

RESEARCH ARTICLES

The Impact of Otitis Media With Effusion on Infant Phonetic Perception

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The effect of prior otitis media with effusion (OME) or current middle ear effusion (MEE) on phonetic perception was examined by testing infants' discrimination of *boo* and *goo* syllables in 2 test sessions. Middle ear function was assessed following each perception test using tympanometry. Perceptual performance was compared across 3 infant groups: (a) *history-negative*, infants with normal middle ear function who had never received medical treatment for OME; (b) *history-positive*, infants with normal middle ear function who received medical treatment for prior episodes of OME; and (c) *MEE*, infants presenting tympanograms indicating middle ear effusion on the day of testing. History-negative infants performed significantly better than MEE infants in both test sessions. History-negative infants also performed significantly better than history-positive infants in the 2nd test session. Findings suggest that OME has a negative impact on infant phonetic discrimination that may persist even after middle ear function has returned to normal.

Current theories of language acquisition recognize the critical importance of the infant period in the language learning process and highlight the active role that the infant plays in abstracting linguistic knowledge from the input (Jusczyk, 1997). Bootstrapping and statistical learning perspectives (see Morgan & Demuth, 1996) have led to an explosion of research that is concerned with the properties of the

input that is provided to infants. Empirical investigations of infant responses to naturally occurring variations such as those that occur across languages (Best, 1995), social classes (Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991), talkers (Ward & Cooper, 1999), and speech registers (Cooper, Abraham, Berman, & Staska, 1997) are common. Studies employing the artificial language learning paradigm have further illuminated the infant's ability to discover linguistic structure by attending to distributional and statistical regularities in the input (Saffran, 2001).

A complete understanding of the process by which the infant learns from speech input requires greater knowledge about those variables that impact the infant's ability to receive that input, including aspects of the environment, such as background noise, and aspects of the child, such as the integrity of the peripheral and central auditory mechanisms. One variable that may significantly hamper infant reception of speech input in both natural and laboratory environments is otitis media with effusion (OME). OME refers to conditions involving the presence of fluid in the middle ear space, with or without an accompanying acute infection. Typically, an episode of OME lasts for approximately 1 month, although in some cases the effusion persists for many months following identification of an acute infection (Klein, 1983). Fria, Cantekin, and Eichler (1985) reported that the average hearing threshold during an episode of OME was 23 dB, although thresholds may vary from as low as 10 dB to as high as 50 dB. In contrast, infants and young children who have never had OME typically demonstrate hearing thresholds that are 10 dB or lower (Gravel & Wallace, 2000; see also Sabo, Paradise, Kurs-Lasky, & Smith, 2003). Hearing thresholds vary with the amount of fluid in the ear, which itself changes throughout an episode; thus, the degree of hearing loss experienced by the child can fluctuate considerably within and across ears throughout a period of recurrent or persistent OME.

OME should be of particular interest to researchers of infant development because it is more likely to occur in infancy than at later ages, the majority of infants experience one or more episodes, and the documented sequelae are most likely to occur when recurrent OME has its onset during the infant period (Paradise et al., 2000; Paradise et al., 1997; Teele, Klein, Rosner, & the Greater Boston Otitis Media Study Group, 1984).

A large range of developmental sequelae to early-onset OME have been reported, including comparatively poor performance on tests of central auditory processing, auditory attention, speech perception, verbal working memory, phonology, vocabulary, morphology and syntax, narrative structure, phonological awareness, reading, and behavior (see Bennett & Haggard, 1999, for a comprehensive review). A recent meta-analysis concluded that the reported effect sizes are small but nonetheless there is good evidence for a negative association between frequency of OME and preschoolers' language development and a negative association between OME-related hearing loss and language development in infancy (Roberts, Rosenfeld, & Zeisel, 2004).

