THE EFFECTS OF OTITIS MEDIA ON PHONOLOGICAL AND MORPHOLOGICAL PERCEPTION IN YOUNG CHILDREN

by

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Abstract

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The purpose of this prospective cohort investigation was to examine the effects of otitis media (OM) and its associated fluctuating conductive hearing loss on phonological and morphological perception in 2-year-olds.

It was hypothesized that experience with an inconsistent speech signal associated with the transient fluctuating hearing loss, as a result of OM, would have a negative effect on phonological and morphological perception. It was predicted that children free of OM (OM-) would make all target distinctions and their performance would be better than that in otitis positive (OM+) children. It was further predicted that for OM+ children morphological perception would be harder than phonological, because the former category carries additional linguistic load (e.g., plurality).

Sixteen children ages 26-28 months (M = 26.5, SD = .6) were divided into two groups, OM- (n = 8) and OM+ (n = 8) based on OM history in the first year on life. OM documentation was based on tympanometry, pneumatic otoscopy, and behavioral audiometry. OM- children were free of the disease for 4/5 visits and their PTA was 12.6 dB HL (SD = 4.8). OM+ children were positive for 3/5 visits and their PTA was 23 dB HL (SD = 2.7).

Stimuli included six monosyllabic novel word-pairs, three phonological and three morphological. Members of each pair were assigned to unfamiliar objects and differed only in the presence of final voiced or voiceless fricative (e.g.,[di]/[diz],[gɔ]/[gɔs]). Subjects were taught the unfamiliar words during fast mapping procedures. A bimodal preferential looking paradigm was used to test perception.

Experience with OM during the first year of life had a negative impact on phonological perception and a greater effect on morphological perception. OM- children performed significantly better than OM+ children on both phonological and morphological contrasts. Furthermore, results from individual word-pair analysis showed that OM+ children performed more poorly than OM- children on one phonological and two morphological targets, all ending with [s]. The two groups were not significantly different on final [z] targets. Within OM+ group, paired comparisons among word-pairs revealed that perception of morphological {-s} was more difficult than perception of phonological [s]. The results were examined in terms of a synergistic relationship between the low acoustic and the high linguistic weight of [s].

To my parents Christakis and Loulla, and to their grandchildren Kyriakos, Zoē, and Alexandra.

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Table of contents

Page

ABSTRACT.......... iv

ACKNOWLEDGMENTS.......... vii

LIST OF TABLES.......... xiii

LIST OF FIGURES.......... xiv

LIST OF APPENDIXES.......... xvii

CHAPTER 1 : INTRODUCTION.......... 1

Audiometric profiles of children with otitis media 2

The linguistic sequelae of otitis media 3

General language profiles of OM children 4

Speech production.......... 8

Speech perception.......... 8

Acquisition of morphological markers.......... 10

Morphological development in OM children..........10

Morphological development in normally developing children..........12

Research questions..........14

CHAPTER 2 : METHODS..........18

Subjects..........18

Subject selection criteria..........18

Parental language information.......... 18

Otitis media documentation.......... 21

Stimuli.......... 24

Phonological appropriateness of stimuli.......... 25

Editing of stimuli........ 25

Vowel duration........ 26

Total Word duration........ 26

Procedures........ 31

Fast mapping........ 31

Speech perception paradigm........ 32

Presentation of stimuli........ 34

Data reduction........ 34

Scoring of eye-gaze........ 34

Scoring reliability........ 34

Comparison of audio versus silent trials........ 35

CHAPTER 3 : RESULTS........ 38

Results based on first year OM history........ 38

Comparison of correct versus incorrect looking time in OM- and OM+ children (absolute values)........ 38

Comparison of OM- and OM+ groups on proportion correct looking time (relative values)........ 46

Comparison of OM- and OM+ groups on proportion correct looking time for each word pair........ 49

Results based on selective perception of final fricative..... 55

Results based on first and second year OM history........ 60

Subgroup 1........ 60

Subgroup 2........ 61

Subgroup 3........ 61

Subgroup performance on individual word-pairs........ 62

CHAPTER 4 : DISCUSSION 65

Group performance based on first year OM history 66

Perceptual distinction abilities in OM- and OM+ children based on correct versus incorrect looking time (absolute values) 66

Perceptual distinction abilities in OM- and OM+ children based on proportion correct looking time (relative values) 67

Performance of OM- and OM+ children on individual word pairs 69

Between group performance 69

Within group performance 70

Selective perception of final fricative word-pair members 73

Performance based on first and second year OM 73

General conclusion and directions for future research 74

Appendix A 77

Appendix B 78

Appendix C 79

Appendix D 80

Appendix E 81

Appendix F 82

Appendix G 83

Appendix H 84

Appendix I 85

References 86

List of tables

Table		Page
1	Subject Information	20
2	First year OM history	22
3	Word pairs and their corresponding unfamiliar object referents	27
4	Means and standard deviations for correct, incorrect, and inattention responses (absolute values)	40
5	Means and standard deviations for proportion correct looking time for phonological and morphological contrasts (relative values)	47
6	Means and standard deviations for proportion correct looking time on individual word pairs in study groups	50
7	F ratios and p values for paired comparisons between and within groups for phonological and morphological word-pairs	53
8	Means and SD for proportion correct looking time for selective perception of no final and final fricative members within word-pairs in OM- and OM+ groups	56
9	F ratios and p values for within group paired comparisons on selective perception of no final and final fricative members within word-pairs	57
10	F ratios and p values for between-group paired comparisons on final fricative members within a word-pair	57
11	Subgroup OM history based on first and second year of life	63
12	Performance of each subgroup on all word-pairs	63

List of figures

Figure		Page
1a	Average hearing thresholds in OM- and OM+ groups during the first year of life	23
1b	Number of visits free of OM in the two groups during the first year of life	23
2 a	Waveform display of word stimulus [teɪz]	28
2 b	Waveform display of word stimulus [teɪ] matched to [teɪz] for word duration	29
2 c	Waveform display of word stimulus [teɪ] matched to [teɪz] for vowel duration	30
3	Schematic representation of the visual perception paradigm	36
4	Description of experimental trial events during perception experiments	37
5	OM X EYE-GAZE interaction for correct versus incorrect looking time in OM- and OM+ groups (absolute values)	41
6a	Correct versus incorrect looking time in OM- on phonological and morphological contrasts (absolute values)	43
6b	Correct versus incorrect looking time for OM+ on phonological and morphological contrasts (absolute values)	43
7a	Duration of looking time for correct, incorrect, and inattention responses in OM- for phonological and morphological contrasts (absolute values)	45

Figure		Page
7b	Duration of looking time for correct, incorrect, and inattention responses in OM+ for phonological and morphological contrasts (absolute values)	45
8	OM main effect for proportion correct looking time	48
9	Proportion correct looking time for phonological and morphological contrasts in OM- and OM+ groups	48
10	Proportion correct looking time for OM- and OM+ groups on all word-pairs	51
11	Proportion correct looking time in OM- and OM+ groups on all word-pairs plotted by session	51
12a	Paired comparisons for proportion correct looking time on all word-pairs within OM- group	54
12b	Paired comparisons for proportion correct looking time on all word-pairs within OM+ group	54
13a	Proportion correct looking time for selective perception of no final and final fricative members of target word-pairs for OM- group	58
13b	Proportion correct looking time for selective perception of no final and final fricative members of target word-pairs for OM+ group	58
14	Proportion correct looking time for selective perception of final fricative members of target word-pairs for OM- and OM+ group	59
15a	Proportion correct looking time in the three subgroups for	

phonological and morphological contrasts 64

Figure | Page

15b Proportion correct looking time on phonological and morphological contrasts for the three subgroups on individual word-pairs 64

Appendixes

Appendix		Page
A	Individual subject's OM history information during the first and second year of life	77
B	Acoustic analysis information for all experimental words	78
C	Speech perception presentation sequence for [gɔ]/[gɔs]	79
D	Speech perception presentation sequence for [bok]/[boks]	80
E	Speech perception presentation sequence for [dæp]/[dæps]	81
F	Speech perception presentation sequence for [teɪ]/[teɪz]	82
G	Speech perception presentation sequence for [pʌk][pʌks]	83
H	Speech perception presentation sequence for [di]/[diz]	84
I	Means and standard deviations for proportion correct looking time for every subject on individual word-pairs	85

Chapter 1: Introduction

Otitis media (hereafter referred to as OM) is one of the most common infectious diseases affecting infants and young children. It is usually accompanied by mild to moderate fluctuating conductive hearing loss. If, during the formative years for language development, the child experiences language input through an inconsistent and degraded speech signal, a linguistic deficit could be a logical outcome. Fluctuating hearing sensitivity might affect the child's ability to perceive frequencies of speech sounds that carry linguistic information (e.g., the frication of {-s} for plurals).

There is an extensive body of research that has attempted to establish a causal link between OM and language deficits. The results from these investigations are contradictory and inconclusive. This is due, in part, to methodological issues, including the failure to report audiometric profiles of subjects, the reliance on standardized batteries to measure language outcomes, and the focus on older (e.g., nine-year-old) children. Thus, a causal relationship between OM and language deficits remains undetermined and many questions remain unanswered. Does OM, when accompanied by a hearing loss, have a negative impact on language development? If it does, what is the impact on specific language domains such as phonology and morphology?

Currently, there is limited information concerning the effects of OM on morphological development, specifically on the comprehension of morphological inflections in young children (e.g., two-year olds) with histories of OM. Morphological inflections are of particular interest because they constitute a class of linguistic elements characterized by weak stress, short duration, and low intensity. Logically, in the presence of a fluctuating conductive hearing loss associated with OM, morphological inflections could be misperceived. The current investigation examined the effects of OM on the comprehension of word final [s] and [z] in phonological and morphophonological contrasts. This was a prospective cohort investigation and included young children with documented OM histories based on frequent tympanometric, otoscopic, and audiometric examinations.

Audiometric profiles of children with otitis media

OM is an umbrella term used to define the presence of inflammation in the middle ear. Subtypes of the disease depend on the condition of the middle ear cavity, the presence of fluid and infection, the mobility of the tympanic membrane, as well as on the frequency and duration of the episode (Silman & Silverman, 1991; Northen & Downs, 1984). Otitis media with effusion (hereafter referred to as OME) refers to the presence of fluid in the middle ear space (Bluestone, 1983; Scheid & Kavanagh, 1986). This fluid may persist for weeks or months (Teele, Klein, & Rosner, 1980). According to epidemiological surveys, OM is one of the most common childhood infectious diseases affecting 75% to 95% of the pediatric population (Klein, 1983). The peak of most episodes occurs between 6 to 18 months (Howie, 1977; Ronald, Finitzo, Friel-Patti, Clinton-Brown, Stephens, et al., 1982; Teele, Klein, Rosner, & The Greater Boston Otitis Media Study Group, 1984), declines after the age of three years, and reaches a plateau during the elementary years (Menyuk, 1986).

