The Effect of Unilateral Ear Occlusion in Children with Central Auditory Processing Disorders: Speech Perception in Adverse Listening Conditions

RUNNING HEAD: Unilateral Ear Occlusion in CAPD

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Abstract

The ability to perceive speech presented in background noise was measured in children with and without Central Auditory Processing Disorders (CAPD). The performance of the children was compared under two listening conditions: 1) listening with both ears not occluded; 2) listening with the less dominant ear occluded with an earplug. It was hypothesized that children with CAPD would perform better on the speech perception task when one ear was occluded with an earplug. It was also hypothesized that a group of non-CAPD children would perform better on the speech perception task when listening with both ears not occluded. The CAPD group did not show a statistically significant difference on speech perception scores under the two conditions. Likewise, the non-CAPD group did not show a statistically significant difference on speech perception scores between the two listening conditions. The results are discussed in terms of evaluating the individual performances of children with CAPD when one ear is occluded with an earplug as opposed to evaluating the average performance of the group.

The processing of spoken language relies on an interactive system of both peripheral and central auditory processing functions. A listener must perceive an acoustic signal from the environment then conduct an auditory analysis of that signal; that is to say, the listener must recognize and understand the acoustic signal as meaningful words or phrases (Chermak & Musiek, 1997). Some individuals who have hearing sensitivity within normal range are able to perceive acoustic signals from the environment but exhibit deficits in the analysis of those signals. These individuals sometimes have difficulties using sound for normal speech understanding. Because the deficits occur within the central nervous system they are broadly referred to as Central Auditory Processing Disorders (CAPD) (Roeser & Downs, 2004).

An individual having CAPD may exhibit difficulty in one or more of the following auditory behaviors: locating the source of sound in space (such as identifying a signal or a speaker); distinguishing between different auditory sounds (such as a whistle and a cry), or between words (such as damp/tamp); recognizing patterns of duration, pitch, volume and intervals; processing of auditory stimuli in the presence of background noise; processing incomplete of corrupted signals such as speech that cuts out; perceiving temporal aspects of audition such as determining order of sound in words (past vs. pats), earlier letters in words (dime vs. time); or perceiving rhythm and melody (American Speech-Language-Hearing Association (ASHA), 2005).

Secondary problems arising from CAPD that are not diagnostic of the disorder included difficulties with learning, speech, reading and spelling. Individuals having CAPD are more likely to exhibit emotional, behavioral and social difficulties than those without CAPD (ASHA, 2005). Children and youth diagnosed with CAPD are often described as passive listeners, appearing inattentive and distracted by irrelevant stimuli (Chermak & Musiek, 1992).

CAPD has been observed in various populations. These include groups of individuals who are suspected of having neurological pathology or disorder (e.g., developmental language disorder, dyslexia, learning disability, Attention Deficit Disorder) and individuals who have a clear Central Nervous System pathology (e.g., aphasia, multiple sclerosis, epilepsy, traumatic brain injury, tumor, Alzheimer's disease, psychiatric disorder). Most commonly, individuals diagnosed with ADD, ADHD, learning disabilities or language impairment experience some deficit in central auditory processing (Chermak & Musiek, 1997).

Prevalence data for CAPD has remained inconclusive due to the co-morbidity of the disorder. Chermak and Musiek, (1997) estimated the prevalence of CAPD in children to be between 2 and 3%. Given the diverse clinical populations in which CAPD is observed, in particular ADD and learning disabilities, one may speculate a fairly significant prevalence rate of CAPD that will continue to rise.

The effects of CAPD are likely to be seen in the classroom environment, where there is such a heavy reliance on spoken language. Acoustical characteristics of an environment plays an important role in the perception of spoken language and the acoustical conditions of the classroom often present additional challenges to individuals with CAPD. Acoustical variables that can compromise auditory perception include the reverberation time (RT) of the room, the overall level of background noise, the relationship between the level of the speaker's voice and the background noise (Signal-to-Noise Ratio), and the distance from the teacher to the child (Crandell & Smaldino, 2000).

