DEVELOPMENT AND EVALUATION OF THE NEW ZEALAND CHILDREN'S-BUILD-A-SENTENCE TEST (NZ Ch-BAS)

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Abstract

Objective: The purpose of this current study was to develop an audiovisual speech perception test for New Zealand English (NZE) speaking children by adapting the American version of the Children's-Build-A-Sentence (Ch-BAS) test. Three hypotheses were formulated for this study. First, it was predicted that the New Zealand version of the Ch-BAS test would show list equivalency. A second hypothesis was that all children would perform significantly better on the auditory-visual (AV) condition of the test in comparison to the vision-only (V-only condition). A third hypothesis was that older children would perform significantly better than younger children on both test conditions.

Design: The American version of the Children's-Build-A-Sentence test was adapted for use with NZ children and an audiovisual recording was made of an adult NZE speaker saying the sentence stimuli. This was then edited into a picture response matrix format to make up the NZ Ch-BAS test which is comprised of three lists made up of mono, bi, and tri-syllabic words. Equal numbers of sentences were allocated to the three test conditions: auditory-only (A-only), V-only, and AV conditions. The NZ Ch-BAS test was then administered to 30 normal hearing (NH) NZE-speaking children aged between 7-11 years with equal numbers (n=6) in each age group. All testing was conducted in the presence of multi-talker babble noise, set individually for each child to obtain approximately equivalent performance for the A-only condition.

Results: Results revealed that the NZ Ch-BAS test lists were equivalent for both the V-only and AV test conditions when testing NH children. A significant age effect was also found, where older children showed superior speech reading performance in comparison to younger children. A stronger age effect was seen for the V-only condition in comparison to the AV condition. All children performed significantly better on the AV condition in comparison to the V-only condition.

***Conclusions*:** The three Ch-BAS test lists demonstrate list equivalency and therefore can be used to develop a reliable test for NZ-English speaking children. As anticipated, there was an age effect in regard to speech reading performance; however this effect was only found for the V-only condition. All children performed significantly better on the AV condition in comparison to the V-only condition. A number of possible explanations for superior performance are provided and clinical uses for the NZ Ch-BAS test are discussed.

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Abbreviations

A-only	Auditory-only
AE	American English
APD	Auditory processing disorder
AV	Auditory visual condition
AV-LNST	The Audiovisual-Lexical Neighborhood Sentence Test
CAVET	The Children's Audiovisual Enhancement Test
CI	Cochlear implant
dB	Decibels
FM	Frequency modulation
HI	Hearing impaired
NZ Ch-BAS	New Zealand Children's-Build-a-Sentence-Test
NH	Normal Hearing
NZ	New Zealand
NZE	New Zealand English
PSI	Pediatric Speech Intelligibility test
SNHL	Sensorineural hearing loss
SNR	Signal-to-noise ratio
V-only	Vision-only condition

Introduction

Audiovisual speech recognition

Speech perception is an inherently multimodal phenomenon. Information from the visual speech signal (lip-reading) is used by all perceivers and is readily integrated with the auditory speech signal (Rosenblum, 2008). This is also known as 'speech reading' which has been defined as "speech recognition using both auditory and visual cues such as facial expression and gesture" (Tye-Murray, 2009). The visual speech signal through speech reading provides useful information that allows us to better understand someone speaking in a noisy environment or who has heavily accented speech (Rosenblum, 2008). The visible articulators including the teeth, tongue, lips and other facial features provide information about the acoustic speech signal and can convey information about the place of articulation of consonants (e.g., /b/ versus /d/), or voice onset time which allows the distinguishing of a voiced from a voiceless consonant (e.g., 'b' from 'p') (Green & Kuhl, 1989). This allows the listener to perceive speech more accurately and enhances comprehension, especially when the auditory signal is weak (Rosenblum, 2008; Summerfield, 1992). While there are wide individual differences in speech reading skill, evidence suggests that all sighted individuals from every culture use visual speech information (Rosenblum, 2008).

Children develop language through having access to the auditory signal, which requires adequate hearing for the language learning process (Kirk, et al., 1995). Access to the visual speech signal has also been shown to play an important role in the language learning process (Jerger, Tye-Murray, & Abdi, 2009). Current research has shown evidence for a sensitive phase of development in early infancy, during which visual acuity must be sufficiently high to discriminate lip movements in order to allow for the emergence of a regular neural speech reading system (Putzar et al., 2010). When we recognize speech, auditory and visual information are integrated as the speech signal is decoded. This integration is combined to form a unified percept and is called audiovisual (AV) integration (Grant, Walden, & Seitz, 1998). AV integration is thought to occur at a distinct stage of the speech recognition process and it is has been proposed that there are three stages for AV speech recognition (Massaro, Thompson, Barron, & Laren, 1986; Summerfield, 1992). The first stage entails perceiving the auditory and visual cues associated with a spoken word. The second stage involves the integration of the two signals, and the third stage involves making discrete phonetic and lexical decisions (Massaro et al., 1986; Ouni, Cohen, Ishak, & Massaro, 2007).

Speech reading performance can be difficult to predict. There is debate as to whether speech reading ability can be predicted by factors such as intelligence or practice with the speech reading task (Summerfield, 1992). Some studies have shown that there is a correlation between speech reading ability and intelligence (Rodríguez Ortiz, 2008). Others have found that some particular cognitive skills (e.g., working memory, lexical identification speed, phonological processing, and verbal inference making) may correlate with speech reading ability but not other measures of intelligence (Summerfield, 1992). Tye-Murray (2009) suggests that a person's ability to speech read is influenced by other factors, including speaker variables, the message, the speech reading environment, the communication situation, and the speech reader.

The neighborhood activation model of speech recognition

The neighborhood activation model (NAM) of speech recognition performance was first described by Luce and Pisoni (1998), who demonstrated that the number and phonetic similarity of neighboring words in a lexicon affect the speed and accuracy of word recognition. According to these researchers, stimulus input activates a set of options in the mental lexicon and the listener makes a single selection from multiple viable alternatives (Luce & Pisoni, 1998). Lexical neighborhoods include groups of words differing from each other by one phoneme through substitution, deletion or insertion. According to this model "easy" words are those that have few lexical neighbors, and "difficult" words have many lexical neighbors (Mendel, 2008). Easy words that occur in sparse neighborhoods are recognized better and are processed more quickly than difficult words from more dense neighborhoods, as there is less competition from surrounding activated words. For the listener who is hearing impaired, the acoustic-phonetic code is degraded and distorted which makes words with similar phonetic features more difficult to perceive (Mendel, 2008).

Recent research has provided further evidence, not only for the existence of auditory lexical neighborhoods, but also visual lexical neighborhoods (Feld & Sommers, 2011; Tye-Murray, Sommers, & Spehar, 2007). The visual lexical neighborhood is comprised of words that look visually similar when spoken (e.g. 'bat' versus 'pat'), and this can also have an influence on AV speech recognition (Tye-Murray et al., 2007). Tye-Murray et al. showed that the visual neighborhood density of words impacts performance in a visual (V)-only condition and that auditory neighborhood density impacts performance in an auditory (A)-only condition in their test of 131 NH adults. It has been suggested that word recognition in the AV condition involves the simultaneous activation of the acoustic and visual lexical neighborhoods which are progressively narrowed down as the speech signal unfolds (Tye-Murray et al., 2007).

Speech reading and normal hearing

Both children and adults with NH as well as those with hearing loss benefit from combining auditory and visual speech reading cues in speech recognition (Holt, Kirk, & Hay-McCutcheon, 2011). However, there are a number of differences between the speech reading ability of adults and children. Studies have shown that children are poorer speech readers than adults and that they use less visual information for speech recognition (Jerger et al., 2009). Dick, Solodkin, and Small (2010) found age-related differences in the functional interactions among the fronto-temporo-parietal network of brain regions that contribute to speech production and recognition. Specific regions in the brain such as the ventral premotor cortex were shown to have more influence in different age groups for AV speech recognition, but not A-only speech recognition. It is thought that development of this brain structure might reflect changes in the mechanisms that relate visual speech information to articulatory speech representations through experience of producing and perceiving speech (Dick et al., 2010). This may explain the improvement in AV integration and the ability to recognize speech-in-noise which continues quite late into the childhood years (Ross et al., 2011).

There is conflicting evidence whether a sex difference exists for speech reading ability between NH men and women. Some studies have shown no sex differences (Tye-Murray, Sommers, & Spehar, 2007), while other researchers report that a sex difference in speech reading ability does exist in NH adults (Strelnikov et al., 2009). Strelnikov et al. showed that in NH controls, women speech read words better than men. However this difference was not shown for speech reading of isolated phonemes. It has been suggested that this superior speech reading ability by women can be attributed to their greater predictive and integrative strategies for speech processing (Strelnikov et al., 2009). Studies of brain imaging during speech reading have also shown some sex differences in NH participants. In one study the researchers found that there were sex differences particularly in the right inferior frontal and left inferior parietal regions and to a lesser extent in the bilateral angular and precentral gyri (Ruytjens, Albers, Van Dijk, Wit, & Willemsen, 2006). The sex differences in the parietal multimodal region support the hypothesis that male and females process visual speech stimuli differently without differences in overt speech reading ability. The authors also suggest that females associate the visual speech image with the corresponding auditory speech sound whereas males focus more on the visual image itself (Ruytjens et al., 2006).

Speech reading in unfavorable listening conditions

Viewing a speaker's articulatory movements substantially improves a listener's ability to understand spoken words in noisy and reverberant environments, where hearing impairment makes it difficult to categorize the acoustical speech stream phonetically (Summerfield, 1992). Some authors have introduced a multisensory integration model to explain the phenomena of inverse effectiveness (Ross, Saint-Amour, Leavitt, Javitt, & Foxe, 2007). This principle predicts that when the auditory signal of phonemes is weakest, the contribution of visual information will lead to significantly increased gain in understanding of the spoken speech signal. Ross et al. showed that although multisensory speech enhancement can occur at very low SNRs (e.g., -24dB), there is a "special zone" at more intermediate speech SNRs (e.g., -12 dB) where audiovisual enhancement is greatest and more than predicted by the principle of inverse effectiveness.

Speech reading and hearing impairment

Children with hearing impairment rely more on the visual speech signal for language learning than their normal hearing peers and therefore are often superior speech readers (Auer & Bernstein, 2007). Jerger et al. (2009) found that the speech representations in children with hearing loss are initially disproportionally structured, with initial reliance on visual speech, and with more emphasis on auditory encoded information with age. Auer and Bernstein (2007) examined the speech reading performance of children and adults with early-onset hearing impairment (HI) in comparison to those with NH. The HL group performed significantly better than the NH group on speech reading tasks. Those with hearing impairment early in life will often develop an enhanced speech reading ability because they rely more on visual speech throughout life, and particularly for the acquisition of spoken language (Auer & Bernstein, 2007).

Audiovisual enhancement is particularly beneficial to those who 'hear' through the use of cochlear implants (CIs), as the speech signal is degraded and therefore listeners must recognize words with limited auditory cues. Desai, Stickney, and Zeng (2008) showed that during a categorical perception task NH listeners discriminate sharp phoneme boundaries and have a strong reliance on the auditory cue. In contrast, simulated and actual CI listeners have much weaker categorical perception but stronger dependence on the visual cue. This enhanced auditory visual integration ability has been correlated with implant experience and not duration of deafness. These results suggest that both altered sensory experience and improvised acoustic cues contribute to the AV speech perception in CI users (Desai, Stickney, & Zeng, 2008).

