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Auditory Deprivation in Children with Otitis Media with Effusion and its Effect on Temporal Resolution

Privation auditive chez les enfants ayant une otite moyenne avec effusion et son incidence sur la résolution temporelle

J. Cyne Topshee Johnston, Walter B. Green

Abstract

The effect of diminished auditory sensitivity due to otitis media with effusion on a child's developing auditory system is an important issue for researchers as it may affect a child's linguistic, psychological, and behavioural development. There is a need for an assessment paradigm that may indicate more subtle, delicate central processing deficits in children with a history of otitis media. Word recognition in interrupted and continuous noise has been successfully used to test temporal processing in individuals with presbycusis, multiple sclerosis, and normal hearing. This paradigm has shown both cochlear and retro-cochlear temporal processing disorders. Scores of two groups of six- and seven-year-old children were compared in an interrupted and continuous noise task at four signal-to-noise ratios (-10, 0, +10, +20). One group had a history of chronic otitis media with effusion while the control group had minimal exposure to the disorder. It was found that there was no significant difference between the groups on the interrupted and continuous noise task. There was a significant difference between the two types of competition and the signal-to-noise ratios, which is also seen in normal listeners. The results of this research do not indicate any long-term temporal processing disorder in children with a history of otitis media.

Abrégé

Les effets de la privation auditive due à l'otite moyenne avec effusion sur le développement du système auditif de l'enfant est une question importante pour les chercheurs car elle peut affecter le développement linguistique, psychologique et comportementale de l'enfant. Il existe un besoin pour un modèle d'évaluation pouvant déceler des diminutions plus subtiles ou fines sur le plan du traitement central chez les enfants ayant des antécédents d'otite moyenne. On a employé avec succès la reconnaissance des mots en présence de bruit interrompu et continu afin d'évaluer le traitement temporel chez des individus ayant une presbyacousie, la sclérose en plaques et une audition normale. Ce modèle a révélé des troubles de traitement temporel tant cochléaires que rétrocochléaires. Les scores de deux groupes d'enfants de six et sept ans ont été comparés à l'aide d'une tâche en présence de bruit interrompu et continu pour quatre rapports signal-bruit (-10, 0, +10, +20). Un groupe avait des antécédents d'otite moyenne chronique avec effusion, tandis que l'autre groupe n'y avait été que très peu exposé. Il a été établi qu'il n'existait aucune différence significative entre les deux groupes pour ce qui est de la tâche en présence de bruit interrompu et continu. On a cependant relevé une différence significative entre les deux types de compétition et les rapports signal-bruit, situation également relevée chez les auditeurs normaux. Les résultats de cette recherche n'indiquent aucun trouble de traitement temporel à long terme chez les enfants ayant des antécédents d'otite moyenne.

Key words: otitis media with effusion (OME), temporal processing, auditory deprivation, interrupted and continuous noise, six- and seven-year-old children, audiology, hearing

J. Cyne Topshee Johnston
School of Human Communication Disorders
Dalhousie University
Halifax, Nova Scotia

Walter B. Green
School of Human Communication Disorders
Dalhousie University
Halifax, Nova Scotia

Otitis media with effusion (OME) is certainly the most common type of auditory disease among children. It has an incredibly high incidence rate; seventy-five percent of children will suffer from at least one bout of otitis media before their third birthday (National Institute on Deafness and Other Communication Disorders, 2002). Some researchers have suggested that 20% of children suffer from chronic otitis media for more than half of their first three years of life (Hogen, Meyer, & Moore, 1996).

The high incidence of OME in children highlights the possible negative impact that OME may have on the developing population. The mild to moderate, predominantly low-frequency, conductive hearing loss associated with the disorder has both short and possibly long-term effects on the auditory and subsequent language development of the population (Gravel & Wallace, 1998). Should OME affect the developing auditory system, a huge percentage of the population could be affected. Those children who suffer from repeated bouts of otitis media, and who are thus considered chronic sufferers, are likely to be the segment of the population which is most affected by the physiological, and possible psychological and educational repercussions of repeated periods of hearing loss associated with OME.

These periods of reduced hearing occur at a time that is crucial for the auditory and linguistic development of children (Ruben & Rapin, 1980). As such, the result of diminished auditory input due to otitis media with effusion on a child's developing auditory system is an important issue for researchers to study in an attempt to discover the short and long-term effects of this form of auditory deprivation. The hearing loss and auditory deprivation caused by fluid in the middle ear cavity occur commonly and have been studied using a wide variety of short and long-term measures.

For example, first-time language babbling (Rvachew, Slawinski, Williams, & Green, 1999) and later expressive and receptive language development (Wallace, Gravel, McCarton, & Ruben, 1988) have been studied in this population. Various psychoacoustic measures such as masking level difference (Hall & Grose, 1993), localization (Stollman, Snik, Schilder, & van den Broek, 1996), and central processing tests (Updike & Thornburg, 1992) have been used to compare OME-positive children to their OME-negative peers. As well, electrophysiological studies of the auditory brainstem response (ABR; Hall & Grose, 1993; Wallace, Gravel, McCarton, Stapells, et al., 1988) have been used to evaluate children with a history of OME with various results. Overall, these studies have shown significant effects among the child sufferers of OME in comparison to the control groups.

Some of the most effective and comprehensive research on the topic of OME has been conducted by Gravel and other researchers at the Albert Einstein College of Medicine in the Bronx, New York (Gravel, McCarton, & Ruben, 1988; Gravel & Ruben, 1996; Gravel & Wallace, 1998, 1992; Gravel, Wallace, & Ruben 1996, 1995). They have reported a number of research studies on the psychological and educational after-effects of OME. Gravel and colleagues used a prospective, longitudinal research design to study short and long-term effects. Pneumatic otoscopy was used to identify children during their first year of life as otitis-positive or otitis-negative. The OME-positive group was identified with bilateral middle ear effusion on at least 30% of their visits to the health centre. The OME-negative group had clear middle ear spaces on at least 80% of their visits.