Reverberation refers to the persistence of prolongation of sound within an enclosure as sound waves reflect off hard surfaces. Reverberant energy overlaps direct signals which results in the making or smearing of speech signals. Reverberation particularly affects the perception of consonants. Classroom environments commonly have reverberation times (RT) between 0.4-1.2 seconds, whereas the ideal listening environment has a RT of 0.4-0.6 seconds (Crandell & Smaldino, 2000).

Background noise is any undesired auditory stimulus that interferes with what an individual wants, or needs to hear. It can include things such as taking, sliding of chairs, shuffling of feet, construction, traffic, noise from ventilation systems, etc. Background noise often leads to the degradation of linguistic cues. Background noise levels should not surpass 30-35 dBA but often do in the classroom (Crandell & Smaldino, 2000).

The most important consideration for accurate speech perception is the relationship between the intensity of the signal and the intensity of the background noise, or the Signal-to-Noise Ratio (SNR). For example, if a speech signal is presented at 75 dB and noise is 65 dB, the SNR would be 10 dB. The ability for an individual to perceive speech improves as the SNR increases and it decreases as the SNR decreases. An optimal listening environment would have a SNR that equals or exceeds +15 dB, however SNRs in classrooms have generally measured between +5 dB and -7 dB (Crandell & Smaldino, 2000).

Remediation strategies for individuals having CAPD incorporate both bottom-up (i.e., elicitation and enhancement of acoustic signals from the environment) and top-down (i.e., the use of prior experience/knowledge to draw conclusions about what it is the individual perceives) approaches to auditory processing. Remediation programs are individually determined and involve three programs employed concurrently. These include: 1) direct skills training; 2) compensatory skill training; 3) environmental modifications (ASHA, 2005).

One type of environmental modification that has been recommended for individuals with CAPD is sound control devices (i.e., earplugs or earmuffs) (Hasbrouck, 1980; Willeford & Burleigh, 1985; Katz & Wilde, 1994). Willeford & Burleigh (1985) asserted that individuals having CAPD have difficulty integrating the messages they are receiving simultaneously from the left and right ears, particularly under adverse listening conditions. Willeford and Burleigh speculated that minimizing the participation from the less dominant ear through occlusion, could improve acoustic signals to the brain. This is particularly important is noisy listening conditions where important speech signals are often compromised. This technique has been studied with others, however no known studies have examined the effects of this technique with individuals having CAPD.

Hasbrouck (1980) was the first to investigate the effects of unilateral (one ear) occlusion on auditory discrimination in background noise with children having auditory figure-ground disorders (that is, difficulty attending to important auditory information in the presence of background noise). Hasbrouck (1980) proposed that occluding one ear with an earmuff would reduce ambient noise and allow children with figure-ground disorders to pay attention to more important auditory information. Participants performed significantly better on auditory discrimination tasks in the ear occlusion conditions (right/left/both) than in conditions requiring binaural listening. Hasbrouck (1987) replicated this study with adults having auditory figure-ground disorders and found similar results. .

Most people use small time differences of signals arriving at both ears to process acoustic information. For individuals with CAPD the signals may interfere with each other so that processing is poorer. This is referred to as binaural interference and has been reported in other populations such as those with schizophrenia and learning disabilities. There have been several studies of unilateral ear occlusion as a remediation technique in individuals who have binaural interference (Green & Kotenko, 1980; James, 1983; Birchwood, 1986; Green & Josey, 2002).

Green and Kotenko (1980) found that some individuals with schizophrenia perform better on a speech comprehension task under monaural rather than binaural listening conditions. These findings led to several single-case studies in which an earplug was found to reduce auditory hallucinations in individuals with acute schizophrenia (James, 1983; Birchwood, 1986). Also, children with learning disabilities who have demonstrated binaural interference have performed better on tests of speech comprehension when one ear is occluded with an earplug (Green & Josey, 2002).