AV integration of the speech signal allows children with HI to 'fill in the blanks' to correctly recognize words that are in their mental lexicons (Kirk et al., 2007). Kirk et al. studied AV spoken word recognition in 15 native English-speaking children who were implanted with CIs before the age of three years. The researchers found that these children performed best in the AV presentation format in comparison to the A-only and V-only conditions. Some of the participants who showed relatively poor speech perception abilities in the A-only conditions appeared to show large improvements when both auditory plus visual speech cues were available. This finding has also been demonstrated in other studies (Kaiser, Kirk, Lachs, & Pisoni, 2003; Kirk et al., 2007; O'Donoghue, Nikolopoulos, Archbold, & Tait, 1998). Holt et al. (2011) have also shown that children with CIs performed better than their NH peers at speech reading in the V-only condition. However, there appears to be a sensitive phase of development that underlies consistent visual-auditory fusion which was found to decline with age at implant beyond 2;6 years (Schorr, Fox, Van Wassenhove, & Knudsen, 2005). Given the benefit of AV speech integration for CI users, it has been suggested that AV speech tests should be included in test batteries for evaluating the outcomes of CIs (Kirk et al., 2007). The information from an AV speech recognition test also has important implications for determining CI candidacy. AV speech recognition appears to be a reliable pre-implantation predictor of post-implantation success and benefit in pre-lingually deafened children (Holt et al., 2011).

As with NH children, a lexical effect has been shown for word difficulty for CI implant users (Kirk et al., 2007). Pediatric CI users are also significantly better at identifying multisyllabic words than monosyllabic words. This finding is thought to be due to multisyllabic words having fewer lexical neighbors than monosyllabic words and therefore there is reduced competition for lexical selection (Kirk, Pisoni, & Osberger, 1995).

Unlike NH adults, some studies have shown that both women and men who use CIs do not show sex differences in speech reading ability (Strelnikov et al., 2009). Strelnikov et al. showed that there was no significant difference between women and men during speech reading in tasks in a study of 97 CI users. The authors propose that a progressive cross-modal integration occurs in male CI users after cochlear implantation which involves a synergistic perceptual facilitation and results in recovery of the visual and auditory modalities. This leads to improved performance in both auditory and visual modalities to compensate for the crude information provided by a CI (Strelnikov et al., 2009).

Aural rehabilitation

Aural rehabilitation involves intervention aimed at minimizing and alleviating the communication difficulties associated with hearing loss. The main aim is to restore the patient's participation in activities that have been limited as a result of the hearing loss (Tye-Murray, 2009). Aural habilitation is defined as intervention for persons who have not yet developed listening, speech, and language skills. The aim is to develop skills that were not present beforehand (Tye-Murray, 2009). The procedures and techniques that speech and hearing professionals use to provide auditory training have evolved gradually over time. There have been reports of analytic training exercises for aural training that date back as early as the 1700s (Tye-Murray, 2009). Rapid advances in technology during the 20th century increased the potential importance of residual hearing. The concept of aural rehabilitation was developed in the 1940s as a response to those who suffered hearing loss during World War II (Robb, 2010). This led to specialists in fields such as speech pathology, psychology, medicine, and deaf education developing auditory training programmes which became a meaningful component of aural rehabilitation for people with hearing impairments (Robb, 2010). The advent of CIs in the latter part of the 20th century further led to an explosion in the development of auditory training materials and methods (Tye-Murray, 2009).

Speech reading training was a core component of most aural rehabilitation programs before the introduction of hearing aids, CIs, and assistive listening devices which have allowed individuals to better access the auditory signal (Fitz & Paetsch, 1997). A number of investigators have attempted to evaluate the efficacy of speech reading training, using a variety of training methods and tests focusing on different participant groups (Blamey, Cowan, Alcantara, Whitford, & Clark, 1989; Grant et al., 1998; Jerger et al., 2009; Lonka, 1995; Tye-Murray, 1992). However, the authors provide support both for and against the benefits of speech reading training, although most gains from speech reading training are reported to only result in modest benefits for most individuals (Lonka, 1995; De Filippo, Sims, & Gottermeier, 1995; Bernstein, Auer, & Tucker, 2001).

Kujala et al. (2001) evaluated the outcomes of an audiovisual intervention programme without the use of linguistic materials for auditory processing in children with dyslexia. The changes in brain plasticity resulted in improved auditory processing in the auditory cortex which was reflected in changes in enhanced mismatch negativity and faster reaction times to sound changes (Kujala et al., 2001). The outcome was improvements in reading skills and amelioration of reading difficulties for children with general auditory perceptual difficulties (Kujala et al., 2001). Other researchers have studied AV integration in HI participants and they concluded that their integration modelling results suggest that speech reading and AV integration training could be useful for some individuals, potentially providing as much as 26 percent improvement in AV consonant recognition (Grant et al., 1998).

Some studies have shown that substantial benefit may be gained from computer-based, AV vowel identification training. In one study it was shown that auditory training using perceptual training software, altered the neural encoding of complex sounds for nine children with dyslexia by improving neural synchrony in the auditory brainstem (Russo, Nicol, Zecker, Hayes, & Kraus, 2005). In another study, Richie and Kewley-Port (2008) trained and tested NH adults under AV conditions in the presence of background noise which was designed to simulate the effects of a hearing loss. Improvements were seen in AV speech recognition for trained compared with untrained participants for vowels in monosyllabic words and key words in sentences in difficult listening conditions (Richie & Kewley-Port, 2008).

The inclusion of V-only and AV speech perception measures can provide important information for designing maximally effective audiological rehabilitation strategies (Tye-Murray, Sommers, & Spehar, 2007). It is possible that children receive more benefit from AV training than adults, although this matter has not received as much attention as speech reading training in adults. There are many potential benefits of combining A-only training with AV training in intervention programmes for children. By combining A-only and AV training, a associations between corresponding A-only and AV representations of speech will be (Tye-Murray, 2009). Building a child's aural awareness and representations of words can an increase in the amount of words that the child can identify. Another advantage is that children learn how to monitor their own speech production including the suprasegmental qualities of their speech (Tye-Murray, 2009). AV training has also been shown to significantly improve literacy and perception of speech sounds in children with auditory processing disorder (Veuillet, Magnan, Ecalle, Thai-Van, & Collet, 2007). Davies, Kidd, and Lander (2009) suggest that including visual feedback with current and future therapies is important as a therapeutic tool, however there is a need for further research to determine the role that speech reading has on communication development.

Variables in speech perception test stimuli, format and procedures

Test stimuli

A range of different speech stimuli can be used in speech recognition tests. These include phonemes, nonsense syllables, words, phrases, and sentences (Tye-Murray, 2009). The advantages of using real words are that they have higher face validity than nonsense syllables, they are easier to score, and they allow a wide range of skill levels to be assessed (Mendel, 2008; Madell & Flexer, 2008). Words that are phonetically balanced are often used. Phonetically balanced words are those that include phonemes that occur in the same proportion in which they occur in spoken English (Siegenthaler & Gruber, 1969). Alternatively, tests may consist of sentences that are based on a particular theme or topic and can include sentences that are unrelated (Tye-Murray, 2009). Sentence stimuli have high face validity because they are more typical of everyday communication exchanges and may better reflect how a person performs in the real world in comparison to performance on a phoneme or isolated word test (Mendel, 2008).

Response format

Open-set tests are those in which the listener is free to give any response which is not defined by a set of response items. In contrast, closed-set tests require that the listener make a response to the task by selecting an item from a fixed number of possible responses (Kirk et al., 1995). Open-set tests are not always appropriate for use with children. An important consideration is that a child may not be able to give a response or they have poor speech production and therefore their responses cannot be discriminated. In addition, some children are too shy or unwilling to give a response (Kirk et al., 1995). In an open-set task the child has to compare the stimulus item to all possible words in their lexical memory, while a closed-set tasks require only a limited number of comparisons among the set of response items (Mendel, 2008). The impacts of talker variability and lexical competition are less critical to the closed-set task and are easier than open-set tests (Madell & Flexer, 2008). Closed-set tests can be used with individuals who cannot read or write well enough to make a response and can be used to test speech recognition ability in young NH children and CI users (Kirk et al., 1999). The response set size and features can be varied according to the features of speech recognition that are being assessed (Tye-Murray, 2009).

Pre-recorded vs. live voice presentation

An important consideration in relation to selecting speech recognition test materials is whether monitored live-voice or standardized recorded stimuli should be used for a speech recognition test (Kirk et al., 2011). Live-voice presentations of the stimuli are spoken by the tester in real time, whereas pre-recorded stimuli are presented via a playback system such as a computer or DVD player. The use of live voice presentation has the advantage that the speaker can change their stimulus presentations according to the type of stimulus required, and younger children are more comfortable with live-voice testing in comparison to the use of pre-recorded test presentation (Kirk et al., 2011). However, there are a number of disadvantages with live-voice test presentation, including the variability of speaking styles and the difficulty with keeping presentation consistent across stimuli and from one test session to the next (Mendel, 2008). Therefore, pre-recorded speech reading tests are thought to be more reliable than live-voice tests (Madell & Flexer, 2008; Kirk et al., 2011).

Available tests for audiovisual speech recognition in children

Speech recognition assessments must provide accurate measurements of a child's ability to recognize phonetic segments and patterns as well as words, sentences, and connected discourse (Mendel, 2008). AV speech recognition tests better reflect the demands of everyday communication than A-only tests, and can be a valuable component of the test battery used to assess speech recognition development in children with sensory aids (Holt et al., 2011). There are a large number of tests that have been developed to assess speech perception in an A-only condition for adults and children, however there are few standard clinical tests available that assess AV speech recognition in children (Holt et al., 2011). A summary of some of the available AV speech recognition tests for children are outlined below.

Audiovisual Feature Test for Young Children

The Audiovisual Feature Test is a closed-set test of consonant feature recognition that was developed by Tyler, Fryauf-Bertschy, and Kelsay (1991) to assess speech recognition abilities of young children. The stimulus items consist of seven phonemes (all consonants) and three words that are judged to be familiar to young children. Due to the closed-set nature of the task, the same stimulus items can be used in consecutive test administration to compare performance in multiple modalities (Holt et al., 2011). However, this test does not use connected speech, has limited stimuli available for repeated testing, and is not commercially available.

The Children's Audiovisual Enhancement Test

The Children's Audiovisual Enhancement Test (CAVET) test was developed by Tye-Murray and Greers (2001) to assess the speech reading enhancement of children who have significant hearing loss. The test is comprised of three audio-visually recorded word lists of 20 words each. Each list contains 10 words that are difficult to speech read and 10 words that are easy to speech read as was determined by administering word lists to young, NH adults (Tye-Murray et al., 2007). The advantage of this test is that children do not typically achieve floor and ceiling effects in the V-only condition like some other speech perception tests (Tye-Murray, 2009). Although this test is useful for assessment of speech reading of isolated words, it does not test connected speech which is more representative of receptive communication in everyday life (Mendel, 2008).

The Audiovisual-Lexical Neighborhood Sentence Test

The Audiovisual-Lexical Neighborhood Sentence Test (AV-LNST) is an AV speech recognition test that has been developed by Holt et al. (2011). The test is based on the original Lexical Sentence Test (Eisenberg, Martinez, Holowecky, & Pgorelsky, 2002). The AV-LNST consists of six lists of eight sentences that can be administered in three different presentation formats: V-only, A-only, and AV conditions. The lists are equal in difficulty for the three test conditions. The five to six word sentences are low in word predictability because they contain words that are semantically neutral from each other and the lexical word features are controlled for. Each list contains eight sentences which include four lexically easy key words and four lexically difficult key words (Kirk et al., 2007).

An advantage of tests like the AV-LNST is the empirical support for the NAM by demonstrating that neighborhood density and frequency affect both the speed and accuracy of spoken word recognition (Mendel, 2008). However, preliminary reports by Holt et al. (2011) who tested 57 children using who ranged in age from 3;0 to 5;11 years, showed that they produced floor and ceiling effects across the test conditions. They found that by the time children were 3;6 years-old, most were performing at or near ceiling in both the A-only and AV presentation modalities. Floor effects were also found for the V-only conditions.