The two groups of children were followed by the Bronx group for nine years. Since the children suffering from repeated episodes of OME and their otitis-negative peers were studied prospectively, complete audiometric and case history information could be gathered and differences could be established. Because of the longitudinal nature of the study, the children could be followed through infancy and school-age years and tested on a variety of measures to give a more complete picture of the disease process.

During the first year, OME-affected children were found to have expressive language difficulties when tested with the Sequenced Inventory of Communication Development (SICD) and compared to the unaffected group (Wallace, Gravel, McCarton, & Ruben, 1988). It was also found that the OME-affected group had decreased auditory sensitivity when measured through auditory brainstem response (ABR; Wallace, Gravel, McCarton, Stapells et al., 1988). The OME-positive group had thresholds that were, on average, eleven decibels higher in the OME-positive group than in the OME-negative group. It was also found that the OME-affected group had elevated ABR thresholds on more visits than the otitis-free group.

At two years of age, the OME-affected children produced more phonological errors and had a smaller consonant inventory than their OME-free peers (Abraham, Wallace, & Gravel, 1996). By four years of age, the receptive, expressive, and global language scores of children in the two groups were found to be equivalent (Gravel & Wallace, 1992). However the OME-affected children needed an improved signal-to-noise ratio to score equivalent to the nonaffected group on the Pediatric

Speech Intelligibility (PSI) task. Essentially, the speech signal needed to be more intense in relation to a competition signal for the OME-affected children to score on par with the unaffected group. This measure has significant implications for listening in the classroom where it is essential to pick out the message from the background noise.

At six years of age, no differences were found between the affected and nonaffected groups on reading or math measures (Gravel et al., 1995). The only differences between the groups were in teachers' ratings of the children on a screening tool used to help identify children with hearing loss (Screening Instrument for Targeting Educational Risk [SIFTER]) and on a visual-auditory learning task.

Other researchers have found that in the early years, child sufferers of OME have reduced scores on other measures as well. Babbling and early language development was studied by Rvachew et al. (1999) and their results indicated differences between an otitis media positive and negative group. A lower rate of canonical babbling was observed at six months of age in children with early-onset OME. Moore, Hutchings, and Meyer (1991) have observed reduced binaural hearing, as measured by their binaural masking level differences, in cases of unilateral conductive hearing loss in children aged five to 16 years of age. Reduced performances on complex masking tasks (Hall, Grose, Dev, Drake, & Pillsbury, 1998) have also been found in children aged five to 12 with a history of OME. These reduced abilities were presumably due to the after-effects of the mild to moderate conductive hearing loss that is associated with having fluid in the middle ear cavity.

Gravel et al. (1996) followed the OME-positive and OME-negative groups until nine years of age. They found that children who have successfully recovered from OME often show that some of the early negative effects seem to resolve during the teenage or adult years. While this is true, "Results show that children with a first-year history of otitis media demonstrate deficits in the longer term in some aspects of higher-order auditory processing" (p. 219). At nine years of age, scores on a Story Recall-Memory task were found to be significantly lower in the OME-positive group than in the OME-negative group. No other differences were measured between the groups.

Other researchers have also shown that lower-order auditory processing, such as auditory sensitivity and speech recognition in quiet, may resolve while higher-order auditory processing may still be affected (Gravel, Wallace et al., 1996; Hogen et al., 1996; Stollman et al., 1996). Additional studies have shown linguistic, behavioural, and developmental problems for children with a history of OME (Groenen, Crul, Maassen, & van Bon, 1996; Hall & Grose, 1994; Updike & Thornburg, 1992; Webster, Bamford, Thyer, & Ayles, 1989). Although the results are disputable, these studies indicated that OME sufferers might have long-term auditory effects. However, the measures used in these studies are not those that are being routinely used by audiologists such as pure tone threshold, speech recognition threshold in quiet, or speech perception tasks. Therefore, these children may not have a diagnosed deficit during routine clinical testing.

Hall et al. (1998) have suggested that it may take longer for the responses to some, more difficult, tasks such as complex masking or central processing tasks to return to normal in OME sufferers. Hall and associates further describe how complex auditory processing may require more stable input from the environment and for a longer period of time before optimum functioning will occur. In essence, the more difficult and specific the tasks may be, the more gaps in input from the environment may cause impairment.

A child's inability to perceive and develop speech and language due to the conductive hearing loss associated with OME is one of the main concerns associated with the disease. As such, the use of complex auditory stimuli, such as sensitized and degraded speech that taxes the higher processing centres of the central auditory nervous system has been shown to be more susceptible to the lack of environmental input due to OME (Clarkson, Eimas, & Marean, 1989; Zargi & Boltezar, 1992).

In the normally developing child, some measures of audition, including auditory sensitivity, undergo rapid changes and seem to approach adult levels of hearing relatively early. More complex measures, such as temporal processing, do not approach adult levels until late childhood. Temporal processing is essential in understanding the developing auditory system. While a fair amount of research has been conducted on temporal processing in adults, the development of temporal processing in children has received limited study. Temporal processing is essential for many aspects of auditory behaviour. Sound localization, the segregation of sound sources, and pitch perception are only a few of the processes that require this ability. Behavioural studies of the development of temporal processing have focused on the development of envelope processing. Tasks such as gap detection, amplitude modulation, and duration discrimination have all been used to track the developmental process (Elfenbein, Small, & Davis, 1993; Jensen & Neff, 1993; Werner, Marean, Halpin, Spentner, & Gillenwater, 1992; Wightman, Allen, Dolan, Kistler, & Jamieson, 1989.) There is still a great deal of research required, using unique testing paradigms, on a variety of auditory processes before the developmental process of auditory behaviour will be clear.