Most children with OM experience some degree of mild to moderate fluctuating conductive hearing loss. Bess (1983) estimated that 26% to 55% of children with OM have mild to moderate losses in the speech frequencies. The hearing loss is predominantly flat with a peak in threshold sensitivity at 2000 Hz. This particular audiometric configuration may interfere with the perception of F2 transitions which are important acoustic cues to place of articulation. The degree of the loss varies and can range from levels of normal sensitivity to hearing losses as great as 50 dB HL. In combining data from a number of investigations, Bess (1986) illustrated the distribution of hearing loss within the speech frequencies (500, 1000, 2000 Hz) in 627 ears with effusion. Accordingly, 70% of the ears exhibited losses between 16 and 40 dB HL. Within this range 50% of the affected ears exhibited losses between 21 and 30 dB HL. Fria, Cantekin, & Eichler (1985) reported similar values with 50% of ears with effusion having pure tone average (PTA) thresholds poorer than 23 dB HL and 20% poorer than 35 dB HL.

In summary, large numbers of children who experience episodes of OM, have a mild to moderate fluctuating conductive hearing loss occurring during the critical years for language development. The high incidence of OM and its associated hearing loss early in life have become the impetus for many investigations of the effects of the disease on different linguistic parameters.

The linguistic sequelae of otitis media

The research question posed by many investigators has focused on a possible causal relationship between the fluctuating hearing loss during the formative years of life and the adverse developmental outcomes reported in otitis positive children (hereafter referred to as OM+). The existence of such a relationship remains controversial, because of differences in methodology, design, and results (see Paradise, 1981 and Ventry, 1980 for a critical review). One limitation is that most of the studies have been retrospective in design, a factor that poses threats to internal and external validity. In addition, the definition and diagnosis of OM have varied significantly from study to study. By necessity, retrospective investigations have omitted audiometric information of the ears affected during each episode. In documenting OM, the primary sources of information have included doctor's medical records in combination with parental reports. Both sources have proved to be highly unreliable.

In studying the language profiles of otitis positive and otitis negative children (hereafter referred to as OM-), investigators have been concerned with areas including general language outcomes, phonological acquisition, and speech perception (e.g., discrimination and identification of stimuli differing in voicing dimensions; phonemic awareness involving fricatives). Morphological development has received minimal attention. In testing the effects of OM on production and comprehension of morphological inflections, researchers have used general measures (e.g., standardized tests), examined older children, and omitted audiometric information. Therefore, the effects of the disease on morphological and phonological perception in developmentally young children are currently not known. This section presents a literature review on the language profiles of children with histories of OM, and focuses on the impact the disease may have on phonological and morphological perception.

General language profiles of children with OM. The research today on the linguistic profiles of OM+ children has yielded a confusing picture. Several studies have reported comprehension and production problems in OM+ children (Friel-Patti & Finitzo, 1990; Holm & Kunze, 1969; Teele, Klein, Rosner, & the Greater Boston Otitis Media Study Group, 1984; Teele, Klein, Chase, Menyuk, Rosner, & the Greater Boston Otitis Media Study Group, 1990). Others have reported no significant deficits on either comprehension or on production (Grievink, Peters, van Bon, & Scheilder, 1993; Roberts, Burchinal, Davis, Collier, & Henderson, 1991; Wright, Sell, McConnell, Sitton, et al., 1988). More puzzling are the results from studies reporting production, but not comprehension problems (Wallace, Gravel, McCarton, & Ruben, 1988a; Wallace, Gravel, McCarton, Stapells, Bernstein, & Ruben, 1988b; Menyuk, 1986). These equivocal results may be attributed to issues such as the degree of hearing loss associated with each OM episode, the chronological age of children studied, and the methods used in examining speech and language outcomes.

It remains controversial whether OM has a negative impact on linguistic development. Menyuk (1986) discussed two opposing positions regarding an association between OM and linguistic outcomes. One view holds that OM does not have any immediate or persistent impact on language development. This framework relies on the fact that children usually experience only mild to moderate hearing losses and that their hearing thresholds return to normal after an OM episode. Consequently, the linguistic input available to children between episodes should enable them to overcome any limitations imposed by fluctuating conductive hearing loss .

The other view is that OM does have an effect on language development. This position is based on the assumption that a fluctuating hearing loss during the early years of life presents the child with an inconsistent and degraded speech signal. Consequently, experience with an unsTable speech signal may inhibit the normal course of language development.

In supporting the former view, a number of investigators have reported no adverse speech and language outcomes in children with histories of OM (Black, Gerson, Freeland, Nair, Rubin, & Hutchison, 1988; Grievink et al., 1993; Roberts et al., 1991). The focus has been on the language skills of infants and preschoolers (Black et al., 1988; Roberts et al., 1991), and of school-age children (Grievink et al., 1993). Areas addressed included comprehension and production of vocabulary items (Black et al., 1988), of morphological and of phonological distinctions (Grievink et al., 1993), as well as of syntactic forms and of word classes (Roberts et al., 1991). The results challenge the hypothesized relationship between OM and language development. However, if the hypothesis is that language problems, as a result of OM, are attribuTable to the presence of a fluctuating hearing loss, the absence of audiometric data is troublesome. OM is not always accompanied by hearing loss. During an OM episode, hearing thresholds may range from levels of normal sensitivity to losses as great as 50 dB HL (Bess, 1983; Bluestone, Beery, & Paradise, 1973; Fria et al., 1985). Thus, in the absence of audiometic data, evidence for a causal relationship between the conductive hearing loss associated with OM and language deficits remains inconclusive.

In support of the latter framework, a series of prospective and retrospective investigations have provided converging evidence of the linguistic and academic deficits in children with histories of OM. The strong claim is that the association between OM and language problems is mediated by the fluctuating conductive hearing loss. That is, OM as a disorder (when accompanied by a hearing loss) is responsible for diminished language skills in OM+ children. Investigators have reported adverse outcomes in receptive and expressive language abilities (Feagans, Kipp, & Blood, 1994; Feagans, Sanyal, Henderson, Collier, & Applebaum, 1987; Friel-Patti & Finitzo, 1990; Holm & Kunze, 1969; Teele et al., 1990; Teele et al., 1984; Wallace et al., 1988a), in phonological acquisition (Needleman, 1977; Paden, Novak, & Beiter, 1987; Roberts, Burchinal, Koch, Footo, & Henderson, 1988), and in speech perception (Eimas & Clarkson, 1986; Groenen, Crul, Maassen, & van Bon, 1996; Nittrouer, 1996). A retrospective study revealed that older children with histories of OM associated with a moderate conductive hearing loss (> 20 dB HL), exhibited persistent receptive and expressive language problems (Holm & Kunze, 1969). Specifically, subjects exhibited deficits in expressive and receptive vocabulary acquisition, in speech sound production, and in syntax. In a series of cohort prospective studies, three-year-olds who experienced prolonged periods with OM during the first year of life (more than 60 days with effusion), had lower scores on tests than children who spent less time with the disease (no more than 20 days with effusion) (Teele et al., 1990; 1984). Early onset of OM (e.g., during the first and second year of life) appeared to affect language development at seven years of age. Language problems included depressed scores on lexical production, but not on comprehension; deficits in the production of morphological endings, but not in comprehension; production errors on sibilants (e.g., [s] and [z]); and perception errors on voiced-voiceless stops in all positions. Production-comprehension asymmetry has also been reported in the language profiles of one-year-olds with documented bilateral OM (Wallace et al., 1988a; 1988b). Expressive and receptive language profiles were measured with a standardized test. The authors reported positive correlation between the percentage of time children experienced bilateral episodes of OM and expressive language outcomes. No significant differences were found between OM- and OM+ groups in receptive language scores. Others though (Friel-Patti & Finitzo, 1990) have suggested that duration of an OM episode and the hearing loss (>20 dB HL) experienced by infants during the first year of life , were associated with depressed scores on the receptive scale of the Sequenced Inventory of Communicative Development Test-Revised (SICD-R) (Hedrick, Prather, & Tobin, 1984). Friel-Patti & Finitzo (1990) reported receptive and expressive problems when children were assessed with the same instrument at 24 months of age.

Despite the fact that some investigators do report audiometric data of the study populations, the general picture with regard to the language profiles of OM+ children remains confusing. The discrepancies across studies are difficult to resolve because of differences in the diagnosis and documentation of OM, in the omission of audiometric data, and in the methods used to test language. One critical limitation in testing language outcomes is the reliance on standardized tests. The use of standardized tests in measuring language outcomes in OM+ children is, unfortunately, a common characteristic of many investigations. Such tests typically include only a small number of items that test a specific language parameter (e.g., production or comprehension of plurals). The scoring system of standardized tests is also limited psychometrically. The scores reported may either underestimate or overestimate the child's linguistic ability. For example a single item on the Preschool Language Scale-3 (PLS-3) (Zimmerman, Steiner, & Evatt-Pond, 1992) yields a standard score that, when translated into its corresponding age-equivalent score, makes a six-month difference. If a child misses a single target item within a developmental section on the test, she falls six months behind on the age-equivalent score. Consequently, standardized batteries may not be sensitive to the subtle effects OM may have on speech production or perception. Morphological and phonological perception and production are areas that have not been fully explored. Thus, any focal deficits of OM on phonological and morphological parameters warrant further investigation.

Speech production. One area that has received a great deal of attention is phonological acquisition. Investigators have focused on consonant errors in the speech of children with histories of otitis media. The results are mixed because of diversity in the design, in data collection and in data analyses. Researchers have typically used standardized tests in which error analyses were based on single-word productions. Relevant to the current study are the results from investigations reporting substitutions and omissions of fricative sounds in single words (Needleman, 1977), omission of postvocalic obstruents by three-year-olds with histories of OM (Paden, Novak, & Beiter, 1987), and persistent final consonant deletion by four-year-olds (Roberts, et al., 1988).