It must be acknowledged that these studies are largely correlational in nature and thus a causal relation between OME and the reported sequelae has not been established. It has been proposed that the relation between OME and slower language development is spurious, resulting from an unknown common sociodemographic (Paradise et al., 2003) or genetic (Feldman et al., 2003) causal variable. A recent randomized control trial of the impact of early versus late tympanostomy tube placement revealed no between-group differences in 3-year outcomes despite significant differences in middle ear function during the first 3 years of life (Paradise et al., 2001). The results of this study have been interpreted as evidence against the hypothesis that early-onset OME directly impacts language learning. However, the children in both the early and late tube placement groups shared a common history of significant middle ear effusion during the first 15 months of life, with participants assigned to the early tube placement group receiving this intervention sometime after their first birthday. Thus, the timing of this intervention is not optimal considering the evidence that the acquisition of language-specific patterns in phonetic perception begin to emerge in the first year. Moreover, Teele et al. (1984) found that time spent with OME during the first 12 months of life was most strongly correlated with language performance at age 3 years, in comparison with amount of OME during the second and third years of life. Efforts to understand the way in which OME impacts speech processing during the first 12 months of life may help to resolve the controversy about the source of the correlation between OME and slower language development.

Possible explanations for the relation between early-onset OME and slower language development include effects that may occur during an acute episode of OME as well as effects that may persist after resolution of the effusion. First, OME-related hearing loss may be severe enough to impair an infant's ability to respond to speech (Nozza, 1988), although this hypothesis has not been tested directly. Second, Mody, Schwartz, Gravel, and Ruben (1999) speculated that the fluctuating hearing loss that occurs during an episode of OME might make it difficult for the child to detect the regularities that occur in the speech produced by talkers in the child's environment. Third, there is evidence that a fluctuating unilateral hearing loss can disrupt the normal development of binaural processing abilities that are important to sound localization and speech perception in noise (Pillsbury, Grose, & Hall, 1991). Fourth, researchers have also suggested that the fluctuating input disruptions associated with OME may lead to a general pattern of inattention to speech that surfaces when the child must function in less than optimal listening conditions (e.g., Feagans, 1986). Finally, it has been suggested that OME may interfere with the quality of interactions between caregiver and child, resulting in less than optimal speech input to the infant (Roberts et al., 1998; Yont, Snow, & Vernon-Feagans, 2003).

Although the injurious effects of OME on language development are hypothesized to arise during the first year of life, most of the investigations already cited report the results of outcome assessments that were conducted during the period

from 3 through 7 years of age. Increasing numbers of studies have examined the emergence of expressive vocabulary abilities during the second year of life in these children (Feldman et al., 2003; Friel-Patti & Finitzo, 1990; Paradise et al., 2000). A very few studies have described the impact of OME on prelinguistic speech production skills (Petinou, Schwartz, Mody, & Gravel, 1999; Rvachew, Slawinski, Williams, & Green, 1999). However, to assess any of the preceding hypotheses, it is necessary to describe the impact of OME on more basic aspects of prelinguistic speech processing during the first year of life, such as the development of sensitivity to language-specific phonetic categories.

The study reported here was designed to examine whether phonetic discrimination measures are sensitive to variations in infant perception associated with OME. We chose a phonetic discrimination test with minimal pair syllables because this is a very common measure in the infant speech perception literature; such measures have played a central role in current models of speech perception development. The visually reinforced conditioned head turn (VRCHT) procedure that was used in this study to test syllable discrimination is a well-accepted procedure for assessing infant speech perception and audition in both clinical and research settings. A primary advantage of this research paradigm is that it yields data that permit interpretation of individual as well as group performance.

To our knowledge, there are no studies reported in the infant speech perception literature that directly examined the impact of OME on this common phonetic perception measure or any others. Researchers studying infant speech perception rarely screen infant hearing or test middle ear status but they typically attempt to remove OME effects from their results by screening out infants who have an active or recent ear infection, a history of repeated ear infections, or an active or recent cold or congestion. In addition, when using the VRCHT, infants who are fussy or inattentive in the initial conditioning phase of the task are typically removed from analyses so as to not confound noncompliance with poor perception. Although there are likely many reasons why infants fail to condition, presumably infants with undetected middle ear fluid contribute to this attrition, although there are no data that address this issue. Thus, it is unclear how OME impacts speech perception skills in the developing infant and whether the sequelae associated with OME begins in infancy with a compromised ability to respond to auditory speech input.