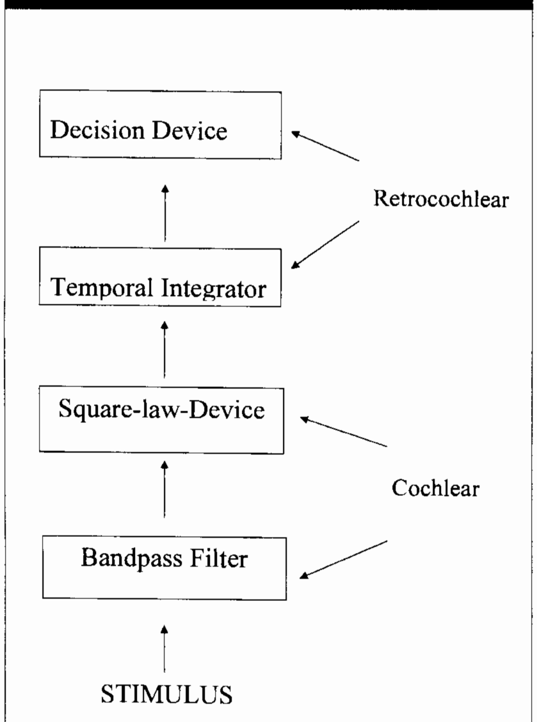
Temporal Processing in Interrupted and Continuous Noise

Speech perception in interrupted and continuous noise has also been identified as a test of temporal processing. Currently, there are no published data on the developmental course of temporal processing as tested by this method.

Stuart (1995) described temporal resolution as, "the ability of a listener to resolve/separate auditory events or detect changes in auditory stimuli over time" (Stuart, p. 4.) Research has shown that poor scores on tasks aimed at testing temporal resolution are highly correlated with low speech intelligibility in noise scores (Dreschler & Plomb, 1985; Tyler, Summerfield, Wood, & Fernandes, 1982). As such, difficulties in understanding speech, particularly in listening situations with poor signal-to-noise ratios, may be accounted for by impaired temporal resolution.

Models for temporal processing have been hypothesized as a set of four elements that begin in the peripheral or cochlear structures and continue into the higher, central auditory system (Moore, 1997; Rodenburg, 1977). These models are hypothesized to consist of stimuli passing initially through a bandpass filter system that tends to favour high frequency centred sounds for analysis. The bandpass filter system then sends the information to a nonlinear device that may be crudely thought of as the mechanism that bridges the cochlear structures with the auditory nerve. The temporal integrator is considered the first structure beyond the peripheral auditory system and is considered a "smoothing" device for the signal. The final element of the model is a central process referred to as the decision device and determines when threshold is reached. Both cochlear and central auditory deficits could affect temporal resolution as the integrity of the temporal system requires that the two function together (See Figure 1). The integrity of both systems is essential for temporal processing and, therefore, for hearing in noise.

Figure 1.
Block diagram of the four-stage model of temporal resolution from Moore (1997).



Word recognition in interrupted and continuous noise masking is a paradigm that has been suggested to test the integrity of the temporal processing systems of those who suffer from sensorineural hearing loss (Stuart & Phillips, 1996, 1998). This particular measure of temporal auditory processing uses word stimuli masked by either continuous or interrupted noise. The interrupted broadband noise consists of gaps of silence and noise that maintain a temporal structure that is similar to that common in speech. The intensity of the noise when sampled from 200 to 8000Hz in 100Hz steps is equal in both the interrupted noise and the broadband continuous noise condition. The interrupted noise is presented in bursts varying in duration from 5 to 95 ms followed by silence of the same range of duration. The continuous noise occurs throughout the speech stimuli in a broadband form. In a nonpathological auditory system, the interrupted masking provides the listener with the opportunity to have a clear "hint" as to the word. This allows the listener to become more accurate in his or her perception of the speech stimuli.

In those auditory systems in which the temporal integrity is compromised, the temporal cues as to the identity of the words are obscured and there is less perceptual benefit in listening in the interrupted paradigm. As only the temporal aspect between the continuous and interrupted conditions varies, those who have a temporal processing deficit do not improve their word recognition abilities in the interrupted masking condition to normal levels.

A great deal of research has focused on cochlear pathologies and their effect on temporal processing. Phillips, Rappaport, and Gulliver (1994) studied the effect of high-frequency, noise-induced hearing loss on temporal processing using the continuous and interrupted noise paradigm. Those who suffered from cochlear loss showed impaired performance in the interrupted noise condition, but performed equivalent to the control group in the continuous condition. According to the authors, this indicated that persons with cochlear hearing loss also displayed temporal deficits.

Stuart, Phillips, and Green (1995) found that even individuals with a simulated, high-frequency hearing loss performed poorly in the interrupted noise condition compared to the normally hearing control group. The hearing loss was simulated by filtering the word stimuli through a low-pass filter at 2000 Hz with a roll-off slope of 48dB/octave. Individuals with the simulated high-frequency hearing loss performed identically to the control group in the continuous noise condition and much poorer in the interrupted condition. The authors suggested that the temporal resolution is best in the high-frequency range. Therefore, those with a high–frequency hearing loss are more disadvantaged in their temporal processing.

With the predominantly retrocochlear condition associated with multiple sclerosis (MS), temporal processing deficits have also been seen. Rappaport et al. (1994) used the continuous and interrupted noise task to determine the extent of the temporal deficit in individuals with retrocochlear lesions. These individuals who suffer from MS were found to have normal hearing sensitivity, as well as normal performance in the continuous condition, but they performed well below the control group in the interrupted condition. The results of this study indicate that temporal processing deficits, as displayed in the continuous and interrupted noise task, can be found due to retrocochlear pathologies as well.