Speech perception. Only a few investigations to date have examined the speech perception skills of children with histories of OM. One study compared speech perception skills of 7-year-old children with different duration of middle ear effusion (Menyuk, 1986). On the Goldman-Fristoe-Woodcock Test of Auditory Discrimination (GFW)(Goldman, Fristoe, & Woodcock, 1974), children in the "higher effusion" group (> 130 days with effusion in the first three years of life) made more errors on speech contrasts involving voiced-voiceless stops and fricatives, when compared to their lower effusion counterparts (< 30 days with effusion). The second investigation demonstrated that six-year-olds with histories of OM (at least 9 episodes during the first three years of life) had difficulty discriminating synthetic ([da] versus [ta]) and natural stimuli (bath versus path) differing in voicing dimensions (Eimas & Clarkson, 1986). Specifically, OM+ subjects were less consistent in assigning the stimuli to their respective phonetic contrasts on the bases of voice onset time (VOT), required longer VOT intervals before perceiving a change in voicing, and had lower levels of discrimination when compared to their counterparts with no significant histories of OM (only 2 episodes during the first three years of life). The authors suggested that recurrent OM during the early years of life was responsible for perceptual difficulties at the phonetic and phonological level. A more recent study (Groenen et al., 1996) provided converging evidence concerning a negative impact OM may have on phonetic processing skills. This investigation included 9-year-old Dutch children with severe histories of OM between ages two to four years. OM+ subjects had difficulties in the identification and discrimination of word-pairs (e.g., [bak] vs. [pak]) varying in the dimensions of VOT as well as in duration and amplitude of the stop burst. The subjects' difficulty with phonetic categorization tasks might have been the result of auditory deprivation resulting from frequent episodes of OM. The findings by Groenen et al. (1996) support the results from Eimas & Clarkson (1986) and suggest that the effects of OM on phonological perception may persist later in life (e.g., at nine years of age). Nine-year-olds with OM histories during the first three years of life were also observed to perform more poorly than their OM- counterparts on phonemic awareness and perceptual labeling tasks involving fricatives (Nittrouer, 1996). During the phonemic awareness tasks, OM+ subjects had difficulties with removing a specified segment from a nonsense word, in order to make a real word (e.g., "Say [k a u t] without the [t]."). In addition, OM+ subjects had difficulties discriminating initial [s] and [ʃ] segments. Nittrouer's investigation supports the presence of a perceptually based limitation, a result that can be attributed to insufficient and unstable linguistic experience as a result of OM. However, it is unclear whether this perceptual limitation could be attributed to raised hearing thresholds associated with OM. Within the OM+ group, subject responses formed a bimodal distribution. Some OM+ children performed equally well when compared to their OM- counterparts. It is not known whether the OM+ subgroup had normal hearing thresholds, despite recurrent episodes of OM.

Although there is converging evidence that OM may have a negative effect on speech perception involving stop or fricative segments, in the absence of audiometric data such a causal relationship cannot be proven. Investigators need to take into account the issue of raised auditory threshold associated with the disease and its effect on speech perception.

If OM, as a disorder, does have a persistent negative effect on speech, the onset of this impact needs further investigation. If the negative impact of OM takes effect early in life (i.e., at 12 months of age), one could argue that language development will also be affected. Difficulties at either the phonetic or phonological level may prevent the effective and efficient encoding of categorical contrasts, and later, can interfere with the child's ability to hypothesize phonological and morphophonological rules. Dobie & Berlin (1979) suggested a possible causal link between the conductive hearing loss associated with OM and the misperception of sentences by adult listeners in a simulated conductive hearing loss condition (i.e., a filtered signal resembling a 20 dB HL hearing loss). To date, there are no investigations of speech perception in young children who experience OM associated with a fluctuating hearing loss. Few studies that have examined phonological and morphological skills in OM+ populations, have included only older children. Furthermore, investigations have not tested perception systematically. Finally, production data have been used in making inferences about perception (see the following section).

Acquisition of morphological markers

Morphological development in children with otitis media

Although researchers have suggested that morphological endings may be vulnerable to OM (Dobie & Berlin, 1979; Menyuk, 1986), investigations on this topic have been scarce. Seven-year-olds with positive histories of OM during the first three years of life exhibited problems in the use of morphological markers (Teele et al., 1990). OM during the second and third years of life accounted for the differences seen between the children in the high effusion group versus those in the low effusion group. Morphological ability was assessed with the WUG test (Berko, 1958). Children were presented with the carrier phrase: " This is one wug. Here you have two wug-s.". No problems were reported in perceiving the targets, although children omitted morphological inflections for plural and possessive {-s}, and for regular past tense {-ed}. Another retrospective study examined the comprehension of morphological markers in two groups of 6-year-olds differing in their OM histories during the first three years of life (Weber, 1982). OM documentation was based on medical records, tympanometric data, and otologic examinations. OM+ subjects had suffered more than 6 episodes; OM- had suffered no more than two episodes. The testing paradigm included the comprehension of marked and unmarked verb tenses at three presentation levels: 65, 50, 35 dBA. The dependent variable was the number of correct repetitions produced by the subjects when prompted by items (e.g., skip-skips-skipped) presented over loud speakers. When compared to their OM- counterparts, OM+ children had difficulties repeating verbs marked for third person singular and regular past tense. This difference in performance between the two groups was seen only when stimuli were presented at 35 dBA. The author suggested that children's difficulties in repeating the target items was attributable to perceptual difficulties caused by OM.

Overall, the results from these investigations suggest a specific effect of OM on morphological skills. Because the investigations did not provide audiometric data, the influence of the fluctuating hearing loss remains undetermined. Another issue concerns the paradigms used by investigators to test comprehension; the value of the interpretability of the data is limited by the fact that inferences about perception were based on production data. When children produce targets accurately, it is safe to assume that they have perceived the target accurately. However, when productions are inaccurate, it is impossible to determine whether the source of the error is in production or in perception.

Morphological development in normally developing children

Given the possible effects of OM on morphological inflections (Teele et al., 1990; Menyuk, 1986; Weber, 1982), it is important to determine how early in life any influence of the disease begins to take place. In the normal course of language development children appear to produce morphological markers around their second birthday. Although children are variable in the development of the production of morphological markers, there is generally a common sequence in the order of acquisition (Brown, 1973; deVilliers & deVilliers, 1973; Cazden, 1968). By four years of age, children have an internalized knowledge of morphological rules (Brown, 1973). Although children of comparable chronological age may be at different stages of mean length of utterance (MLU), there is a remarkable amount of invariance in the order of morpheme acquisition. Stable production of a morpheme is assumed when children produce a target inflection 90% of the time in obligatory contexts. The development of a morphological inflection takes as long as one year from its first appearance until it reaches stable production (Cazden, 1968). According to Brown (1973), the plural marker ranks 4th in the developmental order, when children are between MLU stage II-III around 26 months of age. Recently, Lahey and her colleagues (Lahey, Liebergott, Chesnic, Menyuk, & Adams 1992) reported on the variability of morphological development. Proportional use of plurals within a language sample of 100 consecutive utterances ranged from 0-1.00 at 25 months, .33-1.00 at 29 months, and .82-1.00 at 35 months in language samples obtained from 42 normally developing children. The most stable production of plurals in spontaneous speech (.50-1.00) appeared when children were MLU stages II or III, between ages 24 to 36 months.

Two more recent studies have examined the development of plural markers in children with specific language impairment (SLI) (Oetting & Rice, 1993), and in children with slow expressive language development (Paul & Alforde, 1993). Both studies compared the production of morphological inflections of two groups of 4-year-old language impaired and normal children. Normal and language-impaired children consistently produced plural markers with 90% accuracy in obligatory contexts. The absence of group differences may be attributed to the advanced age of the subjects; they may have differed during earlier stages of acquisition. The typical or atypical development of morphological inflections (e.g., plural {-s}), might have been more profitably examined in children who are at the threshold of morphological acquisition (i.e., two-year-olds).

How do children succeed in forming linguistic rules? Pinker's learnability theory (Pinker, 1984), provides a theoretical account for the child's learning of morphological rules. According to Pinker, morphological inflections are represented as lexical entries in the form of linguistic equations (e.g., Subject/Number = singular/plural). Pinker proposed that children learn these equations by creating paradigms. Initially, a child creates word-specific paradigms which correspond to every new word learned through exposure to the ambient language. A word-specific paradigm contains the stem of the word and its affix (e.g., rock-s). This particular paradigm contributes to the development of general paradigms containing the inflections free of word stems. A linguistic rule is learned and internalized when the child is able to use the information in the general paradigm (e.g., the inflections) and apply it to new words. For example, in hypothesizing the linguistic rule for plurals in words such as rock versus rocks, the child must not only perceive [s], but also hypothesize it as a morphological marker {s} and place it in a word-specific paradigm. Consequently, the formation of linguistic rules (e.g., plurals) goes beyond the perception of an inflection as a mere phonological entity.

Although there is a plethora of information about the development of plural production by normal and language-impaired children, little is known about comprehension. The investigations leave unanswered a host of questions about the comprehension of morphological inflections in both normally developing children and in children with histories of otitis media. In studying children with specific language impairments (SLI), Leonard (1989) hypothesized that SLI children experience difficulties in producing, perceiving, and processing different morphological markers. Leonard argued that the selective problem these children have in producing morphological inflections is not in hypothesizing regularities about morphological aspects of the ambient language, but merely in perceiving and processing these features. A plausible explanation is related to the acoustic properties of morphological inflections: they are unstressed, and thus usually short in duration and low in intensity. These acoustic characteristics constitute some morphological markers as elements of "low phonetic substance." SLI children do not have difficulty differentiating pairs such as play and place, but do have difficulties with pairs such as rock and rocks. Although Leonard did not study children with otitis media, one can argue that a possible difficulty OM children may have with inflectional markers could be related to the low phonetic substance.

Research questions

The purpose of the present investigation was to examine the effects of OM and its associated fluctuating hearing loss on phonological and morphological perception in OM+ and OM- children during the first year of life.

The first hypothesis was that the OM- children would make all target distinctions (phonological and morphophonological contrasts), and their overall performance would be better than that of OM+ children. Consequently, OM+ children would have difficulty with the perception of target contrasts, and their overall performance would be worse than that of OM- children. This hypothesis was based on the premise that an attenuated and inconsistent speech signal associated with OM and the resulting fluctuating hearing loss during the critical years for language development, might have had a deleterious effect on children's speech perception.

The second hypothesis was that for the OM+ children the perception of morphological contrasts would be more difficult than phonological contrasts. This prediction was related to Pinker's learnability theory (Pinker, 1984) and Leonard's (1989) low phonetic substance hypothesis. The input speech signal children experience between episodes may be sufficient for the formation of phonological contrasts (e.g., play vs. place), but not sufficient for the formation of morphological contrasts such as plurals (e.g., discrimination between rock and rocks). This is because the formation of morphological rules is a higher order linguistic operation (e.g., the child needs not only to perceive [s] as a phonological unit, but also recognize it and categorize it as a plural marker {-s}). Furthermore, the perceptual salience of morphological inflections may be limited because of their low acoustic phonetic substance.

An additional source of prediction is the relationship between the hearing loss associated with OM and the acoustic characteristics of speech sounds. The focus of this investigation was on final fricatives which marked words phonologically (e.g., play vs. place) and morphologically (e.g., rock vs. rocks). Speech sounds have different intensity (power) and frequency spectra (Northen & Downs, 1984). In the case of mild to moderate conductive hearing loss, the signal is not only distorted, but is also attenuated. Thus, sounds which are the weakest in the speech spectrum may not be audible. In relation to an audiogram, the fricatives [f], [s] and [θ] display their least intense energy (15 dB HL) at 4000 Hz. The least intense energy (20 dB HL) for their voiced cognates [v], [z], and [ð] lies around 500 Hz. If normal conversational speech is around 60 dB SPL, the intensity of fricatives falls between 35 and 40 dB SPL (there is a 20 dB difference between HL and SPL scales), then children who experienced multiple episodes of otitis media accompanied with a mild to moderate conductive loss may later present with difficulties in the comprehension of morphological and phonological endings. The perceptual salience of fricatives is lessened when the child attempts to perceive these elements through a degraded and inconsistent speech signal. Consequently, OM+ children are likely to have difficulties in perceiving and forming representations of inflectional regularities in the speech stream.