Some researchers have demonstrated a binaural advantage for listening under difficult conditions, that is, individuals perform better on speech perception tasks when listening with both ears. A binaural advantage has been found when children with or without learning difficulties are required to listen to speech in difficult listening conditions (e.g., fast speech, temporally distorted speech) (Bornstein & Musiek, 1992) and when typical achievers are required to listen to speech presented with competing messages (Cherry & Rubinstein, 2006). The results of these studies challenge the use of a unilateral earplug as a remediation technique for CAPD. This technique has been studied with other subjects; however it appears that no studies have examined the effects of this technique with individuals having CAPD.

It was hypothesized that children having CAPD would perform better on a speech perception task when fitted with an earplug in their less-dominant ear than they would when required to perform the task with both ears. Occlusion of the less-dominant ear will minimize competing inputs from the environment and produce a clearer acoustic signal. It was also hypothesized that a control group of non-CAPD children would perform better on a speech perception task when both ears are not occluded.

Speech perception is best assessed with measures that are similar to real life listening situations. Much of language processing occurs in noisy environments such as classrooms, workplaces and in public areas, all of which are places in which speech signals are degraded by background noise. For this reason, in this study speech perception will be assessed with the QuickSIN Speech in Noise test Version 1.3. The QuickSIN requires the listener to identify key words in sentences presented in background noise (babble).

If children having CAPD demonstrate improved performance on the QuickSIN test under the ear occlusion condition, then this provides further empirical support for the hypothesis that use of an earplug improves speech perception in adverse listening conditions. It also provides a remediation tool that is low cost, requires no complicated technology, and is accessible, safe and cosmetically unobtrusive.

Method

Participants

Seventeen male and female children ranging from six to twelve years of age participated in the study (average age was eight years). Children in the experimental group were nine children (five males, four females) who had scored below average (<100) on the SCAN-C Test for Auditory Processing Disorders-Revised indicating a possible Central Auditory Processing Deficit. These children had previously undergone screening for a Central Auditory Processing Disorder by a certified audiologist and were identified as possible participants for the study. A control group of eight children (five males, four females) who had scored above average (>100) on the SCAN-C also participated in the study. Participation in the study was entirely voluntary, based on the consent of the parents and the willingness of the participants.

Materials and Apparatus

Speech perception was assessed using the QuickSIN Speech in Noise test Version 1.3. The QuickSIN test assesses word recognition performance under varying conditions and is typically used for hearing aid evaluation. The QuickSIN test consists of twelve equivalent lists of six sentences. The test requires the listener to identify key words spoken by a female speaker presented in sentences. The sentence material used in the QuickSIN test is words that are not typically predictable from the surrounding context, therefore the listener cannot "fill-in" the sentences based on contextual cues and knowledge. The sentences are presented with a background of four-talker babble (three females and one male) at prerecorded signal-to-noise ratios (SNRs) which decrease in 5 dB steps from 25 (very easy) to 0 (extremely difficult). The SNRs used in the QuickSIN are 25, 20, 15,10,5 and 0 (Niquette, Gudmundsen & Killion, 2001). SNR is the relationship between the intensity of the signal (speech) and the intensity of the background noise. An ideal SNR for optimal speech perception is +15 dB.

The QuickSIN assesses an individual's SNR loss that is, the dB increase in signal-to-noise ratio required for an individual to identify fifty percent of the key words within the sentences. One point is awarded for each key word repeated correctly in a sentence. A total is calculated for each of the six sentences presented for each list. SNR loss is calculated for each list by using the formula: SNR loss= 25.5-Total Correct. A normal hearing individual requires approximately +2 dB SNR to identify fifty percent of the key words. The QuickSIN score is averaged across the number of lists presented. For this study, two lists were administered twice under each condition. The QuickSIN score obtained from two lists is accurate to approximately +/-1.9 dB at a 95% confidence level and +/-1.6 dB at an 80% confidence level. Completion of each list takes approximately one minute (Niquette, Gudmundsen & Killion, 2001).