Additional modified tests

Two pediatric A-only tests have also been modified for AV speech reading testing in young CI users (Holt et al., 2011). These include the *Common Phrases Test* (Robbins et al., 1995) and the *Pediatric Speech Intelligibility* (PSI) test (Jerger, Lewis, Hawkins, & Jerger, 1980). The first test is an open-set test of word and sentence recognition that was initially used to evaluate auditory processing skills in children (Holt et al., 2011). The PSI is a closed-set test of word and sentence recognition that originally developed for children as young as three to six years of age for evaluating both peripheral and central components of central auditory processing in children (Kirk et al., 1995). The tests are administered in word and sentence conditions using live voice, where the child points to the corresponding item that the speaker says from a selection of five picture cards. These tests have been adapted by researchers and clinicians for multimodal speech perception testing of outcomes for children who used hearing aids or CIs (Holt et al., 2011).

Other tests that are available for assessing speech reading in children include the *Craig Sentences* and the *Craig Words* that were developed by Craig in 1964 (Tye-Murray, 2009).

Although these tests are valuable for various purposes, there is a need for a multimodal speech perception test that is pre-recorded, uses connected speech, and is based on a theory of spoken word recognition (Holt et al., 2011). Live-voice presentation does not allow for control over factors that affect spoken word recognition, including speaking level, speaking rate, inflection, and vocal clarity across speakers and stimuli within a single speaker (Holt et al., 2011).

Matrix Tests

A type of test that avoids some of the limitations described previously in AV speech reading testing is a matrix test. Matrix tests are used in closed-set tasks and are made up of a set of distracter items and also include the target word or stimuli. They can be word or picture based matrices and can vary in the number of response choices for different types of tests (Tyler, 1991). A major advantage for using matrix tests is the avoidance of both floor and ceiling affects that occur in other AV speech perception tests. A picture response matrix can easily be used to assess speech perception abilities in younger children without them having to repeat the speech stimuli. Instead the child can respond by identifying the picture as soon as the stimulus is presented. The response matrices can also be presented on a computer touch screen which allows easy presentation and scoring of the child's responses (Tyler, 1991).

One of the problems with repeated speech perception testing using the same test is that it can result in learning effects. This occurs when performance on a test improves due to learning either the test items or the test procedures with repeated administrations (Yund & Woods, 2010). Therefore the specific test may not reliably measure the effect of an aural intervention programme as it often does not truly reflect improvement in speech perception. One way in which the learning effect problem has been addressed is with the use of equivalent lists, where lists are compiled that are presumed to be equally difficult to recognize visually and auditorily (Tye-Murray, 2009). List equivalency is often established by playing the separate lists to a large group of participants and determining whether they are able to recognize an equal number of words on each list in each test condition, e.g. V-only in comparison to an AV test condition (Tye-Murray, 2009).

A closed-set matrix test can be used to reduce the impact of learning effects on test scores (Tye-Murray, 2009). A closed-set of words is presented in the same sentence format or in one of a number of possible sentence frames. The closed-set nature of the response set ensures list equivalency, both within and across conditions (e.g. vision-only and auditory-only). Learning effects that may result from repeated testing are minimized because the participant is familiarized with the matrix of key words prior to each test session by means of practice sessions and the same sentence does not need to be used twice if enough sentences are recorded (Tye-Murray, 2009). A possible disadvantage of using this test format is that only a limited number of words can be assessed and it may be too easy for those participants who have very good listening and/or speech reading abilities (Tye-Murray, 2009).

The Children's-Build-A-Sentence test

The Children's-Build-A-Sentence (Ch-BAS) test is a matrix test that has recently been developed in the US to assess speech reading enhancement in American English (AE) speaking children by Nancy Tye-Murray and her research team at the Washington University School of Medicine (St Louis, MO). This test is not yet commercially available. The Ch-BAS is a closed-set sentence recognition test that is designed to avoid the floor effects typically associated with V-only testing and to be appropriate for the vocabulary levels of young children who have significant hearing loss. The Ch-BAS is also referred to as the Tri-BAS test because it includes one-syllable, two-syllable, and three-syllable words. The test was modeled from the Build-A-Sentence (BAS) test that was developed to assess speech recognition abilities of adults (Tye-Murray, Sommers, & Spehar, 2006).

The first step in the development of the Ch-BAS involved the generation of word lists that fit the description of "nouns with eyes" such as animals and people, and that were comprised of one-, two- and three-syllabic words. Lists were reviewed by five educators of the deaf to make sure the vocabulary was appropriate for children with hearing loss as young as five years. The lists were then made up into three test matrices of nine words each, based on word frequency (i.e., words that have similar frequency of occurrence in everyday language use), so that each matrix included words with similar word frequency. Three separate matrices were constructed for each of the monosyllabic, bi-syllabic, and tri-syllabic word lists. Lists of sentences were then generated that included word pairs from the response matrices in the format, "The ___ watched the ___." The sentences were spoken by a local AE-speaking actress for every combination of word pairs.

The Ch-BAS requires the participant to respond to a stimulus sentence that is presented in the A-only, V-only, or AV condition by pointing to the pictures of the two words within the sentence. For example, if the participant heard the sentence, "The tiger watched the penguin," he or she would see a matrix appear with nine pictures to choose from and should touch the tiger followed by the penguin in sequential order (see Figure 1 for an example screen shot). Pilot testing of the Ch-BAS test with four HI children showed that the children all scored above chance in the V-only conditions and below ceiling in the AV conditions. Further analysis and testing of normal-hearing AE-speaking children is currently being carried out.

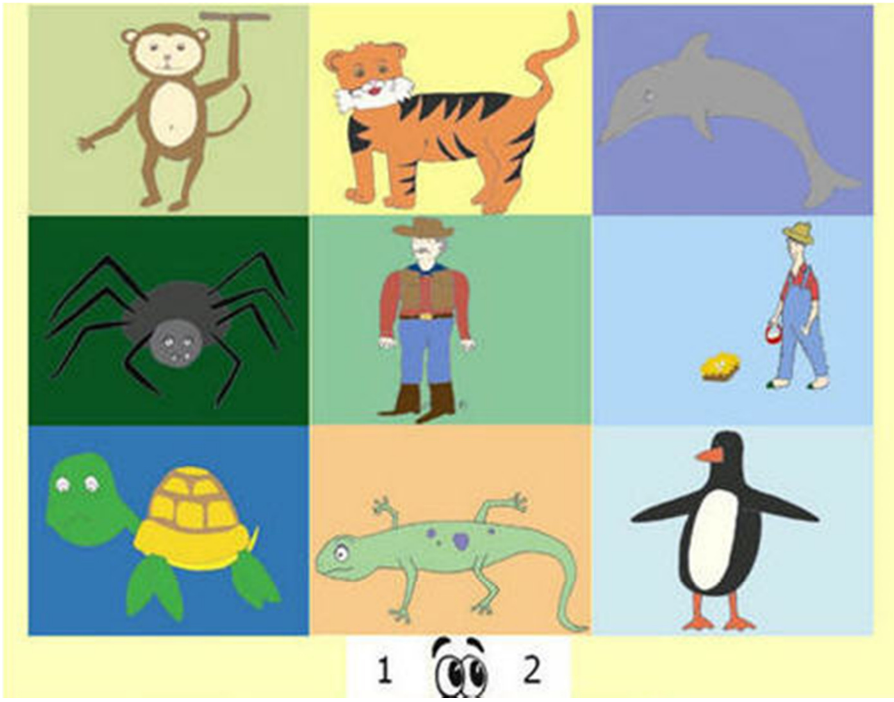

Figure 1. *A sample monitor touch screen response matrix. The sentence prompt was, "The tiger watched the penguin."*

The Present Study

Despite the importance of multimodal spoken word recognition testing, there are few AV speech recognition tests for children and these tests have been developed exclusively for AE-speaking children. There are no current tests available for children who speak New Zealand English (NZE). The AE and NZE languages differ in a variety of ways. For example, AE contains some vocabulary that is not typically used by NZ English speakers, such as, the words 'rancher' (farmer), 'pitcher' (jug), and 'faucet' (tap) (Nilsson, Soli, & Sullivan, 1994). Dialectical variations can also impact on a listener's ability to perceive speech in the presence of background noise (Clopper & Bradlow, 2008). Therefore there is a clear need for the development of a multimodal speech recognition test for assessing the speech recognition abilities of NZE-speaking children. Such information would serve to validate the Ch-BAS and further support its widespread use. This study aimed to adapt the AE version of the Ch-BAS test for use with NZE-speaking children and to evaluate list equivalency and the relationship between age and speech reading enhancement. Another objective was to develop a test manual and CD version of the Ch-BAS test so that it can be used in speech and hearing clinics in NZ.

Statement of the Problem

Audiovisual integration is a necessary skill in speech reading and is particularly important for people who have hearing difficulties and who use hearing assistive devices such as hearing aids or CIs. Assessment of speech reading ability of adults and children can provide valuable information regarding the individual's communication abilities, and can be used as a tool to measure the outcomes of an aural rehabilitation programme. Currently speech reading tests exist for AE-speaking adults and children, however no such tests are available for speakers of other varieties of English such as NZE. The purpose of this study was to adapt the Ch-BAS speech recognition test for NZE-speaking children (i.e., NZ Ch-BAS). A second objective was to determine whether there was an age effect for NH children's performance on the test. The following hypotheses were proposed:

Hypothesis 1: *All children will perform significantly better on the AV test conditions in comparison to the V-only test condition.*

Hypothesis 2*: Older children will perform significantly better than younger children in the V-only and AV test conditions.*

Hypothesis 3*: The children's performance on the three lists for each condition (mono, bi, and tri-syllabic words) will not differ significantly (indicative of list equivalency).*

Method

Video recording of test materials

A 25-year-old NZE-speaking female student served as the speaker for recordings of the NZ Ch-BAS sentence materials (see Appendix 3 for the list of sentences). The student was an undergraduate student in the Speech-Language Pathology programme from the University of Canterbury, Christchurch, NZ. The speaker was born in NZ and has lived in Christchurch her entire life. She was considered to have a NZ accent that would be typical of a general dialect of NZE according to the opinion of three clinical certified Speech-Language Therapists. The speaker participated in speech and drama class throughout high school.

The NZE-speaker was seated in a sound treated room in front of the video recorder which was placed at head level. A digital HD video camera recorder (HXR-MC50E/ MC50P) and microphone were used to record the sentence material. The video camera was situated on a tripod, placed 1 meter from the speaker's head. A microphone was placed on a separate tripod 0.5 m from the speaker's mouth. The sentence material was projected onto a glass screen in front of the video camera so that the sentences could easily be read by the speaker and so that she was looking directly at the screen. The Ch-BAS sentence lists were spoken by the speaker with each new sentence spoken approximately 6 seconds apart from the beginning of one sentence to the beginning of the next. All of the recorded sentences were edited into one sound file and sent to the Department of Otolaryngology, Washington University School of Medicine for audio leveling and calibration. The materials was then returned to NZ and placed into the LabVIEW software programme which was then readied for testing.

Test participants

A total of 30 NH children (16 boys, 14 girls) who were between the ages of 7-11 years were used in this study. The children were all NZ born and had been educated at NZ schools. Based on parental report, none of the children had any speech or language problems. This was confirmed by the researcher who also holds a degree in speech-language pathology. An equal number of participants (n=6) were assigned to each of the age groups from 7-11 years. Children were recruited through word of mouth, local schools and local church groups in Christchurch. All participation was voluntary and based on availability. The children and/or the children's parents were required to read information sheets (Appendix 1) and sign consent forms before they could participate in the study (Appendix 2). The study received ethical approval from the University of Canterbury Human Ethics Committee.