This was a prospective cohort investigation that examined children between ages 2 and 2-1/2 years who were at the threshold of morphological development (Brown, 1973; deVilliers & deVilliers, 1973; Lahey et al., 1992). The study employed two testing methods, fast mapping and a speech perception paradigm. During fast mapping (e.g., Dollaghan, 1985), children were presented with novel word-pairs referring to unfamiliar objects. Novel words were taught during play activities between child and examiner. The novel objects were incorporated into the play theme.

In this study, perception of the word-pairs (e.g., fricative [s] in novel word contrasts [pʌk] versus [pʌks]) was tested using the visual perception paradigm. This procedure allowed the direct testing of the child's perceptual ability. Currently, there is a gap in the literature regarding speech perception abilities of children between 15 to 36 months. This is true for both normal and OM children. The primary reason for this gap is the lack of a paradigm suitable for testing phonological perception in children. Recently, researchers have successfully used an adaptation of the cross-modal visual perception paradigm (Kuhl & Meltzoff, 1982; Spelke, 1981) in testing phonological perception in young normal and language-impaired children (Schwartz, Davidson-Bryan, Petinou, Gerenser, & Castusciello, 1993; Golinkoff, Hirsh-Pasek, Caulet, & Gordon, 1986; Schwartz & Pollock 1983). Using this method, researchers have been successful in tapping into the child's perceptual representation for syntactical and semantic comprehension(Golinkoff et al., 1986) as well as phonological perception in children as young as 20 months (Schwartz et al., 1993; Schwartz & Pollock, 1983).

This investigation attempted to shed more light on the effects of OM on language development and to clarify some of the immediate impact of the disorder on the young child's ability to perceive final position fricatives in the form of phonological and morphophonological (plural markers) word-pairs.

Chapter 2 : Methods

Subjects

Subject selection criteria. Sixteen children, 7 boys and 9 girls, ranging in age from 26 to 28 months (M = 26.5, SD = .6), served as subjects. All children had been selected from a large cohort of subjects participating in an on-going clinical research project at Rose F. Kennedy Center of the Albert Einstein College of Medicine (AECOM) focusing on the effects of otitis media on language development. For this particular project, subject selection criteria included the child's chronological age, history of otitis media in the first year of life, and parental language input. Table 1 presents subject information including socioeconomic status, gender, chronological age at the time of the experiment, standard scores from the Preschool Language Scale-3 (PLS-3) (Zimmerman et al., 1992) administered at 24 months, mean length of utterance (MLU) based on a language sample collected at 24 months of age, and caregivers' standard score on the Peabody Picture Vocabulary Test-Revised (PPVT-R) (Dunn, & Dunn, 1981). MLU values for all children ranged from 1.2 to 3.5 (M = 1.7, SD = .6). No significant differences were seen in the average MLU values for OM- (M = 1.76, SD = .45) and OM+ groups (M = 1.82, SD = .77), $t(14) = -0.120$, $p > .05$. Standard scores from the PLS-3 ranged from 85 to 123 (M = 101, SD = 18.9) for auditory comprehension, and 85 to 127 (M = 103, SD = 14.3) for expressive communication. Four children came from bilingual homes (Spanish-English), and 12 came from monolingual English home environments (6 of the 12 children were African-American). None of the children had neurological or cognitive problems. From Table 1, subjects #1 through # 8 formed the OM- group, and # 9 through # 16 the OM+ group.

Parental language information. Because of the nature of this project, parental language input and exposure to a language other than English, were considered important factors in subject selection. As part of the on-going project, information about the child's exposure to a language other than English was collected over a number of visits (at 10, 12, 14, 18, and 24 months). Information was collected concerning the main language spoken at home, the television channel children watched most of the time, the amount of time (hours per week) children spent with a non-English speaking baby-sitter, and the language spoken by the child's siblings. Parental language samples were analyzed for grammatical and syntactical structure, as well as for the use of morphological markers (plurals, third person singular, present progressive, possessive and regular past tense). The use of morphological markers produced by caregivers was probed during a ten-minute informal conversation between the examiner and the caregiver. Parents also took the Peabody Picture Vocabulary Test - Revised (PPVT-R) (Dunn & Dunn, 1981) examining single-word receptive vocabulary, and the Goldman-Fristoe Test of Articulation (GFTA) (Goldman & Fristoe, 1986) examining articulation proficiency at the single word level. For a child to be included a caregiver's PPVT-R standard score had to be at least 70, production of plurals in obligatory contexts at least 90% of the time, correct production of target consonant sounds in all positions based on GFTA results, and production of final fricatives in phonological and morphophonological targets. For subjects from bilingual home environments, an additional criterion included the child's exposure to the non-English language (e.g., children spending time with a Spanish-speaking individual) of no more than 35 hours a week (less than 1/3 of waking hours). All 16 caregivers met the language proficiency criteria. On the GFTA, only two caregivers substituted [d] for [θ] (e.g., [dʌm] for [θʌm]), and [d] for [ð] (e.g., [dIs] for [ðIs]). On the PPVT-R, caregivers' standard scores ranged from 70 to 117 (M = 89.6, SD = 15.3). No significant differences were seen between PPVT-R scores for caregivers of OM- children (M = 89.3, SD = 14) and caregivers of OM+ children (M = 90, SD = 17.2), $t(14) = .225$, $p > .05$.

Table 1

Subject information

Subject	SES	Gender	Age (mos.)	PLS-3 Scores AC[a]	EC[b]	MLU	Caregiver's PPVT-R[c]
1	Mid	Girl	27	82	96	1.3	77
2	Mid	Girl	27	85	87	1.2	79
3	Mid	Boy	27	99	95	2.3	104
4	Mid	Boy	26	85	87	1.7	84
5	High	Girl	27	94	108	1.4	92
6	Mid	Girl	26	109	104	2.4	73
7	Mid	Girl	26	123	127	2.08	115
8	High	Girl	26	94	108	1.7	91
9	Mid	Girl	27	99	104	1.5	96
10	Mid	Boy	28	94	99	1.2	79
11	High	Boy	26	150	130	3.5	117
12	Low	Boy	27	80	85	1.5	75
13	Mid	Girl	26	120	120	2.4	109
14	Mid	Boy	27	85	87	1.7	77
15	High	Girl	26	116	116	1.6	97
16	Mid	Boy	26	113	95	1.2	70
M	—	—	26.5	101	103	1.7	9.6
SD	—	—	(.62)	(19)	(14)	(.6)	(15.3)

Note: SES = socioeconomic status; PLS-3 = Preschool Language Scale-3; AC = auditory comprehension; EC = expressive communication; MLU = mean length of utterance; PPVT-R = Peabody Picture Vocabulary Test-Revised.

[a] Auditory comprehension standard score.

[b] Expressive communication standard score.

[c] PPVT-R standard score.

Otitis media documentation. Children were divided into two groups, otitis media positive (OM+ ; n = 8), and otitis media negative (OM- ; n=8). The two groups were defined according to information documented by tympanometry and pneumatic otoscopy during the first year of life (maximum five visits at 2, 5, 7.5, 10, 12 months of age), as well as behavioral audiometry performed at 5, 7.5, 10, and 12 months of age.

The definition for the OM+ group included children who had the disease either bilaterally or unilaterally for at least 40% of the visits (2/5), according to tympanometric or otoscopic results, in combination with average hearing thresholds equal to or greater than 20 dB HL. The OM- group included children with normal middle ear status unilaterally or bilaterally for at least 80% of the visits (4/5) based on tympanometric or otoscopic results, in combination with average hearing thresholds equal to or less than 15 dB HL.

Based on the first year information, the OM+ children, as a group, had the disease for 52% of the visits (M = 2.6 visits, SD = .8). Their average hearing thresholds ranged from 20 to 27 dB HL (M = 23, SD = 2.7). The OM- group had normal middle ear status for 90% of the visits (M = 4.5 visits, SD = .5) with average hearing thresholds ranging from 5 to 20 dB HL (M = 12.6, SD = 4.8). Table 2 presents a summary of the OM information in the two groups based on first year data. One of the OM- children, subject #1, had average hearing thresholds of 20 dB HL. Consequently, her average hearing thresholds were 5 dB higher than the criterion set for inclusion in the study. This child was not excluded from the study for the following reasons: First audiometric information obtained during every visit in the first year, suggested that her elevated thresholds were the result of attention and motivation issues during behavioral audiometric testing. Second, on two occasions (7 and 12 month visits) when the child was more cooperative, average hearing thresholds were reported to be within normal limits (11 dB

HL). Third, based on tympanometric and otoscopic results, this child was free of OM on all visits during the first year, and ABR results at birth were within normal limits.

The difference in hearing thresholds (11.4 dB) between the OM+ and the OM- groups was statistically significant, $t(14) = 6.6$, $p < .05$. The OM- group had significantly lower thresholds than its OM+ counterpart. The difference in the number of visits on which children were free of OM was also statistically significant, $t(14) = 7.5$, $p < .05$. The OM- group was free of the disease for significantly more visits (4.5) when compared to its OM+ counterpart (2.4). Figure 1a and 1b show the means and standard deviations of hearing thresholds in the two groups and the mean percentage of visits subjects were free of OM respectively.

Table 2

First year otitis media information with standard deviations in parentheses

	Otitis Negative Mean	Otitis Positive Mean
Total number of visits	4.7 (.5)	5 (0)
Visits OM- (n)	4.5 (.5)*	2.4 (.3)*
Percentage of visits OM-[a]	90 (12)	48 (14)
Visits OM+ (n)	.5 (.1)	2.6 (.8)
Percentage of visits OM+[a]	10	52
Average Hearing Thresholds	12.6 (4.8) *	23 (2.7) *

*$p < .05$

Note:

[a] The percentage was computed by dividing the number of visits with OM- or OM+ by the total number of visits.