Procedures

Upon arrival to the clinic on the day of testing, written informed consent was obtained from the parents and verbal assent from the participants. Testing procedures were administered in a low-noise environment (i.e., a personal office within a local audiology clinic). Participants were asked to pick up the receiver of the telephone and hold it to the ear they normally would hold it to. The participants' ear preference for this task was noted. Handedness was also noted. Prior to testing, all participants were given the following instructions: "You will hear a woman's voice and a lot of people talking in the background, like you would hear in a busy restaurant. I want you to listen very carefully and repeat the sentences that you hear the woman say. You may find this difficult so it is important that you listen carefully. It is okay if you don't know, just try your best. If you are unsure, just take a guess of what you think the woman said." All participants were administered Practice List A on the QuickSIN to get them familiar with the procedures.

The QuickSIN test was administered by computer with two speakers located on both sides of the participant (45 degrees in front on either side). The participants were seated in a chair that was located one meter away from the speakers. The volume was set at 100% on Windows MediaPlayer and the fifth notch on the computer speakers. Testing took approximately 30 minutes. Participants were administered four trials for each listening condition: 1) listening with both ears; 2) listening with the less dominant ear occluded. One list from the QuickSIN test was randomly selected from Lists 1-12 to be administered for Trials 1 and 4 of condition one. A second list was randomly selected from Lists 1-12 to be administered for Trials 2 and 3 of condition one. This procedure was replicated for condition two. The order in which the participants received the conditions was counterbalanced to control for order effects. For the one ear condition, the less-dominant ear was occluded with a silicone ear mold. The less-dominant ear was determined from the results of the SCAN-C. If the ear dominance was difficult to determine from the SCAN-C then ear dominance was determined from handedness. All ear molds were fitted by an experienced audiologist.

Upon completion of the session, participants were asked to complete a questionnaire regarding their perceived performance under both listening conditions. Parents were asked to complete a questionnaire to determine whether the participants were presently receiving any remediation at school and whether their son/daughter had any other diagnoses that may confound the results. Participants and parents were thanked and participants received a tangible reward for their participation.

Results

TABLE 1. Means, standard deviations and standard errors of the QuickSIN scores for both listening conditions for CAPD and non-CAPD participants. *Note-lower scores indicate better performance.

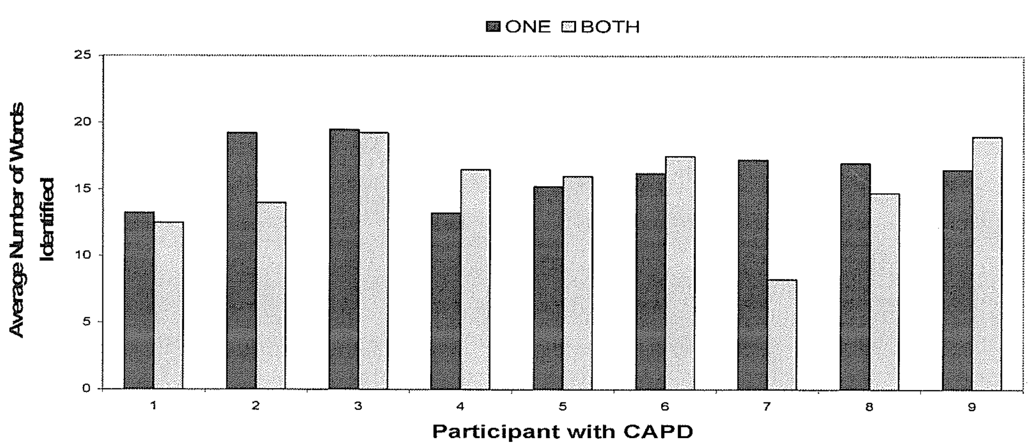
	CAPD (n=9)		**NON-CAPD (n=8)**	
	One Ear	**Both Ears**	**One Ear**	**Both Ears**
Mean	9.11	10.19	4.69	3.53
Standard Deviation	2.24	3.46	3.19	3.30
Standard Error	0.75	1.15	1.13	1.17

Table 1 shows the means, standard deviations and standard errors of the scores on the QuickSIN produced by the CAPD group and the non-CAPD group for both listening conditions (both ears not occluded and the less dominant ear occluded).