In this study we compared phonetic discrimination across three groups of infants: (a) infants with no prior history of OME and no evidence of middle ear fluid on test day (history-negative group), (b) infants who had a prior history of OME but no evidence of middle ear fluid on test day (history-positive group), and (c) infants who failed to show normal middle ear function on test day when tested using tympanometry. This third group is referred to as the middle ear effusion (MEE) group because there is no direct evidence of infection. As mentioned earlier, research in infant audition clearly demonstrates that hearing sensitivity is affected by OME as fluid in the middle ear space effectively raises the sound level that the infant requires to respond

to speech. Thus, we expected that infants in the MEE group would not perform as well as the infants in the history-negative group. The issue, which presents greater uncertainty and concern, is whether experience with OME has a negative effect on infant perception that persists after the middle ear fluid is gone. If OME has a measurable lasting impact on phonetic perception, we expected that the history-positive group would not perform as well as the infants in the history-negative group even though middle ear function was normal in both groups on the day of testing.

We tested infant discrimination twice using the same task and stimuli within a 1-week time frame. This was done to assess the stability of any group differences that might emerge in a single test session. If group differences that emerge in the first test session were transient, we would expect that discrimination differences across the groups would diminish as the babies gain more experience listening and performing the discrimination task (with reinforcement) and hence differences would be reduced or absent when the test is repeated. In fact, our experience with the conditioned head turn task has shown that infants generally perform as well or better in a second test session using the same stimuli when the second session occurs within a 1-week time frame. Thus, infants showing a lower initial performance level may catch up to the level of their peers in a second test session. On the other hand, if group differences were not transient but were more lasting, we would expect that they would persist and would also be evident when the testing was repeated in a second test session.

METHOD

Design

Testing was completed in two sessions that were scheduled within the same week. On Day 1, the VRCHT procedure was used to assess the infant's ability to detect a category change from /bu/ to /gu/. Infants who met the minimal conditioning criteria on Day 1 were invited to return for a second test session on Day 2. To ensure that the experimenter was blind to the infant's middle ear status during the speech discrimination test, tympanometry was performed after the VRCHT procedure on both days.

Participants

Seventy-one infants between 6 and 9 months of age were recruited to the study, and 57 of these infants (27 girls and 30 boys) completed the Day 1 assessment protocol. The remaining infants did not complete the test protocol for various reasons: crying ($n = 4$), failure to condition ($n = 8$), and equipment failure ($n = 2$). Thirty-five infants passed the Day 1 assessment and returned for a second assessment session. Thirty of these infants (11 girls and 19 boys) completed the Day 2 assessment

protocol. The remaining infants did not complete the Day 2 test protocol for various reasons: crying ($n = 2$), failure to condition ($n = 1$), and experimenter error ($n = 2$).

The participants were recruited in Montreal, a city in which multilingual families are common. The parents of the infants provided information about the language or languages spoken in the home by the parents, other caregivers, or extended family members. Any language to which the infant was exposed more than 10% of the time was noted, and the infants were classified as English only, French only, or multilingual exposure. The other languages that the multilingual infants were exposed to included French, English, Italian, Spanish, Greek, Serbo-Croatian, Hungarian, Chinese, and Punjabi. The contrast between /b/ and /g/ is phonemic in all of these languages (Li & Thompson, 1981; Ruhlen, 1976).

The parents were also asked how many times the infant had been treated for an ear infection. Tympanometry tests were used to assess the infant's middle ear function on each day of testing (discussed later). Any infant whose ears were functioning normally on the day of testing and who had never been treated for an ear infection was classified as history-negative. Any infant who had been previously treated for an ear infection but whose ears were functioning normally on the day of testing was classified as history-positive. Any infant with one or both ears showing abnormal function was classified as having MEE. These classifications were made independently on each day of testing. The characteristics of the infants who completed the Day 1 and Day 2 assessment protocols are shown in Table 1. History-positive infants were typically slightly older than history-negative infants either because their parents were more likely to cancel and reschedule their appointments due to infant illness or because testing was postponed to increase the chance that their effusion had resolved.¹

All infants who passed the initial conditioning criteria on Day 1 were scheduled for Day 2 within the time frame of 1 week. Day 2 appointments were made at the end of the Day 1 session. Not all parents were able to keep this appointment or book an alternative time slot within the 1-week time period. In some cases the reason was offered (infant or sibling was ill, logistics problems, etc.); in other cases it was not. The overall return rate was 53% and was similar across groups: history-positive group (63%), history-negative group (50%), and MEE group (48%).