What remains uncertain is the effect of temporary conductive auditory disorders on the retrocochlear structures of the auditory system and how temporal processing would in turn be affected by these changes. As the higher auditory structures which, in part, control temporal processing are dependent upon the presence of normal auditory stimuli for their development, they may be affected by OME (Ruben & Rapin, 1980). Continuous and consistent stimuli may be required for the development of temporal processing. Otitis media with effusion provides inconsistent stimulation during its presence. This may hinder normal development.

The speech perception in the interrupted and continuous noise paradigm could be important in determining if children with a history of OME have any long-term central auditory processing problems, particularly those associated with temporal processing. A poor performance on the temporal processing task may indicate a susceptibility to problems in interpreting speech in various sorts of competing background noises (Dreschler & Plomp, 1985; Tyler et al., 1982). This can have important implications for the linguistic, psychological, and educational development of the child sufferer of OME.

Otitis media with effusion has a high incidence rate among children (National Institute on Deafness and Other Disorders, 1999). Some researchers have suggested that 20% of children suffer from chronic OME for more than half of their first three years of life (Hogen et al., 1996). As such, any possible short- or long-term effects associated with OME may have far-reaching consequences.

Auditory deprivation during an infant's developing years can negatively affect their later auditory ability (Gravel & Ruben, 1996). As OME is a disease that is so common, it is important to determine any possible deficits that may occur due to this form of auditory deprivation or inconsistency.

Temporal processing uses structures in both the peripheral and central auditory systems (Moore, 1997). Auditory input flows through these temporal filters to allow one to determine the changes in auditory events over time. However, if the flow of auditory stimuli is hindered or altered due to the temporary occurrence of OME or another form of auditory deprivation, temporal processing may be affected in the short- or long-term.

The purpose of this preliminary study was to compare scores in the interrupted and continuous noise paradigm of six- and seven-year-old children who have a history of OME to children who have not had great exposure to the disease. Speech perception in interrupted and continuous noise was assumed to be a test of temporal processing.

Method

Participants

Two groups of 14 English-speaking children participated in the study. They were between six and seven years of age (M [Affected group] = 7.04, *SD* = 0.50; M [Control group] = 6.91, *SD* = 0.51). Six males and eight females participated in each group. The experimental group consisted of children seen by the Nova Scotia Hearing and Speech Clinic (NSHSC) for hearing measurement due to repeated episodes of OME. The criteria for inclusion in this study were identical to those used by Hall et al. (1998). That is, the children in the experimental group must have had a hearing loss of 25dB HL or more at a minimum of two frequencies between 250 to 2000 Hz. See Table 1 for the experimental group's mean audiometric results for the test ear. An abnormal tympanogram was also required of the participants during their bouts with OME.

Table 1.
Mean puretone audiometric thresholds (in dB HL) during period of OME of experimental group. Means were calculated for the test ear.

Frequency (in Hz)	250	500	1000	2000	4000
Mean Thresholds					
(dB HL)	36.5	32.1	27.9	21.1	24.6
SD	9.4	8.5	9.3	8.4	12.5

Additionally, the participants must have required tympanostomy tubes at some time due to the severity of their OME. Tympanostomy tubes are the recommended form of treatment for OME once effusion has been present for four to six months and a hearing loss of 20 dB accompanies the effusion (Stool et al., 1994 as cited in Clark & Jaindl, 1996). By ensuring that tympanostomy tubes were part of the course of treatment, we were also ensuring a minimal period of auditory disorder. The child's audiometric history was acquired from their charts at the NSHSC.

The parents of the participants who met the above criteria were mailed a letter describing the study and the requirements for participation. The letter was mailed a year following the child's most recent tympanostomy tube surgery. This ensured a minimum period of stable hearing in the experimental group. It also allowed for an adequate period of time for the tympanostomy tubes to have fallen out and for middle ear function to have returned to normal. The parents were called a week after the letter was sent and any questions they had were answered. They were asked about their interest in participating in the study at this time. If they were interested, a few additional questions were asked. The parents were asked if their child's tympanostomy tubes had fallen out and about the general health of their children. If the child was feeling well and their tubes had come out, an appointment was made.

At the time of testing, the affected group of participants must have had the OME resolved and have presented with a pure-tone air conduction threshold of 15 dB HL or less for octave frequencies between 250 and 8000 Hz. Normal tympanograms must also have been present. As their tympanostomy tubes must have fallen out at the time of testing, it is assumed that the children will have had resolved hearing for at least the previous eight to 12 months (Mandel, Rockette, Bluestone, Paradise, & Nozza, 1989 in Rosenfeld & Isaacson, 1999). Their hearing status at the time of data gathering was consistent with that of the control group.

Only one ear was tested for each participant. The ear chosen for the experimental group was the ear in which a more severe hearing loss had been present. If the ears had equivalent HL, then a coin was tossed. If only one ear had normal middle ear function at the time of testing (i.e., Tympanostomy tubes had fallen out only on one side), that ear was tested. As a result, eight left ears and six right ears were tested. The chosen ear for the control group was matched based on the ear used for his or her matched experimental group peer.

The second group of children, the control group, was matched for age, gender, and ear tested with the experimental group. The control participants had none or minimal history (one or two acute occurrences) of ear disease (OME) by parental report. Additionally, they must have never required tympanostomy tubes. They had pure-tone, air conduction thresholds of 15dB HL or less for octave frequencies between 250 and 8000 Hz as well as normal tympanometric findings. These were also the criteria used by Hall et al. for the control group in their 1998 study. The control group was found by advertising in local schools through handouts to parents. Other advertising was placed on bulletin boards in the Halifax, Nova Scotia community.

Stimuli

The items from Northwestern University's Children and Infants Perception of Speech (NU-CHIPS) were used as the speech stimuli (Elliott & Katz, 1980). While NU-CHIPS was developed as a closed-set, picture-pointing speech discrimination test, the stimuli were used in an open-set, word-repetition format in this task. The fifty monosyllabic words were developed from the receptive vocabularies of normally developing three-year-olds. The vocabulary was believed to not be problematic for these normally developing six- and seven-year olds. All four lists contain the same fifty words but are arranged in a different order in each list. The word lists were burned onto the channel one portion of a compact disk (CD).