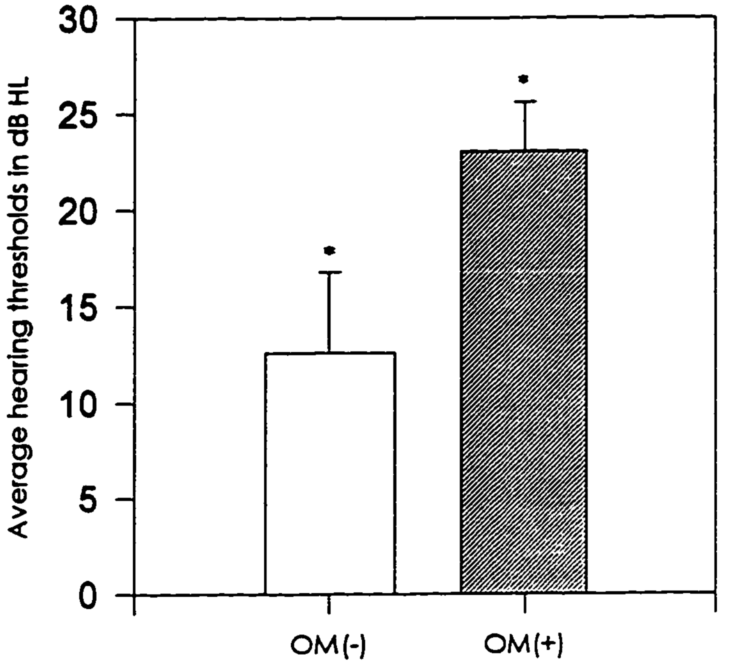

Figure 1a: Average hearing thresholds (year one)
* p < .05

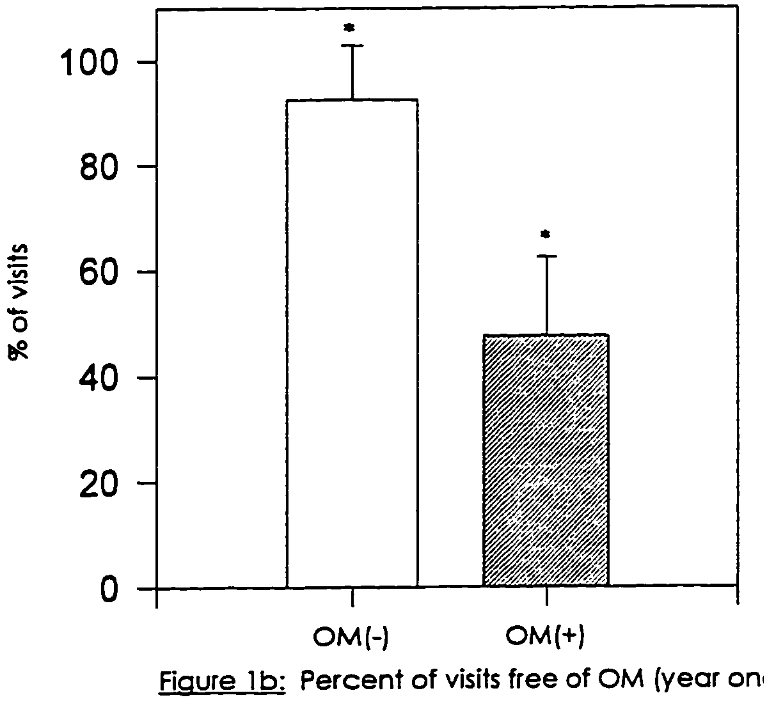

Figure 1b: Percent of visits free of OM (year one)
* p < .05

Because of the longitudinal nature of the clinical research project at AECOM, children continued to be tested during the second year of life (maximum 6 visits at ages 14, 16, 18, 20, 22, and 24 months). Even though otitis media history in the second year of life was not considered as a criterion for inclusion in the study, this investigation examined children's performance on tasks as a function of middle ear and audiometric status during the second year of life. In the OM- group all children continued to be free of otitis media. As a group, they remained free of the disease for 93% of the visits ($\underline{M}$ = 5.3 visits, $\underline{SD}$ = .9), with hearing thresholds ranging from 6 to 18 dB HL ($\underline{M}$ = 11.8, $\underline{SD}$ = 4.8). In the OM+ group, only 3 out of the 8 children continued to be positive. These three children remained positive for 87% of the visits ($\underline{M}$ = 5.3 visits, $\underline{SD}$ = 1.1), and their hearing thresholds ranged from 17 to 24 dB HL ($\underline{M}$ = 21, $\underline{SD}$ = 3.6). The remaining five children (who were positive in the first year) had hearing thresholds ranging from 8 to 16 dB HL ($\underline{M}$ = 11, $\underline{SD}$ = 3.1) and were free of the disease for 66% of the visits ($\underline{M}$ = 4 , $\underline{SD}$ = 1.8). Appendix A presents every child's OM history information during the first and second year of life.

In order to avoid any bias in experimentation and results, the investigator was blind to each child's OM history. The OM status of every child was known only by the audiologist who performed the audiological and audiometric testing. Each child's OM status was revealed to the examiner after the completion of the experiments.

Stimuli

The experimental stimuli were six novel word-pairs of monosyllabic members each referring to an unfamiliar object. The stem of each word consisted of consonant-vowel (CV), or a consonant-vowel-consonant (CVC). The members within each pair differed in the presence of a final voiced or voiceless fricative marking the target word either phonologically (e.g., [pʌk] (soap holder) and [pʌks] (hole puncher), or morphophonologically (e.g., [di] (hose nozzle) and [diz] (hose nozzles)). A female talker presented the target words in phrase-final position in sentences such as "Look at the ____ (target)." Table 3 presents the experimental word-pairs and their unfamiliar object referents.

Phonological appropriateness of stimuli. The six experimental blocks (described in detail in the procedures section) required the presentation of the target words through live and digitally recorded speech. The presentation of words during both procedures was performed by the examiner (KP) who speaks English as a second language. In order to ensure that the experimenter presented the words with phonological appropriateness, the following procedure was followed. After practicing the production of each word, the examiner audio recorded the targets. Each one was produced five times. Recording was conducted in a sound proof booth using a SONY 670 digital audio tape recorder (DAT) and an Electro-Voice 635-A dynamic omni directional microphone. Three individuals unfamiliar with the examiner and the purpose of the study were asked to transcribe the recorded stimuli. These were individuals with training in broad transcription using the International Phonetic Alphabet (IPA). Transcription analysis for each member within a word-pair focused on the following parameters: intra-word vowel production (e.g., the consistent production of the vowel [o] in productions of the target [bok]), intra-word consonant production (e.g., the consistent production of initial consonant [b] and final consonant [k] for target [bok]), inter-word-pair vowel production (e.g., the consistent production of vowel [o] between pairs [bok] vs. [boks]), and inter-word-pair consonant production (e.g., the consistent production of initial [b] and final [k] or [ks] in [bok] vs. [boks]). Two tokens of each word produced with 100% phonological accuracy, were digitized at 12 bit resolution at 22,000 Hz sampling rate using a 2821 Data Translation board.

Editing of the stimuli. The stimuli were edited, to ensure the control over acoustic cues that could confound a subject's selective attention to the final fricative. Vowel duration and total word duration were controlled by editing. During the perception experiment, each target word was heard six times as the picture of its referent was shown. In half of the presentations, the non-final fricative member (NFFM) (e.g., [teɪ]) of a target word-pair was matched to its final fricative member (FFM) (e.g., [teɪz]) for vowel duration. In the other three presentations the NFFM was made comparable to its FFM counterpart for total word duration. The latter procedure restricted the individual variable to temporal differences between the two word-pairs.

Vowel duration. Within a word-pair, one token of (NFFM) was edited in order to match the vowel duration of its FFM counterpart. Thus, the two members of each word-pair were equated with regard to initial stop identity, voice onset time, and vowel duration. For CVC (e.g., [pʌk]) and CVCC (e.g., [pʌks]) targets, the words were made comparable to each other in terms of final position stop closure and burst. The temporal difference between NFFM and FFM corresponded to the duration of the final fricative of the latter word member. The editing was completed from the waveform display of the target word using the Wavexam program (Weiss, 1993). Vowel reduction was accomplished by deleting cycles with equivalent amplitude contours within the steady-state portion of the vowel. All deleted segments began and ended at zero crossings.

Total word duration. Within a word-pair, the FFM was edited, in order to match a second token of the NFFM, in terms of total word duration. This was accomplished by reducing the duration of the final fricative of the FFM. The reduction of fricative duration was performed by removing part of the fricative noise from the end of the segment. Editing was completed from the waveform display of the FFM using Wavexam.

Figure 2a, 2b, and 2c present the waveforms of the word-pair [teɪ]/ [teɪz]. Figure 2a corresponds to the FFM [teɪz], 2b presents the NFFM [teɪ] matched to FFM for total word duration, and 2c shows the NFFM [teɪ] matched to the FFM for vowel duration. Appendix B presents the total duration of each stimulus word and the duration of the component acoustic dimensions for each target.

Table 3

Word-pairs and their corresponding unfamiliar object referents

Phonological	Object referent
1. [gɔ]/[gɔs]	cloth pin/paint roller
2. [teɪ] /[teɪz]	blue latch/bike grip
3. [pʌk]/[pʌks]	soap holder/hole puncher
Morphological	**Object referent**
1. [bok]/[boks]	carpet protector(s)
2. [dæp]/[dæps]	lemon squeezer(s)
3. [di]/[diz]	hose nozzle(s)