Equipment

The children's puretone hearing thresholds were screened across the four speech frequencies (500 Hz, 1 kHz, 2 kHz and 4 kHz) using an audiometer (Grason Stadler GSI-61), where a threshold equal to or below 15 Hz was accepted as normal hearing. Testing took place in a sound treated room which had an intercom system, two loudspeakers, and headphones available. The NZ Ch-BAS speech material was presented as a matrix test which consisted of three test lists which were comprised of monosyllabic, bi-syllabic and tri-syllabic words of relatively low, medium and high frequency usage. The matrix test was presented using the LabVIEW programme software. The recorded sentences and matrix screens were presented on a dual screen setup via a laptop computer (Lenovo T420s) under the control of the tester.

NZ Ch-BAS test procedure

Each child was seated in a sound-treated booth approximately 0.5m from a computer monitor touch screen at zero degrees azimuth. Each child was given a number of practice trials in the A-only, V-only, and AV conditions until the tester was confident they understood the task. The Ch-BAS test was initially administered in the A-only condition for each child, where each sentence was presented through a loud speaker (with no visual signal and a blank monitor screen) to determine the signal-to-noise ratio (SNR) level where the child achieved a 30% correct score. This SNR level was used to set the correct level of the AV test for each child so that performances were approximately equal. The NZ Ch-BAS test materials were then administered in the V-only and AV conditions in a counterbalanced order with half the participants in each age group completing the V-only condition first (where participants could see the talker on the computer monitor with no auditory signal) and the other half completed the AV condition first (where the children could both see and hear the talker).

The children were instructed to watch and/or listen to the speaker say a short sentence and to then choose the two words that corresponded to the spoken sentence. The children responded by pointing to the two pictures in the spoken sequential order from a choice of a 9-item response matrix. The children's responses were scored in the software for a correct or incorrect response and the overall percentage scores for each condition (A-only, V-only, and AV) for mono, bi-, and tri-syllabic words were recorded by the examiner. The results were then analyzed statistically to look at list equivalency, condition effects, and the relationship between age and speech reading ability.

Results

Age effects

The children's individual performances on the three test lists comprised of mono, bi-, and tri-syllabic words are shown in Appendix 4. The mean performance for the V-only and AV conditions (collapsed across word lists) for each age group are shown in Table 1. Among the 7-year-old group the mean performance for V-only ranged from 28.3 percent correct (monosyllables) to 29.5 percent correct (tri-syllables). For the AV condition, the mean performance ranged from 72.8 (bi-syllables) to 77.2 (tri-syllables). Among the 8-year-old group the mean performance for V-only ranged from 28 percent correct (monosyllables) to 95 percent correct (bi-syllables). For the AV condition, the mean performance ranged from 72.2 (bi-syllables) to 92.2 (tri-syllables). For the 9-year-old group, the mean performance for V-only ranged from 28 percent correct (monosyllables) to 95 percent correct (bi-syllables). For the AV condition, the mean performance ranged from 72.2 (bi-syllables) to 92.2 (tri-syllables). Among the 10-year-old group the mean performance for V-only ranged from 28 percent correct (monosyllables) to 95 percent correct (bi-syllables). For the AV condition, the mean performance ranged from 72.2 (bi-syllables) to 92.2 (tri-syllables). Among the 11-year-old group the mean performance for V-only ranged from 28 percent correct (monosyllables) to 95 percent correct (bi-syllables). For the AV condition, the mean performance ranged from 72.2 (bi-syllables) to 92.2 (tri-syllables).

To evaluate whether there was an age effect for speech reading performance for each list condition (V-only and AV) according to word length (mono, bi-, and tri-syllables), a series of one-way ANOVAs were performed. There was a significant age effect for the V-only data for monosyllables [$F(4,25)=5.30$, $p<0.003$] and bi-syllables [$F(4,25)=4.4$, $p<0.008$]. The results for the tri-syllabic task were not significant [$F(4,25)=1.5$, $p<0.242$]. Follow-up t-tests were performed using a Bonferroni correction for multiple t-test comparisons. The results of t-testing for monosyllables found a significant difference between the 7 and 10-year-olds ($p<0.01$); 7 and 11-year-olds ($p<0.001$); and 8 and 11-year-olds ($p<0.01$). Follow-up t-tests for bi-syllables found a significant difference between 7 and 10-year-olds ($p<0.002$) and 7 and 11-year-olds ($p<0.009$).

An ANOVA was also run for the AV condition. A significant age effect was found for bi-syllables [$F(4,25)=2.76$, $p<0.05$]. No significant age effect was found for the AV data for monosyllables [$F(4,25)=2.63$, $p<0.06$] or tri-syllables [$F(4,25)=2.3$, $p<0.084$]. Follow-up t-tests for bi-syllables found a significant difference between the 7 and 11-year-old groups ($p<0.02$), however no other significant age difference was found for this condition. Overall, looking at the age effects, there was a significant age effect for the V-only condition for the mono and bi-syllabic words and for the AV condition for bi-syllabic words.

List equivalency

The mean performances for each list for mono, bi-, and tri-syllabic words are shown in Table 2. To evaluate whether there was a performance difference across the word lists, separate two-way ANOVA (list x task) tests were run for the V-only and AV conditions. Results for the V-only data showed no significant list effect [$F(2,81)=1.619$, $p=0.205$], task effect [$F(2, 81)=0.248$, $p=0.781$], or list by task interaction effect [$F(4, 81)=1.029$, $p=0.397$]. These results were taken to indicate that for the V-only condition the lists were equivalent across mono, bi-, and tri-syllabic words. A two-way (list x task) ANOVA conducted of the AV data showed no significant list effect [$F(2,81)=1.031$, $p=0.361$], task effect [$F(2, 81)=1.65$, $p=0.198$], or list by task interaction effect [$F(4, 81)=0.609$, $p=0.658$]. Similar to the results for the V-only condition, the results for the AV condition indicate that the lists were equivalent across mono, bi-, and tri-syllabic words.

Condition effects

The mean performances for the V-only and AV condition for mono, bi-, and tri-syllabic words are shown in Table 2 and Figure 2. To evaluate whether the overall group of children performed better on the AV condition in comparison to the V-only condition, a series of one-tailed t-tests were performed. The overall results for the mono-syllabic task (collapsed across age groups) were evaluated between V-only and AV conditions. The test was significant, $t(58)=9.29$, $p<0.0001$. A similar test was performed for the bi-syllable task and the tri-syllable task. The results of the bi-syllable task were significant $t(58)=7.9$, $p<0.0001$, as were the results for the tri-syllable task $t(58)=3.2$, $p<0.002$. Overall, looking at the condition effects, the children performed significantly better on the AV task in comparison to the V-only task.

Table 1. Mean performance for each age group for V-only and AV conditions for mono, bi, and tri-syllabic words collapsed across word lists. Standard deviations are shown in parentheses.

	V-only			AV		
Age Group	**Mono**	**Bi**	**Tri**	**Mono**	**Bi**	**Tri**
7	28.3(11.8)	26.7(16.9)	29.4(11.8)	75.0(9.5)	72.8(10.6)	77.2(14.6)
8	38.9(16.9)	35.0(15.7)	29.5(13.9)	78.3(10.2)	72.2(15.1)	77.8(10.8)
9	46.7(16.7)	50.0(16.4)	45.6(13.2)	84.7(8.8)	77.8(8.8)	86.3(8.2)
10	46.1(8.8)	47.2(9.2)	95(118)	86.3(10.0)	83.8(8.2)	87.2(7.1)
11	68(18.9)	65.4(23.9)	55.4(19.9)	90.5(6.7)	88.9(9.1)	92.2(8.0)
Grand Mean	45.7 (19.9)	44.8(20.7)	50.9(56.5)	82.9(10.2)	79.9(11.9)	84.1(11.1)

Table 2. Mean performance (collapsed across lists 1-3) for mono, bi, and tri-syllabic words for the visual (V) only and auditory + visual (AV) conditions. Standard deviations are shown in parentheses.

	Task: No. of Syllables		
Condition	**Mono (n=30)**	**Bi (n=30)**	**Tri (n=30)**
V	45.7(19.4)	44.8(20.7)	50.9(56.5)
AV	82.9(10.2)	79.1(11.9)	84.1(11.1)

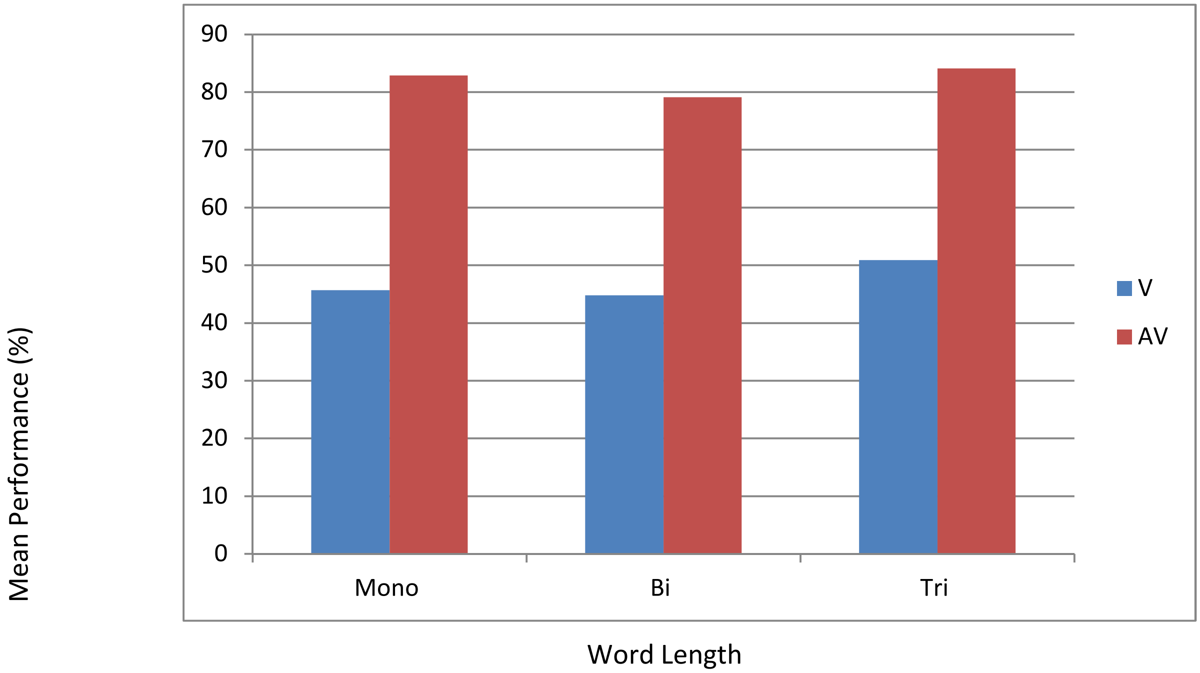

Figure 2. Mean performance (collapsed across lists 1-3) for mono, bi-, and tri-syllabic words for the visual (V) only and auditory plus visual (AV) conditions.

Summary of Results

- Overall, the entire group of children performed significantly better on the AV task in comparison to the V-only task.
- Overall, there was a significant age effect seen for the V-only condition on the mono and bi-syllabic words. An age effect was seen for the monosyllabic task between 7 and 10-year-olds; 7 and 11-year-olds; and 8 and 11-year-olds. For the bi-syllabic task an age effect was found between the 7 and 10-year-olds and 7 and 11-year-olds.
- There was a significant age affect for the AV condition for bi-syllabic words. This age effect was demonstrated for the bi-syllabic condition between the 7 and 11-year-olds only.
- Overall for the V-only and AV conditions, list equivalency was shown across mono, bi- and tri-syllabic words.