A one-sample t-test was used to compare the mean scores that had been obtained for both listening conditions by the nine participants in the CAPD group. A statistically significant difference was not found between listening conditions ($t=0.431$, $p<0.05$). A one-sample t-test was used to compare the mean scores obtained for both listening conditions by the eight non-CAPD participants. A statistically significant difference was not found between listening conditions ($t=0.294$, $p<0.05$). The CAPD group did not perform better on the speech perception task when the less dominant ear was occluded with an earplug as opposed to listening with both ears not occluded. Also, the group of non-CAPD children did not perform better on the speech perception task when listening with both ears not occluded as opposed to listening with one ear occluded. The hypotheses were not supported.

The raw scores (i.e., the average number of key words identified correctly) obtained by the participants in the CAPD group for both listening conditions were examined individually (see Figure 1). Participants identified an average of sixteen key words in the one ear occlusion condition and fifteen words in the no-occlusion condition. Five of the nine participants in the CAPD group identified more words when required to listen with one ear occluded. Four participants identified more words when required to listen with both ears. Interestingly, participants two and seven performed much better when one ear was occluded with an earplug as opposed to listening with both ears. Participant two identified five more words in this condition and participant seven identified nine more words. Therefore, it appears that the use of an earplug as a remediation strategy may be beneficial for some, but not all children with CAPD.

FIG. 1. AVERAGE NUMBER OF WORDS IDENTIFIED BY CAPD GROUP



Discussion

Although a statistically significant difference was not found between listening conditions for both the CAPD group and the non-CAPD group, the results did resemble the expected outcome. Children with CAPD performed slightly better on the speech perception task when listening with one ear occluded and children without CAPD performed slightly better when listening with both ears. The sample sizes for both the CAPD group (n=9) and the non-CAPD group (n=8) were very small. This may be one explanation for the insignificant results. As mentioned previously the estimated prevalence of CAPD in children is 2-3%, therefore identifying participants for this study was difficult. Further research with larger sample sizes is needed.

The QuickSIN Speech in Noise test Version 1.3 is designed to be similar to real life listening situations, however it may have limited ecological validity for several reasons. The QuickSIN is administered via computer software and the key speaker and background noise are pre-recorded and presented together through speakers or a sound field. This limits the direction from which the acoustic signals can come from. For example, in a real life listening situation the important acoustic signal (i.e., the speaker) may be located in front of the listener while the background noise may be located behind or beside the listener. With the QuickSIN test, both the speaker and the background noise are located together in front of, beside, or behind the listener. Also, the sentence material used in the QuickSIN test is words that are not typically predictable from the surrounding context, therefore the listener cannot "fill-in" the sentences based on contextual cues and knowledge. For example, "A cruise in warm waters in a sleek yacht is fun". This is not representative of real life listening situations in which people often use their knowledge of the language and the context of the sentence to fill in the content that may have been missed due to adverse listening conditions. Moreover, when speaking, people typically adjust their language to accommodate to their audience. The sentences on the QuickSIN test are grammatically difficult and are not reflective of the way in which the average person would speak, particularly to a child. Therefore the QuickSIN test may not be representative of a typical listening situation of a child with CAPD. A more accurate assessment of speech perception in an adverse listening condition may be a speech perception task conducted in a classroom environment.

When evaluating the effect of a remediation strategy such as the use of an earplug in one ear, it is important for researchers to look at an individual's performance under the treatment condition rather than the performance of the entire group. CAPD can be considered a spectrum disorder with a variety of difficulties that may arise from it. Each child having CAPD may experience unique deficits therefore it should be expected that there will be differential responses to treatment strategies. Some children with CAPD may benefit from the use of an earplug in one ear, whereas other children may not. For those children with CAPD who did perform better when one ear was occluded, the use of an earplug may be a viable alternative that may improve speech perception in adverse listening conditions. It would provide the most assistance if used concurrently with other remediation strategies such as direct skill training, compensatory skill training and environmental modifications. In addition, it is a remediation tool that could be easily used in many situations and is a simple, inexpensive treatment.

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