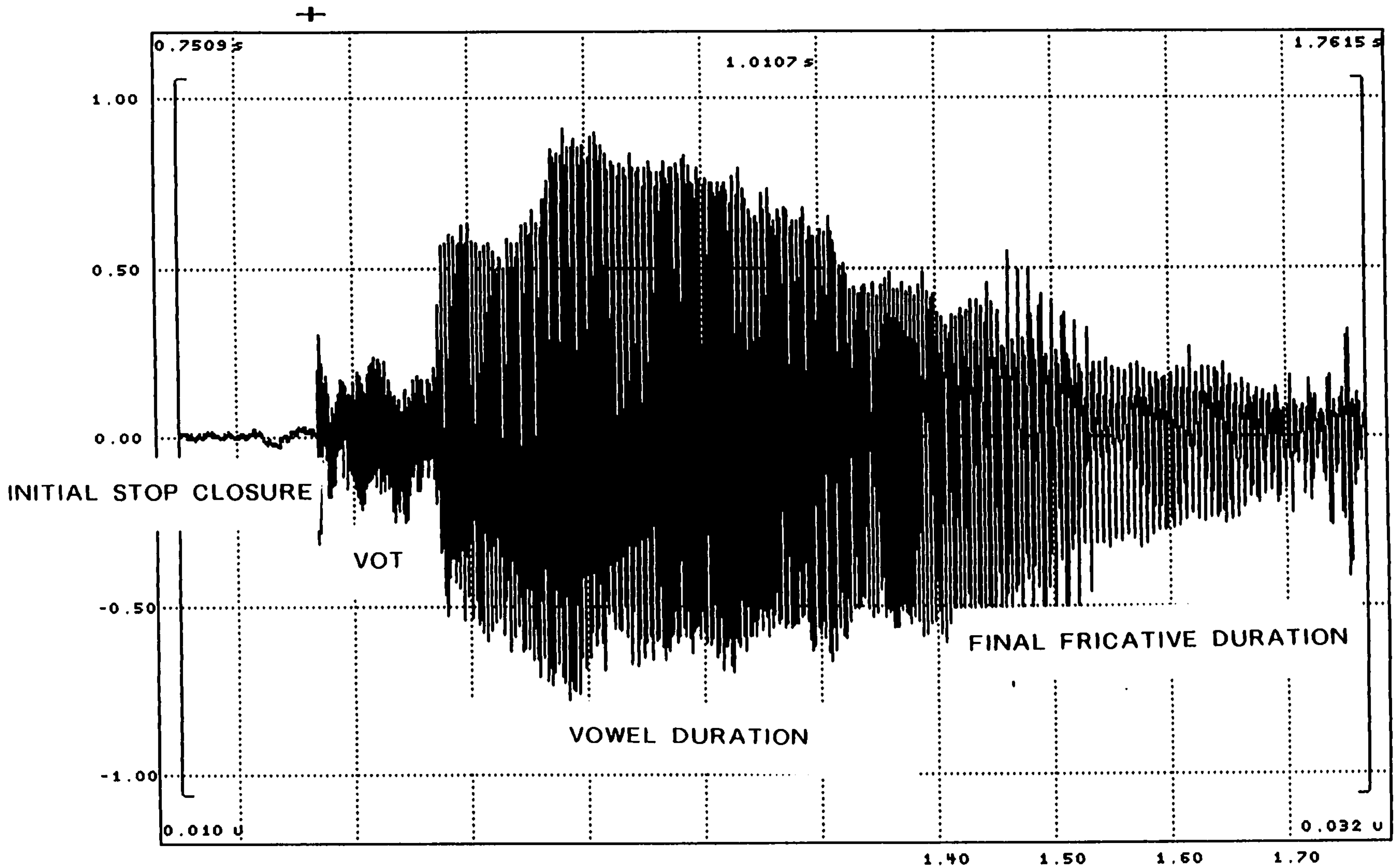

FIGURE 2A: WAVEFORM OF TEIZ

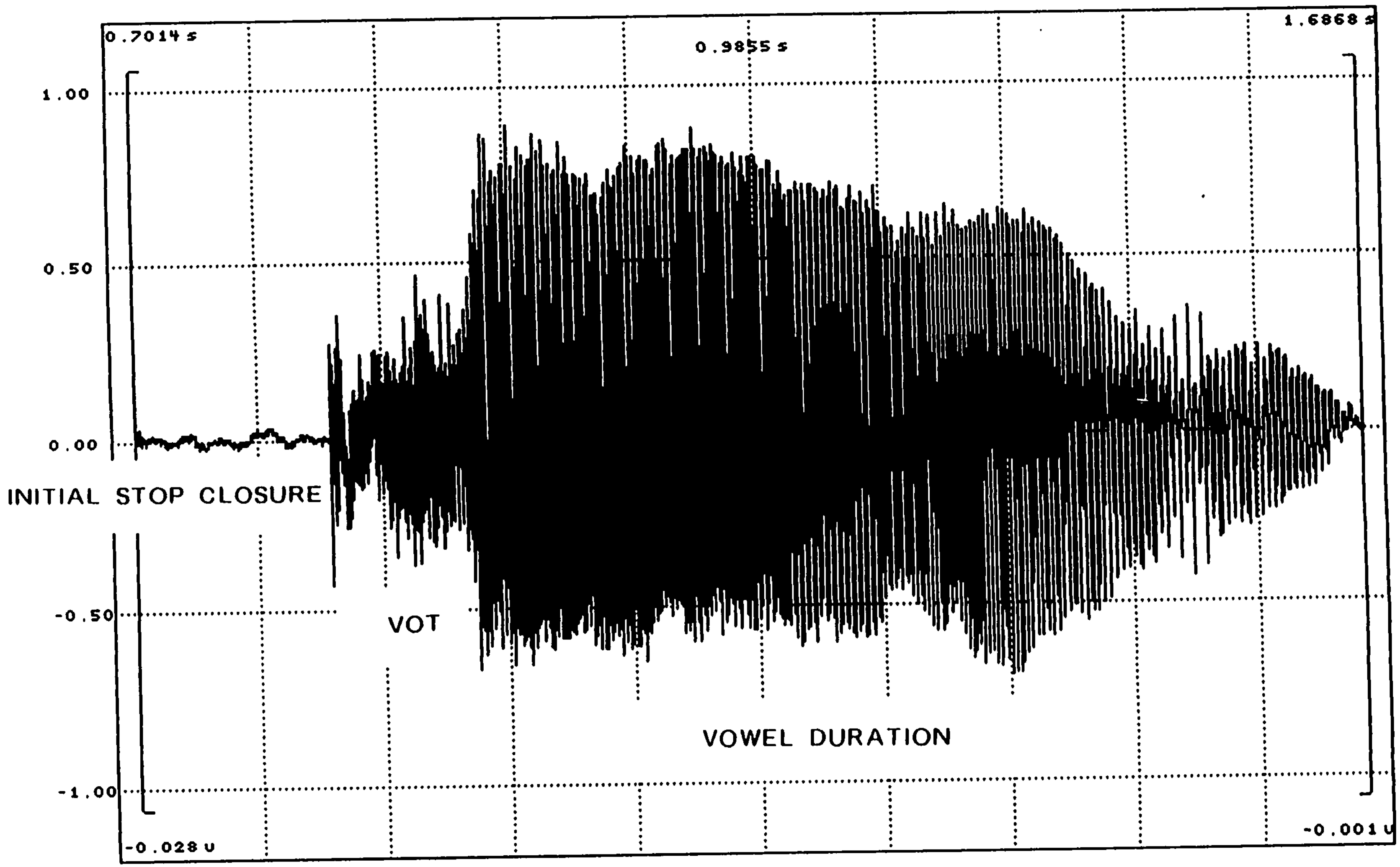

FIGURE 2B: WAVEFORM OF TEI MATCHED TO TEIZ FOR WORD DURATION

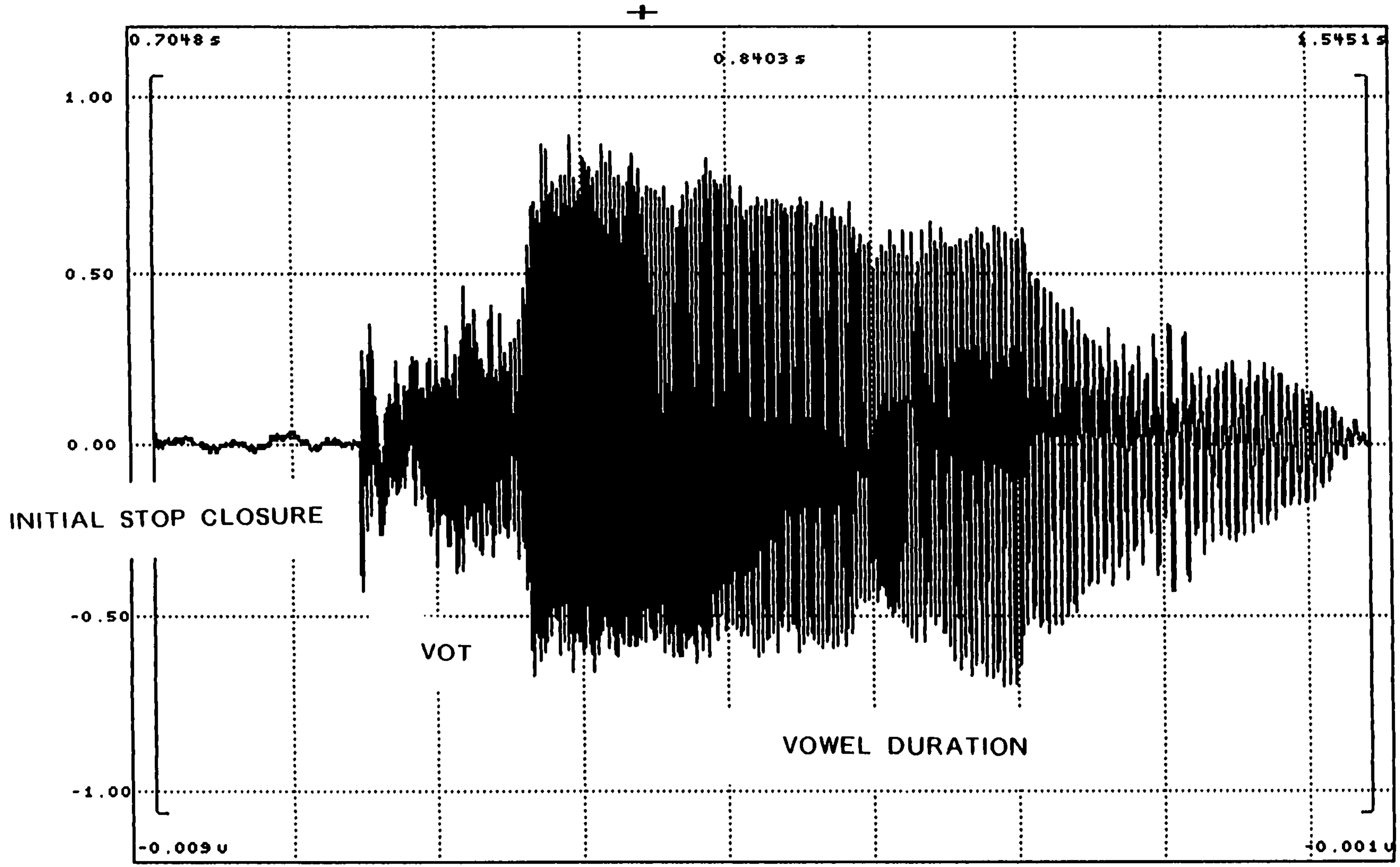

FIGURE 2C: WAVEFORM OF TEI MATCHED TO TEIZ FOR VOWEL DURATION

Procedures

Each child was seen for three one-hour sessions scheduled within a period of no more than 2 weeks. In determining the possible presence of an OM episode, the examiner performed tympanometric screening on every subject prior to each experimental session. Children whose tympanograms with admittance width of greater than 270 daPA, were considered to be at increased risk for OM (Nozza, Bluestone, Kardatzke, & Bachman, 1994). For the subjects who exhibited abnormal tympanograms, the intensity level during the presentation of the stimuli was increased at 10 dB above the predetermined standard level (70 dB SPL, see the following section for details). This increase in intensity level was based on the average hearing threshold difference documented between OM+ and OM- subjects from the cohort (Gravel, Personal Communication). Based on audiometric data from AECOM cohort (n= 62), the difference in average hearing thresholds between OM- (M = 13.7, SD = 5.7) and OM+ (M = 20.7 , SD = 6.2) subjects was 7 dB HL. The 10 dB difference was used as an approximate level of intensity increase for presenting the stimuli to children who were considered at risk for OM during each experiment. Consequently, for children at risk for OM, the stimuli were presented at 80 dB SPL. Only 4 children (all from the OM+ group) had abnormal tympanograms, two children during session 3, one child during session 1, and 1 child during session 1 and 2. During each visit, all subjects were taught 2 pairs of novel words using fast mapping procedures. After the presentation of each pair, perception of the target pair was tested with the visual perception paradigm. Subjects were randomly assigned to the three sessions (each session included one phonological and one morphological word-pair). The order of presentation of the phonological pair and morphological pair was counterbalanced for each session.