Discussion

Assessment of speech reading ability of adults and children can provide valuable information regarding an individual's communication abilities, and can be used as a tool to measure the outcomes of an aural rehabilitation programme (Lonka, 1995; De Filippo, Sims, & Gottermeier, 1995; Bernstein, Auer, & Tucker, 2001). Currently there are speech reading tests that exist for AE-speaking adults and children, however there are no such test for speakers of other varieties of English such as NZE. The purpose of this study was to adapt the AE Ch-BAS speech recognition test for NZE-speaking children and to evaluate the equivalency of the word lists comprising the test. A second objective was to determine whether there was an age effect for children's performance on the test and to evaluate whether children performed better in the AV condition. A total of three hypotheses were developed for this thesis. A discussion for each hypothesis is presented below.

Hypothesis 1: *All children will perform significantly better on the AV test conditions in comparison to the V-only test condition.*

Overall, the entire group of children performed significantly better on the AV task in comparison to the V-only task. This was evident in all word-length conditions. Therefore hypothesis one is accepted. This supports previous research that has found a significant improvement in speech reading when the auditory and visual signals are combined (Auer & Bernstein, 2007; Holt et al., 2011; Ross et al., 2007). All participant groups were sensitive to presentation modality effects on the multimodal sentences. In general, the highest scores were achieved when listeners had access to both the auditory and visual speech cues simultaneously, demonstrating their ability to integrate cues from both modalities to improve performance over one modality alone. This was also demonstrated in a study by Holt et al. (2011). The authors showed that when participants had access to the auditory speech cues only they achieved significantly better scores in comparison to when they only had access to a V-only condition (Holt, Kirk, & Hay-McCutcheon, 2011).

Researchers have proposed that the better speech reading performance obtained in the AV condition is due to the fact that the addition of visual speech cues reduces the competition for lexical selection for the incoming speech signal (Holt, Kirk, & Hay-McCutcheon, 2011; Ross et al., 2007). Another hypothesis is that improved AV integration results from the development of a functional pathway in the fronto-temporo-parietal networks of the brain. This brain region is important for relating motor and sensory information used by listeners to identify speech sounds and is thought to lead to improved speech understanding through experience producing and perceiving speech (Dick, Solodkin, & Small, 2009). Other research has shown that cross-modal compensation has been shown to follow long periods of visual or auditory deprivation (Strelnikov et al., 2009). In the case of deafness, research has shown that there is an associated compensation by the development of enhanced visual processing and therefore improved speech reading capabilitites in these individuals. It has also been demonstrated that CI users rely more on the visual speech signal to supplement the crude information that is provided by the use of a CI to enhance comprehension of the spoken speech signal (Strelnikov et al., 2009).

Although it seems obvious that speech reading performance is enhanced when both auditory and visual aspects of the signal are combined, it is interesting to consider the role of word length on performance. Examination of the results displayed in Figure 2 show a clear difference in performance between the AV and V-only conditions across word length. Examination of the V-only results indicates that the best performance was found for tri-syllabic words compared to mono and bi-syllabic words. Although this difference in performance was not statistically significant, it appears that word length aided speech recognition in the V-only condition.

The scores from both the V-only and AV conditions are useful speech reading measures because they can be used to assess speech reading enhancement. Speech reading enhancement (also known as auditory enhancement) is computed by comparing speech recognition scores in a V-only condition to scores on an AV condition (Tye-Murray, 2009). This score indicates how much a person's performance is improved by having access to the visual and auditory signal, and is often a good indicator of how much benefit a person with significant hearing loss receives by using a listening device during face-to-face communication (Tye-Murray, 2009). The simplest way to calculate a speech reading enhancement score involves subtracting the V-only percentage correct score from the AV percentage correct score. The greater the difference between the two scores, the greater the amount of enhancement provided by the auditory signal (Tye-Murray, 2009).

Hypothesis 2*: Older children will perform significantly better than younger children in the V-only and AV test conditions.*

The results of a series of one-way ANOVA tests showed that older children performed significantly better than the younger children for some, but not all, test conditions. In general, the oldest children (11-year-olds) performed better than the youngest children (7-year-olds). This was the case in the V-only condition for monosyllables and bi-syllables; and for the AV condition for the bi-syllables. On the basis of these results, the second hypothesis is partially accepted. Overall, there was a much stronger age effect for V-only compared to the AV condition. This seems to indicate that V-only skills continue to develop as a child ages and that younger children have less developed skills for adequate speech reading. However, when children are provided with the auditory signal (AV condition), the age effect almost disappears. This finding supports previous research findings that speech reading ability continues to develop into the late childhood years and that normal hearing younger children use less visual information than older children for speech perception (Dick, Solodkin, & Small, 2010; Ross et al., 2011). Dick et al. (2010) showed that the same area of the fronto-temporo-parietal network of the brain is activated for AV speech perception in both adults and children aged 8-11 years. However, there were age related differences in the functional interactions among these regions which support the hypothesis that speech perception processing ability develops with age.

There are other factors to consider in regard to the notion of age effects and speech reading, namely reading ability and attention span. In one study of 76 children aged 2;10 to 4;11 it was found that speech reading ability was significantly correlated with vocabulary size. This suggests that the poorer speech reading ability seen in younger children is actually a product of their language ability and development (Davies, Kidd, & Lander, 2009). Vocabulary size was not measured in the present group of children so it is unknown whether this was a contributing factor in these results. The poor performance shown by the youngest children in the present study may have been affected by their reduced attention span which makes them less likely to attend to the speaker's lips (Massaro et al., 1986). However, this theory has been discredited and it has been shown that developmental differences are more directly related to speech reading ability and not to attentional capabilities (Massaro et al., 1986).

Interestingly, there was no age effect found for speech reading of tri-syllables in either the V-only or AV condition. This pattern of results would seem to suggest that longer words are as easy to recognize by young children as they are by older children. This finding has also been demonstrated in other speech perception studies with children (Krull, Choi, Kirk, Prusick, &

French, 2010; Krull et al., 2010). A possible reason for this finding is that listener's are able to use linguistic redundancy cues in multisyllabic words to aid in speech perception. Secondly, multisyllabic words come from sparse lexical neighbourhoods compared with monosyllabic words (Kirk, Hay-McCutcheon, Todd, Sehgal, & Miyamoto, 2000). Lexically easy words (i.e. those that are easy to recognise visually and that have fewer lexical neighbours) have been shown to be recognised with greater accuracy than lexically hard words (i.e. those that occur less often and have many lexical neighbours) (Kirk et al., 2000). These lexical characteristics most likely explain why no significant difference was found for speech reading of tri-syllabic words.

Hypothesis 3*: The children's performance on the three lists for each condition (mono, bi, and tri-syllabic words) will not differ significantly (indicative of list equivalency).*

The results showed that there was no significant difference in performance across the three lists (1, 2 and 3) for both the V-only and AV conditions. This was taken to indicate that the three lists were equal in difficulty and therefore hypothesis three is accepted. This is an important finding and is suggestive that the V-only and AV conditions on the three lists can be used interchangeably between children without the impact of learning effects. It is essential that lists used for speech recognition ability show inter-list equivalency, otherwise the usefulness of the test is limited (Loven & Hawkins, 1983). The audiologist can therefore determine a child's performance on subsequent testing and evaluate the change in speech reading ability (Tye-Murray, 2009). If differences were shown between the three lists on the NZ Ch-BAS then it could severely limit the usefulness of the test when different lists are used to compare performance across individuals, hearing aids, or listening conditions. The audiologist would not be able to determine whether differences in the word recognition scores obtained from separate lists were the result of differences in hearing aids, listening conditions, or list difficulty (Loven & Hawkins, 1983). The fact that inter-list equivalency has been demonstrated for the NZ Ch-BAS lists suggests that the multimodal sentence materials can be used to test speech perception in multiple presentation modalities down to at least the age of six years in NH children. It seems plausible that NZ children of a similar age or older with HL will also be able to be administered the NZ Ch-BAS materials for speech perception testing.

Limitations

One of the major limitations of this study was that a small sample size of children (n=30) was obtained, with only six children included for each age group. This meant that only two children from each age group were tested on each list. Also, children were not recruited on the basis of sex and therefore there was an uneven number of boys (n=16) and girls (n=14) that participated in the study. Also the six children in each group were not matched for sex and some of the groups had unequal numbers of boys and girls. A number of researchers have demonstrated sex differences in speech reading ability (Irwin, Whalen, & Fowler, 2006; Ruytjens et al., 2006; Strelnikov et al., 2009). Other researchers have shown that there is no significant sex difference in speech reading performance ability between the two sexes (Auer & Bernstein, 2007; Jerger, 2007; Tye-Murray et al., 2007), and therefore this may not be a significant factor in this study.

The children were recruited by word of mouth and through local schools in Christchurch that were close to the University of Canterbury. The normative data therefore may not be truly representative of the actual population's cultural, linguistic, socioeconomic and age variations in New Zealand. If this study was to be expanded, more participants should be recruited for each age group and from different cultural backgrounds and geographic areas in New Zealand. It would also be important to have each age group sex-matched to account for any performance differences between the sexes.

Another limitation to the present research is that some of the test stimuli used in the NZ Ch-BAS were not entirely familiar to NZE-speaking children. For example, the picture of the bird called a "roadrunner" was not known by many of the children tested and a number of children commented that the bird looked like a fantail (i.e., a common NZ bird). Some of the drawings of the pictures also did not clearly depict the actual target word for NZE-speaking children. For example, a small sample of the children commented that the picture of the rooster looked more like a chicken. The children also suggested that the picture of the turkey and chicken were confusing at times and also the picture of the farmer and the cowboy, and the wolf and the dog were also similar and sometimes confusing.

Another limitation is that the present group of NZE children used in this study did not undergo formal assessments for receptive vocabulary, expressive language or working memory abilities. Therefore the results may not reliably predict speech reading ability as there may have been variation across children in their language skills. However, parents were asked to report on their child's speech, language and learning background as a basic screen for any difficulties. Further, the general normalcy of language abilities of the children was confirmed by the researcher who holds an academic degree in speech-language pathology. Still, it would have been useful to perform full assessments of each child's language abilities to rule out the possibility of any delay or disorder. Children that were reported to have speech, language or learning difficulties were not included in the study. Although one child was included who was reported to have phonological awareness intervention for a reading difficulty when he was a few years younger. His mother reported that he no longer had any reading or learning difficulties.

Some of the children's performances could have been impacted on by the effects of fatigue or reduced attention to the speech reading task. Children were tested at a range of different times throughout the day and the test procedure was quite long. According to Bantwal and Hall (2011), an unnecessarily lengthy test may result in depressed scores as a result of an attention deficit or diminished motivation. Some of the younger children seemed to experience difficulty concentrating, particularly in the V-only condition of the test. Children were given breaks during the testing where they were able to play games, have a snack, a short walk and/or talk with the tester in order to reduce the effects of fatigue and reduced attention.

Another consideration is that some of the younger children spent considerable time visually scanning the pictures on the screen so it is possible that there were too many pictures on the response matrix to choose from. Research has shown that too much focus of attention can actually decrease performance during problem-solving tasks (Wiley & Jarosz, 2012). Some of the older children reported using strategies to determine what the speaker was saying and therefore may have performed significantly better than those who were not using similar strategies. For example, a 10-year-old girl reported that she had been counting syllables to work out what the words were for the V-only condition. Imbo and Vandierendonck (2007) showed, in their study of 10-12 year-old children, that working memory ability is needed in retrieval, transformation and counting strategies and that available working memory resources changes across development. It was also found that more efficient counting strategies reduced the working memory requirements and that individual differences (e.g. processing speed, gender, and level of task anxiety) affect strategy efficiency and strategy selection amongst different children (Imbo & Vandierendonck, 2007).

