment I investigated the extent to which tone recognition could be achieved by implanted children, and whether another cue, amplitude variation, could be used to help tone recognition. Twenty-one good implant children, aged between 6 and 15, were asked to identify two types of syllable: natural speech with the original pitch and amplitude contours and processed speech with the original pitch contours but constant amplitude. Group scores were well above chance for both conditions, and around one-third of the children achieved more than 80% correct for natural speech. The amplitude cue showed different effects on different tones. Experiment II manipulated  $f_0$  in sentences so as to examine its effect on sentence recognition. Sentences with natural  $f_0$  contours were compared to sentences whose contours had been manipulated as slightly falling ones. No significant difference was found between these two types of sentences. It thus appears that implanted children can make some use of tonal information in highly constrained situations, but not when listening to running speech. Experiment III examined the effect of  $f_0$  in sentences again, but in four age groups of normal listeners (aged 6, 9, 12, and 20), by using 2-, 4-, 8-, and 16-band vocoding of the same sentences used above. An  $f_0$ -controlled pulse carrier or a pulse carrier with a slightly falling pitch contour was used for voiced speech, and a noise carrier was used for voiceless speech. The natural  $f_0$  was found to enhance sentence recognition significantly while spectral information was degraded. Young children required more information, either from voice pitch or from increased spectral resolution, to achieve the same level of performance as adults and older children. Overall, these results show the importance of pitch information in a tone language and the limitations of current cochlear implants in providing it. Providing more voice pitch information in a cochlear implant is likely to improve speech perception in implanted children using a tone language.