Stimuli

The same test stimuli were used on Day 1 and Day 2. The stimuli were a set of /bu/ and /gu/ syllables produced by a native monolingual male speaker of Canadian

¹The tympanometry results for 4 infants differed on Days 1 and 2 and hence their group assignment was changed. These infants were either in the history-positive group on Day 1 and moved to the MEE group on Day 2 or were in the MEE group on Day 1 and moved to the history-positive group on Day 2. No infants in the history-negative group changed status across days.

TABLE 1
Number of Infants in Each Group Who Completed the Day 1
and Day 2 Procedures by Age and Language Background

	Day 1			Day 2		
	History- Negative	History- Positive	MEE	History- Negative	History- Positive	MEE
Age						
6 months	6	1	2	0	0	0
7 months	4	5	8	5	1	2
8 months	5	5	7	5	3	2
9 months	1	5	8	0	6	6
Home language						
English only	1	0	4	2	2	2
French only	6	6	8	2	3	0
Multilingual	9	10	13	6	5	8
Total	16	16	25	10	10	10

Note. MEE = middle ear effusion.

English. These syllables differ in a single phonetic feature (place of articulation). Multiple tokens were selected to construct a task that required the infants to respond to a change in phonetic category and ignore irrelevant within-category variation. Five tokens of each syllable type were selected and digitized at a sampling frequency of 44100 Hz with 16-bit quantization. As shown in Table 2, there were no systematic differences across the /bu/ and /gu/ stimulus sets on measures that are not cues to the /b/-/g/ contrast, including loudness, duration, and fundamental frequency. The stimuli were digitally altered to ensure similar durations and signal amplitudes across and within stimulus categories and were low-pass filtered removing energy above 4000 Hz using TFR digital analysis software (Avaaz Innovations, Inc.).

Speech Discrimination Testing

The VRCHT procedure was implemented as described by Polka, Jusczyk, and Rvachew (1995). Testing was conducted in a sound-treated chamber, with the infant seated on the parent's lap across a small table from an experimenter. Both adults in the booth listened to vocal music over headphones to prevent them from influencing the infant's behavior. Visual reinforcers were located behind a smoked Plexiglas panel located to the left of the infant, above the loudspeaker. A second experimenter observed the infant through a one-way window and operated the IBM-format computer that controlled stimulus presentation via a Data Translation DT2801 D/A board. The stimuli were routed through a Yamaha

TABLE 2
Acoustic Characteristics of the Speech Stimuli

<i>Stimulus</i>	<i>Syllable Duration (msec)</i>	<i>Transition Duration (msec)</i>	<i>F1 (Hz)</i>	<i>F2 (Hz)</i>	<i>M F0</i>	<i>RMS Amplitude (v)</i>
/bu/ 1	259	23	430	1,291	92	2.44
/bu/ 2	278	28	516	1,464	83	2.39
/bu/ 3	303	30	516	1,378	85	2.32
/bu/ 4	214	30	430	1,464	105	2.38
/bu/ 5	179	29	430	1,464	96	2.36
/gu/ 1	250	36	430	2,067	100	2.38
/gu/ 2	286	46	430	1,898	93	2.43
/gu/ 3	202	33	344	1,722	96	2.36
/gu/ 4	225	42	430	1,808	102	2.24
/gu/ 5	248	33	430	1,722	90	2.36

Note. RMS = root mean square.

Amplifier (Model AX-350) and then presented to the infant via a Cyrus 780 loudspeaker. During all procedures the background stimulus was presented every 1,500 msec, and at random intervals the background stimulus (/bu/) was changed to a target stimulus (/gu/) for an interval comprised of three consecutive target stimuli. Computer software controlled the stimulus delivery, activation of the reinforcers, and trial selection, and recorded hits, misses, correct rejections, and false alarms.

On both days, the session began with a conditioning stage during which the infant was taught to turn his or her head toward a visual reinforcer whenever the background stimulus was changed to the target stimulus. Only a single exemplar of each /bu/ and /gu/ syllable was used during the conditioning stage. Once the infant had made at least three consecutive correct anticipatory head turns, the testing stage began.

In the testing stage on both days, multiple tokens of each syllable type were presented as background and as target stimuli. Change and control (no change) trials were presented according to a semirandom schedule in which no more than three consecutive control or change trials could occur. The experimenter who was outside the booth initiated trials when the infant was in a state of readiness and pushed a button when she observed a head turn during a trial interval. The visual reinforcer was activated automatically on a change trial if a head turn was observed within a 4.5-sec window. On Day 1, 25 trials were presented in the testing stage, with 10 of these trials being control trials. If necessary, up to 6 retraining trials were provided, during which the background was changed to the target and reinforcement was provided even if the infant did not turn to the reinforcer in response to the change in stimulus. Performance on retraining trials was excluded from all data analyses.