Cognitive ability may also impact performance on speech reading tasks. Hinze et al. (2009) showed that working memory ability in children can affect performance on cognitive skill acquisition and the ability to problem solve on certain mathematical tasks (Hinze, Bunting, &

Pellegrino, 2009). Additionally, this hypothesis can be used to explain findings of age-related cognitive declines in working memory that may be exaggerated by decreases in attentional capacities in some older adults. Such attentional impairments may make it more difficult for older adults to comprehend sentences that are more ambiguous or that have complex syntax (Tye-Murray et al., 2008). In another study, Lemaire and Lecacheur (2011) showed that children's skill at both strategy selection and execution improves with age and that also increased efficiency in executive function contributed significantly to age-related improvement in children's strategy selection skill. Therefore these findings have implications for understanding of age-related differences in strategy selection processes and mechanisms of strategic development in children (Lemaire & Lecacheur, 2011).

Finally, another possible limitation is that children's performance was not tested in the A-only conditions due to time constraints with the study. Therefore this part of the test cannot be used clinically in NZ. In addition it would have been interesting to evaluate children's performance on V-only compared to the A-only condition to assess list equivalency and to determine whether children's performance on the A-only condition shows list equivalency and an age effect.

Directions for future research

A possible next step in this line of research would be to test speech reading performance in children with varying levels of hearing impairments, as well as pediatric CI users. Studies have shown that children with early onset HI perform significantly better on a V-only condition in comparison to NH children (Auer & Bernstein, 2007; Holt et al., 2011). In the future, the NZ Ch-BAS test could be evaluated in its usefulness as a monitoring tool for aural rehabilitation with assistive listening devices and or speech reading training. Due to time constraints, list equivalency was only evaluated in the AV and V-only conditions and therefore list equivalency could also be evaluated for the A-only conditions.

A likely next step towards developing the Ch-BAS test for clinical use would be to establish norms and evaluate test-retest reliability and validity for a wide range of NZ children with NH in the context of headphones and in the soundfield. The results of this study are promising in that the NZ Ch-BAS materials can be used as a valid and reliable measure of multimodal sentence recognition in NZE-speaking children with hearing loss. Another interesting line of research would be to evaluate whether NZE-speaking children perform better on the NZ Ch-BAS in comparison to the original AE version of the Ch-BAS. It was originally assumed that linguistic differences between AE and NZE would lead to poorer performance on the original AE Ch-BAS among NZE-speaking children. However this assumption was never directly tested.

Another important investigation could be to look at the use of speech reading tests such as the Ch-BAS to test for modality specificity or for use with other populations such as children struggling with auditory processing disorder (APD) or associated listening and learning difficulties. As was discussed previously, a number of studies have demonstrated the benefit of audiovisual intervention programmes for children with dyslexia, APD, and other learning difficulties (Kujala et al., 2001; Richie & Kewley-Port, 2008).

Future research may involve using speech perception tests like the Ch-BAS to evaluate new technology for those with hearing impairments. One study has looked at the use of AV frequency modulation (FM) systems in the classroom to improve speech reading performance in unfavorable acoustic listening environments for those with severe or profound hearing loss (Gagné, Charest, Le Monday, & Desbiens, 2006). This can provide many perceptual benefits for students and enhances learning potential of hearing impaired children. It has been shown that the benefits of providing AV speech is equivalent to enhancing the signal-to-noise ratio by up to 10 dB (Gagné et al., 2006).

Further research is needed in this area but the development of the AV FM system could be used to greatly enhance speech reading and learning for children with hearing impairments.

Summary

The aim of this study was to adapt the AE version of the Ch-BAS test for use with NZE-speaking children and to evaluate list equivalency and the relationship between age and speech reading enhancement. The results of this study showed that all lists were equivalent based on the children's performance scores for both the V-only and AV conditions. A second objective was to determine whether there was an age effect for children's performance on speech reading using this test. It was found that the older children showed superior speech reading performance in comparison to the younger children particularly for the vision-only conditions. This supports previous research findings that speech reading ability continues to develop into late childhood and that normal hearing younger children use less visual information than older children for speech perception (Dick et al., 2010; Massaro et al., 1986).

The NZ Ch-BAS test has been shown to have equivalent lists and yields similar levels of performance between the 3 lists for each condition (AV and V-only). An ultimate goal is to establish normative data to ready this test for clinical use in New Zealand (see appendix 5 for the test manual), and to assess audiovisual speech perception in children with hearing impairment. It can also be used as a tool to measure the outcomes of specific intervention programmes and may be helpful in counseling children and their parents in the benefits of using both auditory and visual information to help improve speech understanding during everyday communication. The results of this preliminary test of the NZ Ch-BAS are a first step toward this ultimate goal.

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Appendix 1

Project Information Sheet

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Department of Communication Disorders

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PROJECT INFORMATION

Development and evaluation of the New Zealand Children's-Build-A-Sentence Test

The Children's-Build-A-Sentence Test (Ch-BAS) has recently been developed in the United States to assess the way that American English-speaking children use both auditory and visual information (lipreading) for sentence recognition. The tests can be used with children who have hearing impairment to help define the areas where they are having most difficulty and can then be used to develop appropriate intervention programmes for these children.

Currently there is no test for New Zealand English speaking (NZE) children that assesses auditory-visual speech recognition. The purpose of this study is to develop and evaluate the Ch-BAS test for normal hearing NZE-speaking children so that it is ready for clinical use. This project is being carried out as part of a Masters of Audiology thesis and will be available via the University of Canterbury (UoC) database.

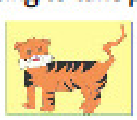
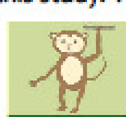
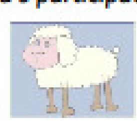
Your child will be required to attend one testing session, which will last approximately 60 minutes with breaks included. At the beginning of the session, your child will receive a brief hearing screening. The task that your child will be required to perform will involve watching a video recording of a speaker saying short sentences with and without access to the auditory signal. Your child will then be asked to point to two picture items from a computer screen that they think the speaker has said, e.g. The talker might say, "The cow watched the dog" and then the child points to the 'cow' and 'dog' from a selection of 9 items on the screen. You can choose to view your child's results on the Ch-BAS test on completion of the test.

The tests are perfectly safe and will in no way cause your child any discomfort or harm. However, you may stop the tests at any time and are free to discontinue participation in this study, and may withdraw your consent for your child or the information you have provided. If your child does not pass the initial hearing screening, then a full diagnostic hearing test will be offered at the UoC Speech and Hearing Clinic free of charge.

Testing will take place at the UoC Speech and Hearing Clinic at a time that is convenient to you. It is required that a parent or caregiver is present throughout the study. Free parking is available for 'clinic clients' in the staff car park. Two $10 Westfield mall vouchers will be provided for you and your child in recognition of your time commitments.

Please note that this study has been reviewed and approved by the University of Canterbury Human Ethics Committee.

Thank you for choosing to take part in this study. Your child's participation is greatly appreciated.

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Appendix 2

Consent Forms

University of Canterbury
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CONSENT FORM - PARENT

Development and evaluation of the New Zealand Children's-Build-a-Sentence Test

D E C L A R A T I O N

I ___________________________(parent/caregiver of child) have read and understood the description and requirements of the above-named study, as outlined in the attached information sheet. Any questions I have asked have been answered to my satisfaction. On this basis, I agree for my child to participate in this study, realising that I may withdraw my child at any time without prejudice.

I understand that all information provided is strictly confidential and will not be released by the investigator unless required to do so by law.

I understand that this project is being carried out as part of Master of Audiology thesis and will be available via the University of Canterbury database. I agree that research data gathered in this study may be published. I provide consent for this publication with the understanding that anonymity will be preserved, and my child's name and any other identifying information will not be used.

I note that this study has been reviewed and approved by the University of Canterbury Human Ethics Committee.

NAME OF PARENT:____

NAME OF CHILD: ____

SIGNATURE OF PARENT: ____

DATE:

University of Canterbury
Department of Communication Disorders

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Child Assent Form

"Development and Evaluation of the New Zealand Children's Build-A-Sentence Test"

Why am I here?
We are asking you to take part in a research study because we are trying to learn more about how children use their ears and their eyes to listen to people talking.

Why are they doing this study?
For this study we have created a special listening activity that can be played on a computer. We want to see how well children of different ages do when they play this computer programme. Some children who have problems with their hearing need help in becoming good listeners. We hope to someday use this computer programme for children with hearing problems to help them become better listeners. For now, we want to first see how children with good hearing perform on this activity. We will also ask your parent/guardian if you can be in the study.

What will happen to me?
If you decide to take part in this study, you will sign this form after I (Emma Rogers) answer any questions you may have. Your parent/guardian will sign a different form. I will have you take part in two activities. The first activity will be to test your hearing by listening carefully to very soft sounds. The second activity will be to perform the special listening activity that is played on a computer.

Will the study hurt?
This study will not hurt.

Will the study help me?
This study will not help you directly but we hope that we may learn more about how well children of different ages use their eyes and ears to listen to people talking.

What if I have any questions?
You can ask any questions you have about the study. If you have a question later that you didn't think of now, you can call me (Emma Rogers - 027 222 9078).

Do my parents know about this?
This study was explained to your parents and they said that you could be in it. You can talk this over with them before you decide.

Do I have to be in the study?

You do not have to be in the study. No one will be upset if you don't want to do this. If you don't want to be in this study, you just have to tell them. You can say yes now and change your mind later. It's up to you.

Writing your name on this page means that you agree to be in the study, and know what will happen to you. If you decide to quit the study all you have to do is tell Emma or your parents.

_____________________________________ __________________

Print Name of Child Date

_____________________________________ __________________

Signature of Child Date

_____________________________________ __________________

Signature of Researcher Date

Appendix 3

Sentence lists

NZ Ch-BAS Sentence Lists

Cond	Pos	Sent	Syll	Plate	Sentence	Word 1	Word 2
X	1	1	Mono	1	The clown watched the hen	Clown	Hen
X	2	2	Mono	1	The hen watched the chef	Hen	Chef
A	3	3	Mono	1	The chef watched the whale	Chef	Whale
X	4	4	Mono	1	The whale watched the ant	Whale	Ant
V	5	5	Mono	1	The ant watched the crab	Ant	Crab
X	6	6	Mono	1	The crab watched the goat	Crab	Goat
X	7	7	Mono	1	The goat watched the owl	Goat	Owl
X	8	8	Mono	1	The owl watched the goose	Owl	Goose
X	9	9	Mono	1	The goose watched the clown	Goose	Clown
X	9	9	Mono	1	The goose watched the clown	Goose	Clown
A	10	1	Mono	1	The clown watched the goose	Clown	Goose
V	11	2	Mono	1	The hen watched the clown	Hen	Clown
A	12	3	Mono	1	The chef watched the hen	Chef	Hen
V	13	4	Mono	1	The whale watched the chef	Whale	Chef
A	14	5	Mono	1	The ant watched the whale	Ant	Whale
V	15	6	Mono	1	The crab watched the ant	Crab	Ant
A	16	7	Mono	1	The goat watched the crab	Goat	Crab
V	17	8	Mono	1	The owl watched the goat	Owl	Goat
A	18	9	Mono	1	The goose watched the owl	Goose	Owl
V	18	9	Mono	1	The goose watched the owl	Goose	Owl
A	19	1	Mono	2	The pig watched the sheep	Pig	Sheep
X	20	2	Mono	2	The sheep watched the shark	Sheep	Shark
V	21	3	Mono	2	The shark watched the moose	Shark	Moose
X	22	4	Mono	2	The moose watched the nurse	Moose	Nurse
X	23	5	Mono	2	The nurse watched the bat	Nurse	Bat
X	24	6	Mono	2	The bat watched the duck	Bat	Duck
A	25	7	Mono	2	The duck watched the cow	Duck	Cow
X	26	8	Mono	2	The cow watched the frog	Cow	Frog
X	27	9	Mono	2	The frog watched the pig	Frog	Pig
X	27	9	Mono	2	The frog watched the pig	Frog	Pig
A	28	1	Mono	2	The pig watched the frog	Pig	Frog
V	29	2	Mono	2	The sheep watched the pig	Sheep	Pig
A	30	3	Mono	2	The shark watched the sheep	Shark	Sheep
V	31	4	Mono	2	The moose watched the shark	Moose	Shark
A	32	5	Mono	2	The nurse watched the moose	Nurse	Moose
V	33	6	Mono	2	The bat watched the nurse	Bat	Nurse
A	34	7	Mono	2	The duck watched the bat	Duck	Bat
V	35	8	Mono	2	The cow watched the duck	Cow	Duck
A	36	9	Mono	2	The frog watched the cow	Frog	Cow
V	36	9	Mono	2	The frog watched the cow	Frog	Cow