The continuous and interrupted noise CD developed by Stuart (1995) was burned onto the channel two portion of the same CD. The continuous and interrupted noise was taped with each of the four lists so that all eight conditions were available on the CD. As the competition and speech were burned separately, each could be presented at different levels and calibrated independently but presented simultaneously.

Apparatus

All testing was done inside a double-walled sound-treated booth (Industrial Acoustics Corporation) that met the recommendations for allowable ambient noise (American National Standards Institute, 1986). The speech stimuli and noise competition were routed from the CD player (Sony, 608-ESD) to the audiometer (Grason Stadler GSI-61) and to the participants through insert earphones (Etymotic Research Model ER-3A). Immittance measures were made on a Grason Stadler, GSI-33 Middle Ear Analyzer.

Procedure

The children and their parents were greeted at the School of Human Communication Disorders at Dalhousie University and the consent forms were filled out. A normal battery of auditory tests was required, including a pure-tone screening at 15 dB HL at octave frequencies 250-8000 Hz and a tympanogram. Word recognition measures on the NU-CHIPS test in quiet were performed before the noise competition was added. These procedures were required to ensure that the participants in both groups were able to cognitively complete the task and that they were familiar with the vocabulary words used in the NU-CHIPS lists. Only the test ear was tested in quiet.

Figure 2.
Affected and Control Groups in Interrupted and Continuous Noise at four S/N.

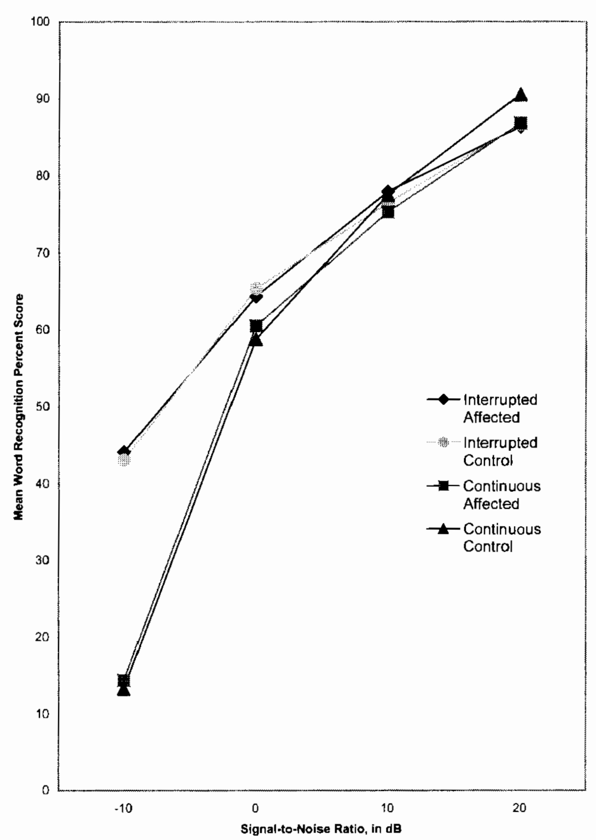


Table 2.
Summary table of descriptive statistics for the control and affected groups (aged six and seven years of age). Mean word recognition percent scores on interrupte and continuous broadband noise at four S/N (-10, 0, 10, 20).

Condition	Signal-to-Noise Ratio			
Continuous	**-10**	**0**	**+10**	**+20**
Affected Group				
Mean	14.4	60.5	75.2	86.8
SD	9.8	13.1	11.8	9.1
SE	2.6	3.5	3.2	2.4
Control Group				
Mean	13.3	58.8	77.6	90.6
SD	6.7	12.2	6.2	6.5
SE	1.8	3.3	1.6	1.7
Interrupted	**-10**	**0**	**+10**	**+20**
Affected Group				
Mean	44.1	64.4	78.0	86.4
SD	11.6	12.9	13.4	10.1
SE	3.1	3.4	3.6	2.7
Control Group				
Mean	43.1	65.4	76.5	86.6
SD	15.2	9.3	7.5	7.5
SE	4.1	2.5	2.0	2.0

After the audiological screening, the children were asked to repeat words from the NU-CHIPS test in four different signal-to-noise ratios (-10, 0, +10, +20). These four signal-to-noise ratio conditions were repeated in both the interrupted and continuous broadband noise settings. Therefore, each child responded in a total of nine conditions; the quiet and the eight experimental conditions. The speech stimuli were presented at 50 dB HL and the competition was varied to give the appropriate signal-to-noise ratio. The presentation order of signal-to-noise ratio was counterbalanced. All continuous or interrupted competition were presented together. Half of the participants had continuous noise presented first and the other half had interrupted noise presented first. As the lists all contain the same fifty words, the lists were presented in the same order to each participant.

Table 3.
Summary table for the three-way ANOVA, one-factor between groups, two factors within groups. Results show the investigation of word recognition score performance in interrupted and continuous broadband noise as a function of group (OME vs. Control) and S/N. Percent correct scores were transformed to rationalized arcsine units (RAUs) before analysis.

Source	Sum of Squares	df	Mean Square	F	P
Group	0.04	1	0.04	5.98E-5	0.994
Error	15216.02	26	585.23		
Noise	3964.81	1	3964.81	33.44	0.0001*
Error	3082.69	26	118.57		
S/N	122665.63	3	40888.54	587.93	0.0001*
Error	5424.63	78	69.54		
Noise X Group	135.78	1	135.78	1.15	0.294
Error	3082.69	26	118.57		
S/N X Group	157.03	3	52.34	0.75	0.5241
Error	5424.63	78	69.54		
Noise X S/N	9951.86	3	3317.29	72.64	0.0001*
Error	3562.13	78	45.67		
N X S/N X G	130.75	3	43.58	0.954	0.419
Error	3562.13	78	45.67		

*Considered significant at $p < 0.01$.
Note: p values for significant results following a Geisser-Greenhouse and Huynh-Feldt correction are all 0.0001.