On Day 2 the infant was reconditioned in the task with a single token of each syllable and then completed four blocks of test trials.² Each block consisted of 10 trials with 6 change trials and 4 control trials presented in random order. No retraining trials were presented on Day 2. The syllables were presented at 72 dBA during the conditioning stage on Day 1 and at 65 dBA for the conditioning stage on Day 2 and for the testing stage on both days.

Tympanometry

We used tympanometry to examine the function of the middle ear to determine whether fluid was present in the middle ear space.³ To record a tympanogram, a soft probe is sealed in the external ear and a steady 226 HZ tone is presented through the probe while the pressure within the ear canal is varied. Information recorded by this probe is analyzed and displayed as a pressure/compliance function; the mobility of the eardrum, the volume of the external ear canal, and the pressure within the middle ear space can be inferred from this function. When mobility of the eardrum is severely reduced or extreme negative pressure exists in the middle ear, the amplitude of signals being transmitted through the middle ear to the cochlea is also reduced, and conductive hearing loss occurs. Conditions that reduce the mobility of the eardrum can be detected using tympanometry. When fluid is present in the middle ear, eardrum mobility is reduced or negative middle ear pressure may be present; either can be detected using tympanometry in infants 6 months or older. If a normal tympanogram is recorded in an infant 6 months or older, it is highly unlikely that the infant has MEE because tympanometry is sensitive to MEE and

²On Day 2, infants heard a distracting sound playing in the background during two of the four test blocks (either Blocks 1 and 3 or Blocks 2 and 4). The distracting sound was a complex noise with energy in a narrow range of high frequencies that do not overlap with the frequency range of the test syllables and hence did not affect the audibility of the syllables. We expected the presence of the distracting sound to reduce infant performance if it disrupted infant attention to the test syllables (see Werner & Bargones, 1991). Because performance levels were virtually identical across trial blocks with and without the distracting sound present, we collapsed data across the four test blocks. It is likely that the distracting noise had no effect on performance because it was introduced late in the test protocol, after the infant was familiar with the stimuli and trained to perform the task.

³In older children, pneumatic otoscopy is often used to identify MEE and is considered the gold standard with respect to diagnosis of MEE. This involves looking in the ear canal while pressure in the outer ear is varied to observe how well the eardrum can move. Pneumatic otoscopy is difficult to implement with young infants because the more horizontal angle of the infant eardrum is very difficult to visualize. However, with respect to assessing effusion, it has been shown that agreement between pneumatic otoscopy (when performed by a validated otoscopist) and tympanometry is excellent; for example, it was 91% in a recent study of children between 6 and 24 months of age (Roberts et al., 1998). Given this high agreement, tympanometry is generally used to assess MEE when pneumatic otoscopy is not successful or available. There is a body of research documenting the relation between tympanometry and pneumatic otoscopy and defining the associated measurement error in both clinical and nonclinical populations (see Nozza, Bluestone, & Kardatzke, 1992; Nozza, Bluestone, Kardatzke, & Bachman, 1994).

is specific to middle ear function. Likewise, a tympanogram indicating reduced eardrum mobility is a strong sign that the middle ear is not functioning normally. Conductive hearing loss can also reduce the sound intensity level at which the middle ear muscles contract in response to a loud sound. This response, called the acoustic reflex, can be measured using tympanometry and is often interpreted along with the tympanogram (for a general reference, see Fowler & Shanks, 2002).

Tympanograms were recorded using a Welch Allyn Autotym (Model TM262). Tympanograms were recorded (using a 226-Hz probe tone) for each ear; ipsilateral acoustic reflexes were also recorded at 1000 Hz. Three values were derived from the tympanograms: peak pressure (in deca-pascals), static compliance (in mL), and ear canal volume (in mL). These measures were interpreted using infant norms and applying criteria suggested by Silman and Silverman (1991). Specifically, abnormal middle ear function was inferred when we observed either (a) a flat tympanogram, or (b) peak pressure below -100 deca-pascals combined with an absent ipsilateral acoustic reflex at 1000 Hz. The vast majority of the abnormal tympanograms in this study showed a flat tympanogram (reflecting an immobile eardrum), which is the pattern most often observed when middle ear fluid is present.