Fast mapping. During this procedure the subjects were presented with the first member of a target novel word-pair. The examiner pulled out from a bag of toys an oddly shaped object that corresponded to the first member of the target pair. During the exposure phase, the examiner produced the name of the object seven times , while performing different actions with it (e.g., "Look what I have! It's a [pʌk]! It can fly, it can jump, it can spin!"). Children were prompted to produce the target name (e.g., "what is it?"). If the child did not name the object, the examiner prompted for delayed imitation (e.g., "look I have a [pʌk] What is it?"). If he did not produce the name through delayed imitation, the examiner prompted for direct imitation. Upon delayed or direct imitation, the examiner removed the first referent from the child's sight and introduced the second member of the word-pair. The same exposure and production guidelines were followed. In the comprehension phase, the child was given five opportunities to identify each individual member from a pool including three other familiar objects (i.e., a cup, a dog, a spoon). The criterion for proceeding to the perception part of the experiment was the child's correct identification of the target with 60% accuracy (3/5 times). For children who did not reach the 60% criterion on the first time, the examiner provided a second opportunity. Three children who did not reach this criterion the second time were given a third opportunity with the target presented three times. For these children, a criterion of 66% (2/3 times) was considered acceptable. During fast mapping, the experimenter controlled the intensity of her voice using a VU meter.

Speech perception paradigm. This method required no speech production and minimal motor movement on the child's part. The child sat on the caregiver's lap and both faced a projection screen. The projection screen was used for the presentation of slides representing the objects used during fast mapping. Throughout the perception experiment, the caregiver listened to music through earphones. This prevented the caregiver from cueing the child. The dependent variable was the duration of time the child looked toward either one of the slides (left or right). A correct response occurred when the child looked at the slide matching the audio stimulus. Eye-gaze behavior was video recorded on a Panasonic X-20 camcorder. Figure 3 shows a schematic representation of the speech perception paradigm setting.

The study consisted of six experimental blocks, each corresponding to one of the six word-pairs (three phonological and three morphological). The blocks were designed using the Speech Perception Software (SPS) and each included 20 trials (4 learning and 16 experimental). Each trial consisted of different events that defined and controlled the sequence of the events taking place during the experiment. The events for each trial were as follows: A centering light came on, directing the child's eye gaze to the midline. Once the child looked to the midline, the examiner pushed a button that triggered the advancement of the slides to the first presentation (trial 1). The presentation of the linguistic stimulus was preceded by a silent period (no audio stimulus) during which the two slides were simultaneously projected and remained on the screen for three seconds. This allowed the child looking time without auditory distraction. The target linguistic stimulus followed the silent period (e.g., "Look at the [pʌk]") presented through a central loudspeaker. The slides remained on the screen for three more seconds and corresponded to the actual time the child had to look at the slides and match the auditory stimulus to its corresponding visual referent. The trial was followed by the advancement of the slides to the next trial. During the video recording, the onset and offset of random looking time (silent trial) and experimental looking time (audio trial) was signaled by the presentation of four tones (two tones for silent, and two tones for audio trials). These tones were used during the scoring procedure. Figure 4 presents the sequence of the tasks within a given trial based on SPS program.

Each perception block lasted approximately three minutes. In 4 out of the 16 experimental trials, the target was a familiar object (e.g., a car or a dog). Each member of the a word-pair appeared on the screen for a total of 12 times (6 out of 12 times as the correct target matching the audio presentation). The presentation of trials within each experiment was randomized and the location of the slides (left vs. right) was counterbalanced (e.g., the correct target was presented three times left and three times right). Appendixes C through H show the presentation sequence of every trial for every experiment.

Presentation level of the stimuli. The target words were presented at 70 dB SPL. This presentation level was chosen based on the current literature regarding infants' optimum response as a function of intensity. When compared to younger children, infants have been shown to require higher intensity levels (at least 20 dB HL) to achieve maximum performance during speech discrimination tasks (Nozza, 1987).

Data reduction

Scoring of eye gaze. The experimenter scored each child's eye-gaze behavior (which had been video-taped during the experiment) using the SPS program. The examiner scored each child's looking behavior video recorded during the experiments. Every experiment was scored for 40 trials, 20 corresponding to silent trials and 20 corresponding to audio trials. The onsets and offsets of each type of trial were signaled by four tones. Tones 1 and 2 signaled the onset and offset of silent trials; tones 3 and 4 signaled the onset and offset to the audio trials. Within a specified amount of time (3000 msec for both silent and audio trials) two voting buttons (left and right) were used to score lateral eye-gaze (left versus right), as well as correct and incorrect looking time. The calculation of eye-gaze included the absolute and relative duration of correct versus incorrect looking time, and the absolute and relative duration of left versus right looking time. The absolute and relative values for every scored parameter were sorted and calculated using a program compatible with SPS.

Scoring reliability. Reliability agreement for scoring was established between two independent voters who scored the responses from four children, each selected randomly. Reliability focused on agreement for correct, incorrect, and inattention responses. Averaged across all children, the difference between voter 1 and voter 2 was 25 msec for correct responses, 65 msec for incorrect responses, and 61 msec for inattention. For the three variables (correct, incorrect, inattention), three separate ANOVAS were performed with RATER (rater 1 and rater 2) as the between-subject variable, and CHILD (four children) as the within-subject variable. An alpha level of .05 was used for all statistical tests. The analyses revealed no RATER main effect for correct $F(1, 62) = .039$, $p > .05$ incorrect $F(1, 62) = .340$, $p > .05$, or inattention responses $F(1, 62) = .06$, $p > .05$ responses. For correct, incorrect, and inattention responses the mean durations from rater 1 were 1015 msec (SD = 844), 1079 msec (SD = 165), and 1169 (SD = 169) respectively. For rater 2, the means for correct, incorrect, and inattention responses were 988 msec (SD = 814), 1014 msec (SD = 198), and 1108 msec (SD = 232) respectively.

Comparison of audio versus silent trials. In order to ensure that children's looking behavior was attributed to the presence of the linguistic stimulus, a comparison was made between silent and audio trials for proportion correct responses for all 16 subjects. Before any statistical analysis was performed, all proportions were transformed to arcsines. The responses scored by rater 1 (KP) were analyzed using an ANOVA with GROUP (positive versus negative) as the between-subject variable, EYE-GAZE RESPONSE (proportion correct audio vs. proportion correct no audio) and LINGUISTIC CATEGORY (phonological vs. morphological) as the within-subject variables. The difference between proportion correct looking time for audio trials (M = .47, SD = .19) was significantly longer than proportion correct for silent trials (M = .35, SD = .23), $F(1, 14) = 21.8$, $p < .05$.

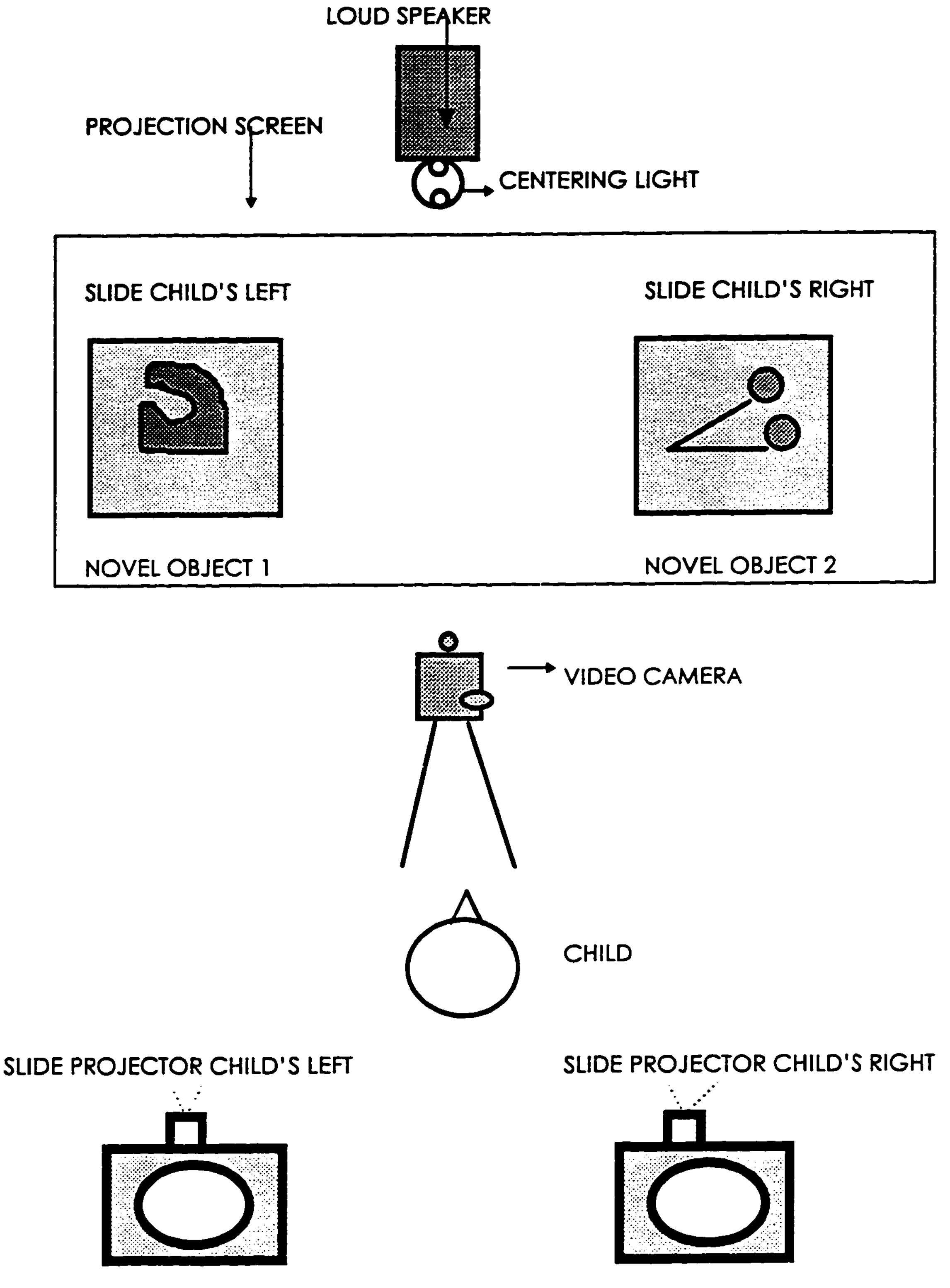

Figure 3: Schematic representation of the visual perception paradigm.