V	37	1	Mono	3	The fox watched the fly	Fox	Fly
X	38	2	Mono	3	The fly watched the dog	Fly	Dog
X	39	3	Mono	3	The dog watched the bull	Dog	Bull
X	40	4	Mono	3	The bull watched the bear	Bull	Bear
A	41	5	Mono	3	The bear watched the horse	Bear	Horse
X	42	6	Mono	3	The horse watched the wolf	Horse	Wolf
V	43	7	Mono	3	The wolf watched the mouse	Wolf	Mouse
X	44	8	Mono	3	The mouse watched the boy	Mouse	Boy
X	45	9	Mono	3	The boy watched the fox	Boy	Fox
X	45	9	Mono	3	The boy watched the fox	Boy	Fox
A	46	1	Mono	3	The fox watched the boy	Fox	Boy
V	47	2	Mono	3	The fly watched the fox	Fly	Fox
A	48	3	Mono	3	The dog watched the fly	Dog	Fly
V	49	4	Mono	3	The bull watched the dog	Bull	Dog
A	50	5	Mono	3	The bear watched the bull	Bear	Bull
V	51	6	Mono	3	The horse watched the bear	Horse	Bear
A	52	7	Mono	3	The wolf watched the horse	Wolf	Horse
V	53	8	Mono	3	The mouse watched the wolf	Mouse	Wolf
A	54	9	Mono	3	The boy watched the mouse	Boy	Mouse
V	54	9	Mono	3	The boy watched the mouse	Boy	Mouse
X	55	1	Bi	4	The mermaid watched the panda	Mermaid	Panda
X	56	2	Bi	4	The panda watched the reindeer	Panda	Reindeer
A	57	3	Bi	4	The reindeer watched the raccoon	Reindeer	Raccoon
X	58	4	Bi	4	The raccoon watched the lobster	Raccoon	Lobster
V	59	5	Bi	4	The lobster watched the rooster	Lobster	Rooster
X	60	6	Bi	4	The rooster watched the zebra	Rooster	Zebra
X	61	7	Bi	4	The zebra watched the hamster	Zebra	Hamster
X	62	8	Bi	4	The hamster watched the giraffe	Hamster	Giraffe
X	63	9	Bi	4	The giraffe watched the mermaid	Giraffe	Mermaid
X	63	9	Bi	4	The giraffe watched the mermaid	Giraffe	Mermaid
A	64	1	Bi	4	The mermaid watched the giraffe	Mermaid	Giraffe
V	65	2	Bi	4	The panda watched the mermaid	Panda	Mermaid
A	66	3	Bi	4	The reindeer watched the panda	Reindeer	Panda
V	67	4	Bi	4	The raccoon watched the reindeer	Raccoon	Reindeer
A	68	5	Bi	4	The lobster watched the raccoon	Lobster	Raccoon
V	69	6	Bi	4	The rooster watched the lobster	Rooster	Lobster
A	70	7	Bi	4	The zebra watched the rooster	Zebra	Rooster
V	71	8	Bi	4	The hamster watched the zebra	Hamster	Zebra
A	72	9	Bi	4	The giraffe watched the hamster	Giraffe	Hamster
V	72	9	Bi	4	The giraffe watched the hamster	Giraffe	Hamster
A	73	1	Bi	5	The dolphin watched the lizard	Dolphin	Lizard
X	74	2	Bi	5	The lizard watched the penguin	Lizard	Penguin

V	75	3	Bi	5	The penguin watched the tiger	Penguin	Tiger
X	76	4	Bi	5	The tiger watched the spider	Tiger	Spider
X	77	5	Bi	5	The spider watched the cowboy	Spider	Cowboy
X	78	6	Bi	5	The cowboy watched the monkey	Cowboy	Monkey
A	79	7	Bi	5	The monkey watched the turtle	Monkey	Turtle
X	80	8	Bi	5	The turtle watched the farmer	Turtle	Farmer
X	81	9	Bi	5	The farmer watched the dolphin	Farmer	Dolphin
X	81	9	Bi	5	The farmer watched the dolphin	Farmer	Dolphin
A	82	1	Bi	5	The dolphin watched the farmer	Dolphin	Farmer
V	83	2	Bi	5	The lizard watched the dolphin	Lizard	Dolphin
A	84	3	Bi	5	The penguin watched the lizard	Penguin	Lizard
V	85	4	Bi	5	The tiger watched the penguin	Tiger	Penguin
A	86	5	Bi	5	The spider watched the tiger	Spider	Tiger
V	87	6	Bi	5	The cowboy watched the spider	Cowboy	Spider
A	88	7	Bi	5	The monkey watched the cowboy	Monkey	Cowboy
V	89	8	Bi	5	The turtle watched the monkey	Turtle	Monkey
A	90	9	Bi	5	The farmer watched the turtle	Farmer	Turtle
V	90	9	Bi	5	The farmer watched the turtle	Farmer	Turtle
V	91	1	Bi	6	The chicken watched the pilot	Chicken	Pilot
X	92	2	Bi	6	The pilot watched the turkey	Pilot	Turkey
X	93	3	Bi	6	The turkey watched the teacher	Turkey	Teacher
X	94	4	Bi	6	The teacher watched the doctor	Teacher	Doctor
A	95	5	Bi	6	The doctor watched the mother	Doctor	Mother
X	96	6	Bi	6	The mother watched the puppy	Mother	Puppy
V	97	7	Bi	6	The puppy watched the baby	Puppy	Baby
X	98	8	Bi	6	The baby watched the father	Baby	Father
X	99	9	Bi	6	The father watched the chicken	Father	Chicken
X	99	9	Bi	6	The father watched the chicken	Father	Chicken
A	100	1	Bi	6	The chicken watched the father	Chicken	Father
V	101	2	Bi	6	The pilot watched the chicken	Pilot	Chicken
A	102	3	Bi	6	The turkey watched the pilot	Turkey	Pilot
V	103	4	Bi	6	The teacher watched the turkey	Teacher	Turkey
A	104	5	Bi	6	The doctor watched the teacher	Doctor	Teacher
V	105	6	Bi	6	The mother watched the doctor	Mother	Doctor
A	106	7	Bi	6	The puppy watched the mother	Puppy	Mother
V	107	8	Bi	6	The baby watched the puppy	Baby	Puppy
A	108	9	Bi	6	The father watched the baby	Father	Baby
V	108	9	Bi	6	The father watched the baby	Father	Baby
X	109	1	Tri	7	The dalmatian watched the hummingbird	Dalmatian	hummingbird
X	110	2	Tri	7	The hummingbird watched the porcupine	hummingbird	porcupine

A	111	3	Tri	7	The porcupine watched the ladybug	porcupine	Ladybug
X	112	4	Tri	7	The ladybug watched the bumblebee	Ladybug	bumblebee
V	113	5	Tri	7	The bumblebee watched the woodpecker	bumblebee	woodpecker
X	114	6	Tri	7	The woodpecker watched the grasshopper	woodpecker	grasshopper
X	115	7	Tri	7	The grasshopper watched the flamingo	grasshopper	Flamingo
X	116	8	Tri	7	The flamingo watched the cheerleader	Flamingo	cheerleader
X	117	9	Tri	7	The cheerleader watched the dalmatian	cheerleader	dalmatian
X	117	9	Tri	7	The cheerleader watched the dalmatian	cheerleader	dalmatian
A	118	1	Tri	7	The dalmatian watched the cheerleader	Dalmatian	cheerleader
V	119	2	Tri	7	The hummingbird watched the dalmatian	hummingbird	dalmatian
A	120	3	Tri	7	The porcupine watched the hummingbird	porcupine	hummingbird
V	121	4	Tri	7	The ladybug watched the porcupine	Ladybug	porcupine
A	122	5	Tri	7	The bumblebee watched the ladybug	bumblebee	Ladybug
V	123	6	Tri	7	The woodpecker watched the bumblebee	woodpecker	bumblebee
A	124	7	Tri	7	The grasshopper watched the woodpecker	grasshopper	woodpecker
V	125	8	Tri	7	The flamingo watched the grasshopper	Flamingo	grasshopper
A	126	9	Tri	7	The cheerleader watched the flamingo	cheerleader	Flamingo
V	126	9	Tri	7	The cheerleader watched the flamingo	cheerleader	Flamingo
A	127	1	Tri	8	The mosquito watched the magician	Mosquito	Magician
X	128	2	Tri	8	The magician watched the octopus	Magician	Octopus
V	129	3	Tri	8	The octopus watched the astronaut	Octopus	astronaut
X	130	4	Tri	8	The astronaut watched the koala	Astronaut	Koala
X	131	5	Tri	8	The koala watched the kangaroo	Koala	kangaroo
X	132	6	Tri	8	The kangaroo watched the fisherman	Kangaroo	fisherman
A	133	7	Tri	8	The fisherman watched the	fisherman	Butterfly

					butterfly		
X	134	8	Tri	8	The butterfly watched the unicorn	Butterfly	Unicorn
X	135	9	Tri	8	The unicorn watched the mosquito	Unicorn	mosquito
X	135	9	Tri	8	The unicorn watched the mosquito	Unicorn	mosquito
A	136	1	Tri	8	The mosquito watched the unicorn	Mosquito	Unicorn
V	137	2	Tri	8	The magician watched the mosquito	Magician	mosquito
A	138	3	Tri	8	The octopus watched the magician	Octopus	Magician
V	139	4	Tri	8	The astronaut watched the octopus	Astronaut	Octopus
A	140	5	Tri	8	The koala watched the astronaut	Koala	astronaut
V	141	6	Tri	8	The kangaroo watched the koala	Kangaroo	Koala
A	142	7	Tri	8	The fisherman watched the kangaroo	fisherman	kangaroo
V	143	8	Tri	8	The butterfly watched the fisherman	Butterfly	fisherman
A	144	9	Tri	8	The unicorn watched the butterfly	Unicorn	Butterfly
V	144	9	Tri	8	The unicorn watched the butterfly	Unicorn	Butterfly
V	145	1	Tri	9	The billygoat watched the teddybear	Billygoat	teddybear
X	146	2	Tri	9	The teddybear watched the seaturtle	teddybear	Seaturtle
X	147	3	Tri	9	The seaturtle watched the truckdriver	Seaturtle	truckdriver
X	148	4	Tri	9	The truckdriver watched the policeman	truckdriver	policeman
A	149	5	Tri	9	The policeman watched the drummerboy	policeman	drummerboy
X	150	6	Tri	9	The drummerboy watched the roadrunner	drummerboy	roadrunner
V	151	7	Tri	9	The roadrunner watched the elephant	roadrunner	elephant
X	152	8	Tri	9	The elephant watched the grandfather	Elephant	grandfather
X	153	9	Tri	9	The grandfather watched the billygoat	grandfather	Billygoat
X	153	9	Tri	9	The grandfather watched the billygoat	grandfather	Billygoat
A	154	1	Tri	9	The billygoat watched the grandfather	Billygoat	grandfather
V	155	2	Tri	9	The teddybear watched the billygoat	teddybear	Billygoat
A	156	3	Tri	9	The seaturtle watched the teddybear	Seaturtle	teddybear
V	157	4	Tri	9	The truckdriver watched the seaturtle	truckdriver	Seaturtle