Tympanometry provides a binary classification of infants with and without effusion, and from this we can make some broad inferences regarding differences in hearing. If we were to measure auditory thresholds in infants with and without normal tympanograms, infants with abnormal tympanograms would be much more likely to have auditory thresholds that do not fall within a range that is considered normal. Tympanometry is not a direct test of hearing and cannot be used to sort infants according to varying degrees of hearing loss. It should also be noted that tympanometry does not guarantee a perfect assignment of infants to normal middle ear and abnormal middle ear groups. However, it is a valid way to sort infants with and without effusion because false normals are rare and false abnormal are infrequent (Nozza, Bluestone, Kardatzke, & Bachman, 1992), and thus misclassifications are infrequent and unidirectional. In this study, misclassifications would mostly result in assigning an infant without MEE to the MEE group; this would shift the mean of the abnormal middle ear group closer to the mean of the groups with normal middle ear function. Therefore, misclassifications should make it harder to detect differences (in perception), if they exist, between infants with and without normal middle ear function.⁴

⁴Otoacoustic emissions (OAEs) are another measure widely used in newborn hearing screening (where detection of sensorineural hearing loss is the main concern) and are also often used with other tests to assess hearing in older infants. OAEs also provide an acceptable method for screening infants with and without hearing loss; however, at present, their performance as a method for detecting MEE is not as well established as tympanometry. Recent findings suggest that OAEs may be less sensitive to MEE than tympanometry. For example, OAEs may be recorded when MEE is present (Margolis & Trine, 1997; Van Cauwenberge, Vinck, De Vel, & Dhooge, 1996) and may depend on the viscosity of the fluid in the middle ear (Amadee, 1995). OAEs can detect both conductive and sensorineural hearing

RESULTS

Day 1

The percentage of correct responses (hits + correct rejections/total trials) was computed for each infant. A one-way analysis of variance (ANOVA) conducted on percentage correct scores across age groups showed that performance was not significantly influenced by the child's age, $F(3, 53) = 1.04, p = .38$. A one-way ANOVA conducted on percentage correct scores across language groups also revealed that performance was not affected by the languages spoken in the child's home, $F(2, 54) = 0.18, p = .833$.

On Day 1, the group means (and standard deviations) for percentage correct responses were 70% ($SD = 15\%$), 60% ($SD = 15\%$), and 57% ($SD = 14\%$) for the history-negative, history-positive, and MEE groups, respectively (see Figure 1, left panel). A one-way ANOVA revealed a significant effect of group, $F(2, 54) = 3.88, p = .027$, corresponding to a moderate effect size (partial $\eta^2 = .126$). As expected, planned comparisons revealed that the MEE group achieved significantly fewer correct responses than the history-negative group ($p = .008$), and that the history-positive group achieved fewer correct responses than the history-negative group, although this between-group difference did not reach statistical significance ($p = .066$). No significant difference in percentage correct scores was observed for the MEE group in comparison with the history-positive group ($p = .498$). To ensure that the findings were not due to differences in response bias across the groups, the one-way ANOVA and planned comparisons were repeated using the number of hits minus the number of false alarms as the dependent variable. This ANOVA yielded the same pattern of results.

As mentioned previously, not all infants tested on Day 1 returned for testing on Day 2. Several analyses were conducted to evaluate the effect of this attrition on the results. In all three groups, infants who returned for Day 2 performed significantly better on Day 1 compared to infants who failed to return on Day 2 [main effect of return status $F(5, 51) = 23.8, p < .001$]. Specifically, the Day 1 percentage correct scores for infants who returned compared to those that did not were 77% versus 56% (history-negative), 69% versus 54% (history-positive), and 65%

loss. However, our main concern in this study was to detect conductive hearing loss due to MEE. In the nonclinical population entering this study, the chances of encountering a child with sensorineural hearing loss is highly remote, whereas it is not uncommon to find children with conductive hearing loss (due to MEE) in this context. Thus, given the characteristics of our participants and our assessment goals, tympanometry was a better choice than OAE. If feasible, we would have implemented a protocol combining the two measures. For further information on infant hearing screening, see Musiek and Rintelmann (1999). Implementing infant hearing screening within a research protocol can be useful. However, given the technical and ethical considerations involved, it is advisable to consult with an audiologist with expertise in pediatric assessment.