Each condition consisted of fifty words. The children were given an ink stamper and a map to help them remain interested in the task. The map consisted of nine boxes. The first box represented the pure-tone screening and the word repetition in silence. The other boxes were for each of the other eight competition conditions. The child was reinforced for his/her participation by placing a stamp two to three times in each box when instructed. A variable reinforcement schedule was used. The stamp and verbal reinforcement were provided after the first fifteen words, the second twenty words, and the final fifteen words in each list. The reinforcement map allowed the child to keep track of his/her progress in the task and to remain attentive to the words. After the first five boxes (the screening and five of the word lists) the child was given a break and a juice box. The next four boxes were then completed.

After performing the task, the child and parent were thanked for their time and a small prize was presented to the child for participating. The results of the child's testing were shared with the parents and any questions were answered before the family left the test site.

Results

The participants' performances were scored in each condition as whole-word percent correct. Mean word recognition in quiet was 99.1% ($SD = 1.7$) for the affected group and 97.7% ($SD = 1.7$) for the control group.

All of the results were transformed to rationalized arcsine units (RAUs) before performing statistical analysis (Studebaker, 1985). The word recognition scores in quiet between the two groups were significantly different on a t-test at the $p < 0.05$ ($t = 2.776$, $p = 0.0157$). On closer inspection of the data it was found that only two of the 14 participants of the control group scored more poorly than the affected group. The mean percent difference between groups was 1.4% or less than a one-word difference between groups on a fifty-item word list. While there was a statistical difference, there was no practical difference between groups.

Performance in the interrupted noise condition was better than in the continuous noise condition,

Figure 3.
Interaction of noise and S/N with combined groups.

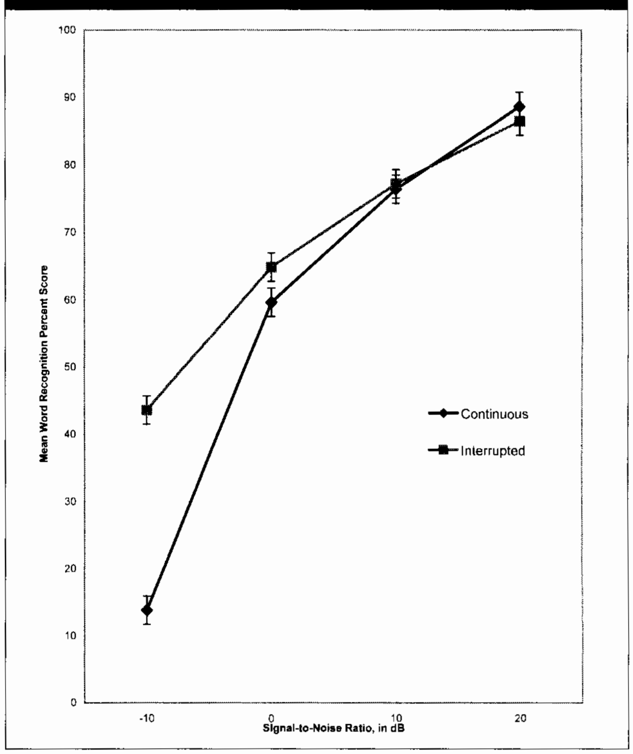


Table 4.
Combined data (*n* = 28) of both affected and control groups (aged six and seven years of age [M = 7.01,SD = 0.57]). Mean word recognition percent scores on interrupted and continuous and broadband noise at four S/N (-10, 0, 10, 20).

Condition	Signal-to-Noise Ratio			
Continuous	-10	0	+10	+20
Mean	13.84	59.66	76.41	88.68
SD	12.10	11.76	9.81	11.36
SE	2.29	2.22	1.85	2.15
Interrupted	-10	0	+10	+20
Mean	43.62	64.86	77.21	86.50
SD	11.96	11.16	11.61	10.69
SE	2.26	2.11	2.19	2.01

particularly at the poorer signal to noise ratios for both groups. The scores of both groups improved as signal-to-noise improved. Additionally, the scores of the two groups overlapped in almost every condition. Results for the two groups in the eight experimental conditions are displayed in Figure 2 and Table 2.

A two factor within, one factor between, three-way Analysis of Variance (ANOVA) was performed on the RAU scores to determine the effect of group (control and affected), noise (continuous and interrupted), and signal-to-noise ratio (-10, 0, 10, 20). Results are displayed in Table 3.

There was no significant difference in task performance between the children with a history of OME and the control group (F = 5.98 E-5, p = 0.9939). There were significant differences between the continuous and interrupted noise scores (F = 33.44, *p* = 0.0001) and the signal-to-noise ratio (F = 587.93, *p* = 0.0001). The interaction of noise type and signal-to-noise ratio was also significant (F = 72.639, *p* = 0.0001). The interaction indicates that the slopes of the lines for interrupted and continuous performance are different.