A	158	5	Tri	9	The policeman watched the truckdriver	policeman	truckdriver
V	159	6	Tri	9	The drummerboy watched the policeman	drummerboy	policeman
A	160	7	Tri	9	The roadrunner watched the drummerboy	roadrunner	drummerboy
V	161	8	Tri	9	The elephant watched the roadrunner	Elephant	roadrunner
A	162	9	Tri	9	The grandfather watched the elephant	grandfather	elephant
V	162	9	Tri	9	The grandfather watched the elephant	grandfather	elephant

Appendix 4

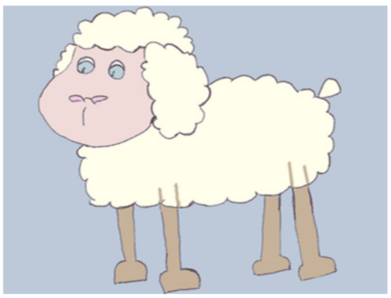
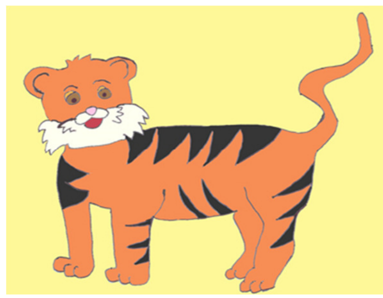
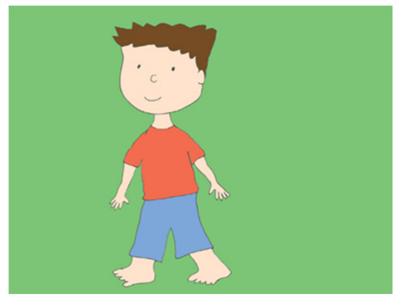
Raw Data

			V-only				AV	
Participant	**List**	**Mono**	**Bi**	**Tri**	**List**	**Mono**	**Bi**	**Tri**
7a	1(b)	16.7	10	33.3	3(a)	66.7	70	70
7b	2(b)	23.3	30	30	1(a)	70	56.7	53.3
7c	3(a)	30	23.3	20	3(b)	70	66.7	73.3
7d	2(b)	26.7	16.7	16.7	2(a)	73.3	80	93.3
7e	3(a)	50	56.7	50	2(b)	93.3	86.7	86.7
7f	1(a)	23.3	23.3	26.7	1(b)	76.7	76.7	86.7
8a	1(b)	46.7	46.7	36.7	2(a)	80	96.7	83.3
8b	1(a)	70	43.3	36.7	1(b)	93.3	76.7	83.3
8c	3(b)	26.7	40	13.3	1(a)	70	63.3	80
8d	2(a)	30	46.7	50	3(b)	86.7	80	90
8e	3(a)	33.3	6.7	20	2(b)	66.7	60	60
8f	2(b)	26.7	26.7	20	3(a)	73.3	56.7	70
9a	1(a)	66.7	63.3	70	2(b)	86.7	90	93.3
9b	3(a)	46.7	36.7	36.7	3(b)	93.3	73.3	86.7
9c	3(b)	36.7	56.7	40	2(a)	76.7	73.3	80
9d	1(b)	60	46.7	43.3	1(a)	78.3	66.7	74.3
9e	2(b)	50	70	50	3(a)	96.7	86.7	96.7
9f	2(a)	20	26.7	33.3	1(b)	76.7	76.7	86.7
10a	2(a)	60	63.3	66.7	3(b)	67.7	70	80
10b	2(b)	33.3	53.3	33.3	3(a)	93.3	80	86.7
10c	1(a)	50	40	40	1(b)	83.3	86.7	90
10d	1(b)	43.3	40	336.7	2(a)	86.7	83.3	83.3
10e	3(b)	46.7	43.3	43.3	1(a)	93.3	90	83.3
10f	3(a)	43.3	43.3	50	2(b)	93.3	93.3	100
11a	1(a)	46.7	36.7	36.7	1(b)	93.3	73.3	86.7
11b	3(a)	83.3	93.3	50	2(b)	90	96.7	80
11c	2(b)	60	43.3	56.7	3 (a)	80	83.3	96.7
11d	3(a)	53.3	53.3	40	2(b)	86.7	90	90
11e	2(a)	73.3	80	56.7	3(b)	100	93.3	100
11f	1(b)	96.2	85.7	92.3	1(a)	93.3	96.7	100

Appendix 5

Test Manual

NEW ZEALAND CHILDREN'S-BUILD-A-SENTENCE TEST (NZ Ch-BAS)

Tester's Manual

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INTRODUCTION AND BACKGROUND

Audiovisual integration is a necessary skill in speech reading and is particularly important for people who have hearing difficulties and who use hearing assistive devices such as hearing aids or CIs. Assessment of speech reading ability of adults and children can provide valuable information regarding the individual's communication abilities, and can be used as a tool to measure the outcomes of an aural rehabilitation programme. Speechreading enhancement (also known as auditory enhancement) is computed by comparing speech recognition scores in a V-only to scores on an AV condition (Tye-Murray, 2009). It indicates how much a person's performance is improved by having access to the visual and auditory signal, and is often a good indicator of how much benefit a person with significant hearing loss receives by using a listening device during (Tye-Murray, 2009).

The Children's-Build- A-Sentence (Ch-BAS) test is a matrix test that has recently been developed in the US to assess speech reading enhancement in American English (AE) speaking children by Nancy Tye-Murray and her research team at Washington University in St. Louis, however the test is not yet commercially available. The Ch-BAS is a closed-set sentence recognition test that is designed to avoid the floor effects typically associated with V-only testing and to be appropriate for the vocabulary levels of young children who have significant hearing loss. The Ch-BAS is also referred to as the Tri-BAS test because it includes one-syllable, two-syllable, and three-syllable words. The test was modeled from the Build-A-Sentence (BAS) test that was developed to assess speech recognition abilities in adults (Tye-Murray et al., 2008).

TEST DEVELOPMENT

The American English Ch-BAS Test

In the first stage of developing the American English (AE) Ch-BAS test, word lists were generated that fit the description of "nouns with eyes" such as animals and people and that included one-, two- and three-syllables words. Lists were reviewed by five educators of the deaf to make sure the vocabulary was appropriate for children with hearing loss as young as 5-years of age. The lists were then made up into three test matrices of nine words each based on word frequency (i.e., words that have similar frequency of occurrence in everyday language use) so that each matrix included words with similar word frequency. Three separate matrices were constructed for each of the mono-syllabic, bi-syllabi, and tri-syllabic word lists. Lists of sentences were then generated that included word pairs from the response matrices in the format, "The ___ watched the ___." The sentences were spoken by a local AE actress for every combination of words pairs.

The NZ Ch-BAS Test

The AE version of the Ch-BAS test was adapted for use with children who speak New Zealand English (NZE). A 25-year-old NZE-speaking female student served as the speaker for recordings of the Ch-BAS sentence materials. The student was an undergraduate student in the Speech-Language Pathology programme from the University of Canterbury, Christchurch, NZ. The speaker was born in NZ and has lived in Christchurch her whole life. She is considered to have a NZ accent that would be typical of a general dialect of NZE according to the opinion of three clinical certified Speech-Language Therapists. The speaker participated in speech and drama class all through high school.

The NZE speaker was seated in a sound treated room in front of the video recorder at head level. A digital HD video camera recorder (HXR-MC50E/ MC50P) and microphone were used to record the sentence material. The video camera was situated on a tripod, placed 1 meter from the speaker's head. A microphone was placed on a separate tripod 0.5 m from the speaker's mouth. The sentence material was projected onto a glass screen in front of the video camera so that the sentences could easily be read by the speaker and so that she was looking directly at the screen. All of the recorded sentences were edited into one sound file and sent to the Department of Otolaryngology, Washington University School of Medicine, St Louis for audio leveling and calibration. The materials was then returned to NZ and placed into the LabVIEW software programme which was then readied for testing.

The NZ Ch-BAS was then evaluated for list equivalency by testing NZE-speaking children with normal hearing. A total of 30 children (16 boys, 14 girls) who were between the ages of 7-11years were used in this study. There were six children in each age group. All of the children were NZ born and had attended all their schooling years in NZ. Based on parental report, none of the children had any speech or language problems. This was confirmed by the researcher who also holds a degree in speech-language pathology. An equal number of participants (n=6) were assigned to each of the age groups between 7-11 years. Statistical analysis revealed that the three test lists were not significantly different and therefore this showed that the three lists result in similar performance scores for the children tested.

TESTING PROCEDURES

Population group

The recommended target audience for the NZ Ch-BAS includes NZE speaking children who are between the ages of seven to twelve years of age. The tests were not specifically designed to be used with children younger than the age of 7 years. The NZ Ch-BAS test can be used for older children with hearing impairments.

Equipment and materials

An audiovideo monitor and VHS or CD ROM player are necessary to administer the *NZ Ch-BAS test*. The audio signal should be delivered through headphones or calibrated soundfield speakers via an audiometer. Materials include the CD ROM (Appendix 3b) and a score sheet (Appendix 2b).

Administration

Each child should be seated in a sound-treated booth approximately 0.5m from a computer monitor touch screen at zero degrees azimuth. The child should be given a number of practice trials in the A-only, V-only, and AV conditions until the tester is confident that the child understands the task. The Ch-BAS test materials are then administered in the V-only and AV conditions. The child is instructed to watch and/or listen to the speaker say a short sentence and to then choose the two words that corresponded to the spoken sentence. The verbal instructions that should be given to the child are shown in Appendix 1. The child responds by pointing to the two pictures in sequential order from a choice of a 9-item response matrix.

Scoring

The child's responses are scored in the software for a correct or incorrect response and the overall percentage scores for each condition (A-only, V-only, and AV) for mono, bi-, and tri-syllabic words should be recorded on the score sheet by the examiner (see Appendix 2b).

Standardisation

The NZ Ch-BAS test has not yet been standardised. It is recommended that the test be administered to a large sample of normal hearing children (minimum of 10) in each clinic to determine norms for that particular clinic setup and equipment.

Appendix 1b

Instructions for NZ Ch-BAS

For A-only/setting the noise: You will hear a talker say some sentences. The talker might say, “The cow watched the dog.” Listen carefully. Other people will be talking in the background. Sometimes the background talking will be very loud. Sometimes the background talking will be very soft. Please look at the 9 pictures that appear on the screen after a sentence. Choose the two pictures that correspond to the sentence. For instance, for the sentence, “The cow watched the dog”, first touch the picture of the cow. Then touch the picture of the dog. Please touch the two pictures in the correct order. Guess when you are not sure.

Once noise is set and A-only version is finished/AV and V part of test: This test is similar to the last test. The talker will say sentences like, “The cow watched the dog.” After the sentence, pictures will appear on the screen. Please touch two pictures that correspond to the sentence. In this test, sometimes you will only hear the talker; sometimes you will only see her; and sometimes you will see and hear her. Please listen or watch carefully. Again, people will be talking in the background. Please guess when you are not sure.

Appendix 2b

<u>Ch-BAS Score Sheet</u>

Name: DOB: Date:

	Mono	**Bi**	**Tri**
A-only			
AV			
V-only			

Comments: *(e.g. comment on attention or distractions throughout the task)*

Appendix 3b

NZ Ch-BAS CD ROM

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