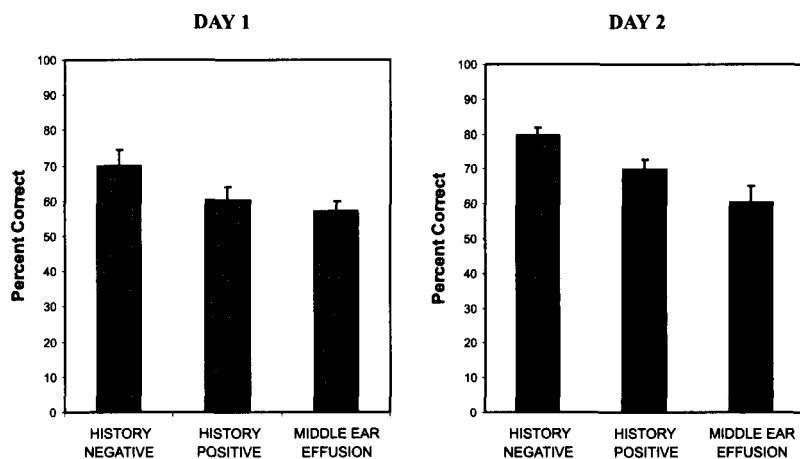


FIGURE 1 Mean percentage of correct responses for the history-positive, history-negative, and middle ear effusion groups. Day 1 performance is plotted on the left, and Day 2 is plotted on the right. Error bars represent standard error.

versus 57% (MEE). Nevertheless, the infants who returned for Day 2 showed the same pattern of group differences in Day 1 performance as was observed when all infants tested on Day 1 were analyzed. Although considerable power is lost by considering the subset of participants who completed both days, a one-way ANOVA and associated planned comparisons reveal the same pattern of results for this subset in comparison with Day 1 performance for all participants [main effect of group $F(2, 27) = 3.45$, $p = .046$; history-negative > MEE, $p = .01$].

Day 2

The means and standard errors of the percentage correct scores are illustrated in Figure 1 (right panel). The group means (and standard deviations) for percentage correct responses were 80% ($SD = 7\%$), 70% ($SD = 9\%$), and 61% ($SD = 14\%$) for the history-negative, history-positive, and MEE groups, respectively. A one-way ANOVA revealed that these between-group differences in percentage correct responses on Day 2 were statistically significant, $F(2, 27) = 8.19$, $p = .002$, with a large effect size (partial $\eta^2 = .378$). Planned comparisons revealed that the history-negative group performed better than the history-positive ($p = .043$) and the MEE ($p = .001$) groups. The difference between the history-positive and MEE groups approached statistical significance ($p = .059$). To ensure that the findings were not due to differences in response bias across the groups, the one-way ANOVA and planned comparisons were repeated using the number of hits minus

the number of false alarms as the dependent variable. This ANOVA yielded the same pattern of results, except that the difference between the history-positive and the MEE groups was statistically significant ($p < .032$) in this analysis.

To examine performance across Days 1 and 2, we also computed the means and standard deviations for each group of infants. For this comparison we included only those infants who completed testing on both days, and we also removed the 4 infants whose middle ear status changed from Day 1 to Day 2 (see footnote 1). For the remaining 26 infants, the mean percentage correct was 77% ($SD = 8\%$) on Day 1 and 80% ($SD = 7\%$) on Day 2 for the history-negative group, 71% ($SD = 8\%$) on Day 1 and 73% ($SD = 9\%$) on Day 2 for the history-positive group, and 64% ($SD = 18\%$) on Day 1 and 57% ($SD = 16\%$) on Day 2 for the MEE group. However, t tests comparing performance across days within each group failed to reach statistical significance. Hence there was no evidence of a significant change in performance across days in any of the infant groups. It is interesting to note that standard deviations for the history-negative and history-positive groups are similar and lower compared to the MEE group.