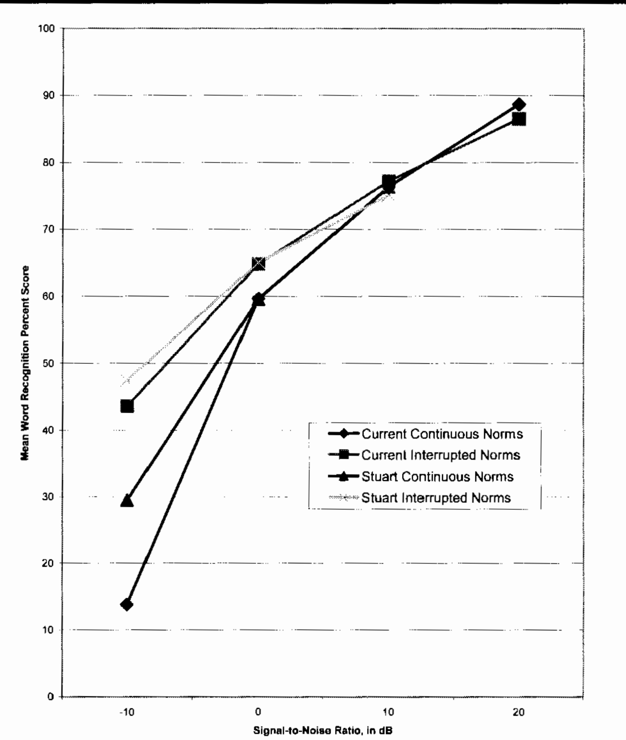
For the purposes of comparing the data in this study with unpublished results of Stuart (2000), the scores of both the affected and control groups were combined to determine the mean scores for children six and seven years of age on the interrupted and continuous noise paradigm. This was acceptable as the results between groups did not vary significantly. These combined results are displayed in Figure 3 and Table 4.

The combined scores of the 28 six- and seven-year-old children tested in this study were comparable to unpublished results obtained by Stuart (2000; Figure 4). Stuart's data are based on a sample of 16 children aged six and seven in the same interrupted and continuous noise paradigm used in this study. Results were not available from Stuart for the +20 signal-to-noise ratio. The sole point at which the norms vary is in the continuous noise paradigm at the –10 signal-to-noise ratio. While there is a significant difference in continuous noise at this S/N (t= 5.60, p< 0.0001), there was no significant difference between the groups from the two research centres (F= 1.765, p= 0.1912). As the norms of the two research groups overlap so well, the cross validity of the results of the current study appears to be strong.

Discussion

The significant difference between the two groups' scores in quiet may be due to the fact that the children in the affected group have had their hearing tested on a number of occasions while the procedure of a hearing test was new to the children in the control group. The significant difference between responses in the two noise conditions (continuous and interrupted) was expected based on past research using this paradigm (Rappaport et al., 1994; Stuart, 1995; Stuart et al., 1995). Normally hearing listeners perform better in the interrupted noise condition than in the continuous noise condition at poorer signal-to-noise ratios. While the acoustic spectra

Figure 4.
Comparison of Stuart (2000) Norms and current results for six- and seven-year-old children on an Interrupted and Continuous Noise Task.



of the two noise types are equivalent, the temporal continuity of the masking noise is varied in the interrupted noise condition (by five to 95 ms) and remains constant in the continuous noise condition. The gaps of silence in the interrupted noise condition provided by the temporal discontinuities of the masker provide listeners with an opportunity to recognize more of the words than in the continuous noise condition. Stuart and Phillips describe speech detection in interrupted noise as revealing, "the auditory system's temporal ability to resolve speech fragments or get "glimpses" or "looks" of speech between the gaps of noise and to patch the information together in order to identify the specific speech stimuli," (Stuart & Phillips, 1998, p. 334). This ability to use the gaps to improve speech detection in the interrupted noise condition was also evident among six- and seven-year-old children in this study.

The improvement of the children's responses as the signal-to-noise ratio improves was clearly an expected result. It is well known that speech recognition improves with favourable signal-to-noise ratios. For the continuous and interrupted noise paradigm used in the current study this phenomenon was also observed and is consistent with other research employing this task. (Phillips et al., 1994; Stuart, 1995; Stuart et al., 1995; Rappaport et al., 1994).

It was surprising, however, that no group effect was found in this study of six- and seven-year-old children with a history of OME. No difference was noted between the two groups in either the interrupted or continuous noise conditions. Other studies have shown deficits in children with a history of OME on tasks of word recognition in noise. Schilder, Snik, Stratman, and van den Broek (1994) found that children with a history of OME during their second and fourth years of life had affected word recognition in noise scores when tested between seven and eight years of age. Gravel and Wallace (1992) found that four-year-old children with a history of OME required a more advantageous signal-to-noise ratio for sentence intelligibility with the (PSI) Test when comparison to a non-OME group. Based on the results of these studies, one would have expected there to be a similar difference between our groups when listening to speech in either the continuous or interrupted noise conditions; however, no difference was found.

Had a temporal processing deficit been present in the OME positive group, we would have expected there to have been a difference between groups that was more significant in the interrupted noise condition. If an effect were present, we would expect a narrowing of the difference between the scores in interrupted and continuous noise due to reduced scores in the interrupted noise condition. In other tasks related to temporal processing, differences have again been found between OME positive and negative groups. For example, Hall et al. (1998) found auditory deficits in children aged five to 12 on a complex masking task up to one year after the placement of tympanostomy tubes. The comodulation masking release (CMR) task that Hall et al. used required temporal envelope analysis performance across frequencies. This task measures the ability of a participant to detect a specific signal among masking noise. In the first condition the masking noise consisted of single amplitude modulation pattern while in the second condition the masking noise had two amplitude modulation patterns. Hall et al. found that the release from masking scores were reduced in the affected group in both the simple and complex masking tasks prior to and one month after the tympanostomy tube insertion. However, the scores of the affected group remained reduced in the complex masking condition up to a year after the surgery. As temporal processing is required to perform the CMR task and deficits were present in the performance of this task it is surprising that deficits were not also present in the interrupted noise condition of the interrupted and continuous noise paradigm used in this study.

Temporal processing is required in a variety of tasks that have also shown impaired performance in children post-OME. Binaural masking level differences were found to be impaired in children aged five to 16 with a history of OME (Moore et al., 1991). Auditory processing as measured by the Goldman-Fristoe-Woodcock Sound Symbols Test Battery in children six and seven years of age was also reduced in an OME positive group (Updike & Thornburg, 1992). The perception of voicing cues in nine-year-old children with a history of OME was reduced when compared to their OME negative peers (Groenen et al., 1996). The performance of OME affected children on these tasks would lead one to expect significant results in the interrupted and continuous noise paradigm.