DISCUSSION

These findings confirm that accuracy in a phonetic perception task, measured using a standard infant test paradigm, is poorer in infants with MEE. The findings also suggest that the negative effect of OME on infant phonetic perception persists after the middle ear fluid has cleared. As expected, on both test days, infants in the history-negative group performed better in a phonetic discrimination task compared to infants with middle ear fluid present. The history-negative infants also performed better than infants with a prior history of OME but normal middle ear function on the day of testing. This difference approached a statistically significant level on Day 1 and was statistically significant on Day 2.

The effect of OME on infant phonetic perception observed in this study probably underestimates the impact on speech processing in the everyday life of an infant for two reasons. First, in this study we used a test procedure in which conditioning and explicit reinforcement were used to actively teach the infant to attend to the relevant difference within a stimulus set. Outside the laboratory, the infant must learn to attend to the relevant phonetic patterns without explicit training and reinforcement. Although this procedure optimizes infant performance, it probably overestimates how well an infant responds in a more natural listening situation. For this reason, it will be insightful to examine effects of OME in other perceptual tasks, including ones that are more comparable to a natural listening situation.

The effects reported in this study may also underestimate the impact of OME on infant perception outside the lab because of the participant selection procedures that were used. Although we report data from infants with MEE as well as infants

with a prior history of OME, our data set included only infants who were able to participate in the head turn task by passing an initial conditioning criterion. Thus, we excluded infants who were too irritable or severely effected by the OME experience to perform the basic perceptual task. In fact, some infants in the MEE group were discovered in the course of our study. That is, in addition to showing no other symptoms of OME, their parents and the experimenters were unaware of the child's middle ear status until the tympanometric evaluation was completed.

Finding that the performance of infants with MEE was poorer compared to the history-negative infants was expected given previous research documenting the effects of MEE on audibility of speech signals in infants. The effect of OME on audibility is temporary and is often considered unproblematic unless the infant spends extended periods with MEE. However, our findings suggest that OME has a negative effect on phonetic perception that lasts beyond the effusion period. Thus, unlike audibility effects, effects of OME on perception may persist for some time after the resolution of the MEE. *This finding suggests that the ability to process speech and to begin learning the sound structure of their native language is compromised in infants who experience OME in the first year of life unless other factors in the infant's experience, such as caregiver responsiveness, act to counter this effect.*

There is substantial controversy about the persistence, clinical significance, and causes of slower language development in groups of children with histories of early-onset OME. Further studies of this type, in which the direct effects of OME on early speech processing are explored, may contribute to a resolution of these controversies. We are continuing to explore this relation between early-onset OME and speech processing in a longitudinal study designed to examine the impact of OME on infant phonetic perception and production skills using a more rigorous and detailed assessment of OME history. In this study, we assigned infants to history-positive and history-negative groups based on whether or not they had been medically diagnosed and treated for an ear infection. We are confident that parental recall of this is highly reliable given that it is a recent and distressing event in their lives. Thus, our history-positive group is unlikely to include infants with no OME experience. Nevertheless, this method for establishing history-positive and history-negative groups is not optimal. It is possible that some infants who experienced asymptomatic effusion were included in the history-negative group, although the prevalence of asymptomatic effusion in infancy is presently unknown. Moreover, the medical diagnosis of ear infections in infants is complex and the rate of misdiagnosis is unknown due to difficulties involved in obtaining a standard for assessing diagnostic accuracy in young infants. Therefore, it is difficult to estimate the rate of misassignment to history-positive and history-negative groups that may have occurred in the study. For this reason these findings suggesting an effect of OME history must be interpreted cautiously. This issue clearly deserves further exploration.

Our findings also have methodological implications for infancy researchers studying audition or speech perception. We found that screening infants using information obtained from parents does not effectively exclude all infants with MEE. Moreover, infants with effusion can pass minimal conditioning criteria that are often used in the VRCHT procedure. Thus, effects of OME on infant phonetic perception measures are not fully controlled unless objective measures such as tympanometry are implemented to screen out babies with MEE. The value of objective screening for middle ear fluid when measuring how infants respond to speech signals presented at suprathreshold sound levels will depend on the researcher's goal. If it is important to obtain optimized measures of infant performance, then objective screening for middle ear fluid is beneficial. If the objective is to measure how infants typically respond, then screening infants who are able to participate in an experimental task may not be warranted. At present, the magnitude of the gap between typical and optimal speech perception and how much it varies with stimulus and task conditions is not known. It is clear, however, that this knowledge is critical for advancing our understanding of the role of input in infant speech perception development.

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