There are a variety of possible explanations for the lack of group effects. One may be the time of testing or the extent of the OME in this particular group. As the children in the affected group had tympanostomy tubes at least one year ago and not at the time of current testing it is likely that they have had resolved OME and consistent auditory input for over a year. Perhaps if testing had been done closer to the time of tympanostomy tube insertion, and therefore more recent OME, an effect may have been present. Additionally, while similar criteria to the Hall et al. (1998) study were used, perhaps the extent of the OME was not as severe in this group as in others. Hall et al. studied children prior to, and in the first year after tympanostomy surgery. We, however, tested the children at least one year following tympanostomy tube surgery. This may explain the Hall group's significant findings while in this study there were no significant group results.

An additional explanation for the lack of a difference between the two groups in this study may be that the interrupted and continuous noise paradigm may not be as sensitive a measure of temporal processing as it has been believed to be. However, as the sole difference between the continuous and interrupted noise maskers is their temporal composition, it has been hypothesized to be a means of analyzing temporal functioning. As well, the interrupted and continuous noise paradigm has been successfully used experimentally as a measure of temporal processing (Stuart, 1995; Stuart & Phillips, 1996, 1998; Stuart et al., 1995; Rappaport et al., 1994). The task has been used to test temporal processing in individuals with cochlear hearing loss (presbycusis and noise-induced hearing loss), simulated hearing loss, and multiple sclerosis. This research has shown, as predicted by Moore's model (1997), that both peripheral and central deficits can independently affect temporal processing.

Central deficits in temporal processing have been found to be related to the demyelination of central pathways secondary to multiple sclerosis (Rappaport et al., 1994). In MS participants with normal or near-normal hearing, a central pathology was found to impair performance in the interrupted condition of the interrupted and continuous noise task. These results indicated a temporal processing deficit that could not be explained by reduced audibility.

Stuart and Phillips (1998) hypothesized that peripheral problems in temporal processing, in cases of high frequency hearing loss, are due to the limitations of temporal processing in the lower frequencies. Temporal processing is hypothesized to be significantly poorer in the lower frequencies than in the high frequencies due to the organization of auditory filters in the cochlea (Moore, 1997). High frequency auditory filter bandwidths are broader and have shorter response times while low frequency auditory filter bandwidths are narrower and have longer response times. Therefore, when a hearing loss affects the high frequencies, the slower and narrower low frequency filters affect temporal processing by slowing down the speed of the response.

Individuals with a simulated and diagnosed cochlear - high frequency hearing loss showed deficits in temporal processing as measured by the interrupted and continuous noise paradigm (Phillips et al., 1994; Stuart et al., 1995; Stuart & Phillips, 1996). While these individuals performed on par with normally hearing adults in the continuous noise condition, deficits in temporal processing became apparent in the interrupted noise condition. These studies have highlighted the importance of high frequency filters for temporal processing while demonstrating that low frequency filters are not as essential for intact temporal processing. This model of temporal processing explains why the children in the current study did not have any measurable effects. The low frequencies affected by OME would not impact temporal processing (a high frequency phenomenon) as measured by the interrupted and continuous noise paradigm.

Another possibility for the lack of significant results could be due to the nature of the auditory deprivation suffered in OME. Otitis media with effusion is a mild, conductive hearing loss that typically affects the low frequencies (National Institute on Deafness and Other Communication Disorders, 2002). The mild conductive nature of the loss would hypothetically cause reduced auditory input at very low intensity levels. In this study, testing was conducted at 50 dB HL. This intensity level could have resulted in suitable auditory signal strength to perform this task even with slightly depressed hearing threshold levels. Due to the conductive nature of the pathology, if the stimulus were intense enough, it would stimulate a normal sense organ and auditory periphery. Perhaps if testing had been done at a lower intensity level, deficits in auditory processing may have become more apparent.

Additionally, as the lower frequencies are typically affected by OME while the hearing sensitivity for higher frequencies remain normal, temporal processing may be unaffected. As stated earlier, Stuart and Phillips (1998) proposed that the lower frequencies are poorer for temporal resolution than the higher frequencies. If this is the case, child sufferers of OME are unlikely to have impaired temporal processing as the hearing sensitivity in the higher frequencies is unaffected by the conductive nature of the pathology. Additional studies in individuals with low-frequency sensorineural hearing loss or individuals with 'cookie-bite' hearing loss may provide new insight into temporal processing in the low frequencies.

Conclusions

The results of this study indicated that there was no significant difference between children with a history of otitis media and children without a history of the disease on a temporal processing task of word recognition in interrupted and continuous noise. While other studies have indicated that there are short- and long-term deficits associated with chronic OME, this research did not find any indication of residual effects secondary to OME.

While OME is a pervasive disorder among children (National Institute on Deafness and Other Communication Disorders, 2002), the results of this investigation indicate that long-term auditory processing effects need not necessarily be the consequence. Results of the current study show that children exposed to chronic otitis media with effusion do not seem to differ from their unaffected peers in the years following their exposure. Furthermore, the implication is that a normal developmental outcome for some forms of temporal processing occurs in children with a history of otitis media with effusion. Additional research could focus on testing younger children with the interrupted and continuous noise paradigm to see if a deficit is present and then resolves as children develop. As well, testing children who are currently exposed to OME and are about to have tympanstomy tubes inserted may provide more information on the disease process and the short and long-term effects.

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Author Notes

The first author is now affiliated with the University of Ottawa. Please address all correspondece to J. Cyne Topshee Johnston, Doctoral Student, Population Health PhD Program, University of Ottawa, 451 Smyth Road, Rm. 1118, Ottawa, Ontario, K1H 8MS.

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