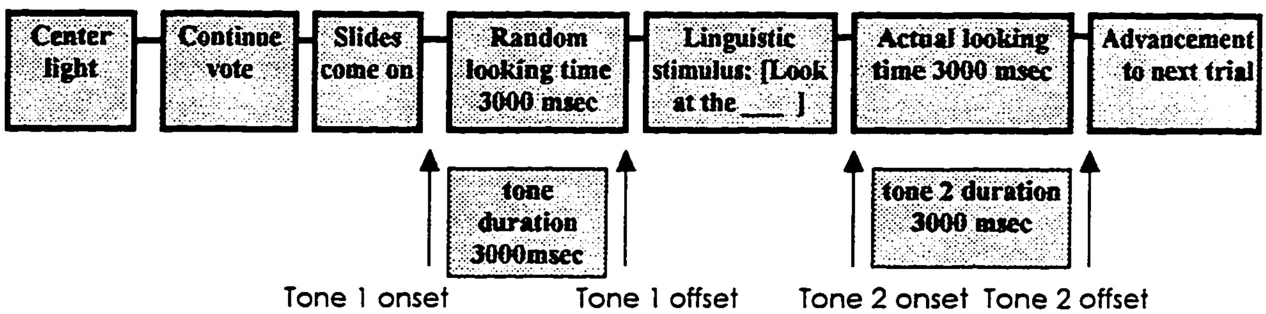

Figure 4: Description of experimental trial events of the perception experiments based on Speech Perception Software program (SPS).

Chapter 3 : Results

Data analysis was conducted in two stages. The first compared the performance of the two groups of children differing in OM history documented during the first year of life. Second, the children who remained positive for otitis media during the second year of life were compared to children who were free of the disease during the first and second year of life, as well as to children who were positive in the first year, but negative in the second year. Thus, the second set of analyses was based on subgroups of children determined by the course of the disease during the second year of life. None of the children who were free of the disease in the first year turned out to be positive in the second year. The data analyses included only the experimental trials (i.e., foils were excluded) accompanied by audio stimulus. Trials on which children were totally inattentive, were excluded from the analyses.

Results based on first year OM history

Comparison of correct versus incorrect looking time in OM- and OM+ groups (absolute values). This analysis examined the pattern of eye-gaze toward the correct versus the incorrect targets in the two groups. Duration of eye gaze is reported in msec. The data for the three phonological and the three morphological word-pairs were collapsed respectively and formed the phonological and the morphological linguistic contrasts. Table 4 shows the means and standard deviations for each child on phonological and morphological contrasts for correct, incorrect, and inattention responses. A three-way ANOVA was performed with OM STATUS (positive vs. negative) as the between-subject variable along with LINGUISTIC CATEGORY (phonological vs. morphological) and EYE-GAZE RESPONSE (correct vs. incorrect) as the within-subject variables. The analysis showed a significant main effect for LINGUISTIC CATEGORY, $F(1, 14) = 5.97$, $p < .05$, indicating that all children, despite OM status and eye-gaze behavior

, looked longer at phonological (M =1066, SD = 191) than morphological category (M= 993, SD = 180). A STATUS X EYE-GAZE RESPONSE interaction was significant, $F(1, 14) = 10.3$, $p < .05$. Figure 5 displays the pattern of correct versus incorrect looking time in the two groups. Post-hoc paired comparisons were performed using the Bonferoni correction procedure at $p < .05$. Comparisons were performed for CORRECT versus INCORRECT response in the OM- group and CORRECT versus INCORRECT responses in the OM+ group. Within-group comparison CORRECT versus INCORRECT looking time was significant for OM-, $F(1, 14) = 10.4$, $p < .01$, but not for OM+, $F(1, 14) = 1.7$, $p > .01$. OM- children looked longer at the correct (M = 1114, SD = 192), than the incorrect (M = 915, SD = 182) targets, whereas the OM+ children did not exhibit this differential looking behavior. In fact, OM+ children tended to look longer towards the incorrect targets (M = 1077, SD = 154) than towards correct ones (M = 987, SD = 152), although the difference was not statistically significant. The pattern of perceptual distinction (difference between correct versus incorrect looking) was larger for the OM- than for the OM+ group. The interaction between OM STATUS and EYE-GAZE was attributed to the fact that OM- children, as a group, had a larger difference between correct versus incorrect looking behavior when compared to the OM+ group. Furthermore, for OM- children longer looking was in favor of correct targets, whereas for OM+ there was a trend towards longer looking towards incorrect targets.

Table 4

Means and standard deviations (msec) for correct, incorrect, and inattention responses on phonological and morphological contrasts (absolute values)

Subjects	Phonological			Morphological		
OM -	Correct	Incorrect	Inattention	Correct	Incorrect	Inattention
1	1493	954	553	1154	1181	665
2	1104	775	1121	1018	938	1044
3	1201	889	910	1460	888	652
4	1208	966	826	1166	891	943
5	1024	1135	841	939	1039	1022
6	926	984	1090	790	692	1518
7	1103	1109	788	1110	1013	877
8	1205	594	1246	1362	597	1059
M	1158	926	921	1125	905	972
SD	(108)	(176)	(221)	(217)	(188)	(258)
OM +						
9	1079	1445	476	1017	1135	848
10	1129	1135	736	903	1057	1040
11	1235	1424	341	1183	759	1058
12	827	972	1201	785	983	1232
13	820	974	1206	873	1086	1041
14	1192	1137	706	1108	1089	735
15	902	1102	996	927	879	1194
16	1021	1078	901	786	993	1005
M	1026	1158	820	948	993	1019
SD	(161)	(182)	(290)	(143)	(126)	(164)

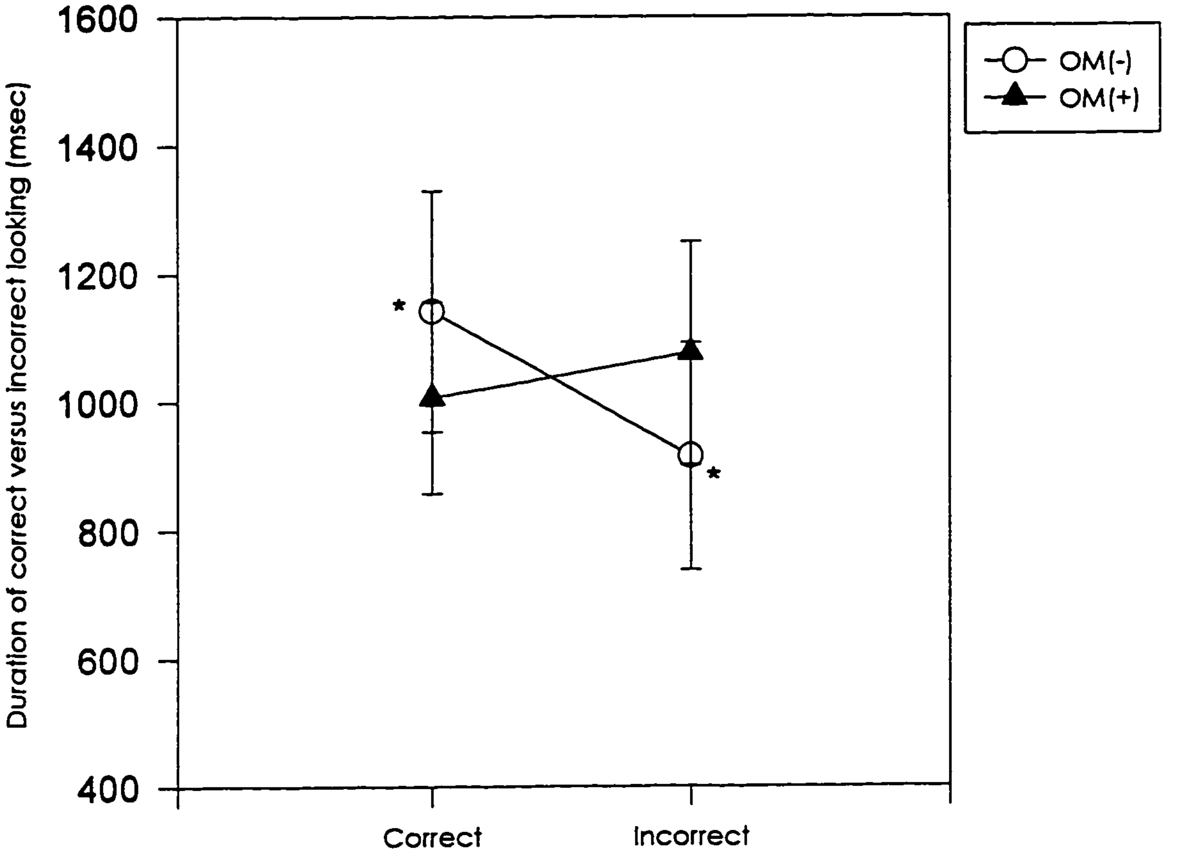

Figure 5: OM STATUS by EYE-GAZE interaction for correct versus incorrect responses (absolute values).
* $p < .01$

A three-way interaction among STATUS X EYE-GAZE X LINGUISTIC CATEGORY was not significant, $F(1, 14) = .25, p > .05$. Figures 6a and 6b present the pattern of correct versus incorrect looking time on phonological and morphological words for OM- and OM+ groups respectively. Planned comparisons at the .05 probability level were used to test the a priori hypotheses that the OM+ children would make all target distinctions (both phonological and morphological), whereas OM+ children would not. For the OM- group, comparisons between CORRECT versus INCORRECT responses were statistically significant for both phonological, $F(1, 14) = 5.77, p < .05$, and morphological contrasts, $F(1, 14) = 9.55, p < .01$. OM- children looked longer at the correct than the incorrect targets for both types of linguistic contrasts, thus maintaining the pattern of perceptual distinction during both phonological and morphological targets. For the OM+ group, planned comparisons between CORRECT versus INCORRECT looking time were statistically significant for phonological, $F(1, 14) = 5.1, p < .05$, but not for morphological stimuli, $F(1, 14) =.28, p >.05$. The eye-gaze pattern seen in the OM+ group suggested that these children had difficulties in making target distinctions during both phonological and morphological comprehension. Accordingly, OM+ children treated the two linguistic contrasts differently. Irrespective of the bimodal direction of eye-gaze, OM+ group spent more time looking at phonological than morphological targets. During morphological perception, the difference between correct versus incorrect targets was only 45 msec. The differential looking pattern, as a function of linguistic category, was examined in terms of children's inattention behavior during the experiment.

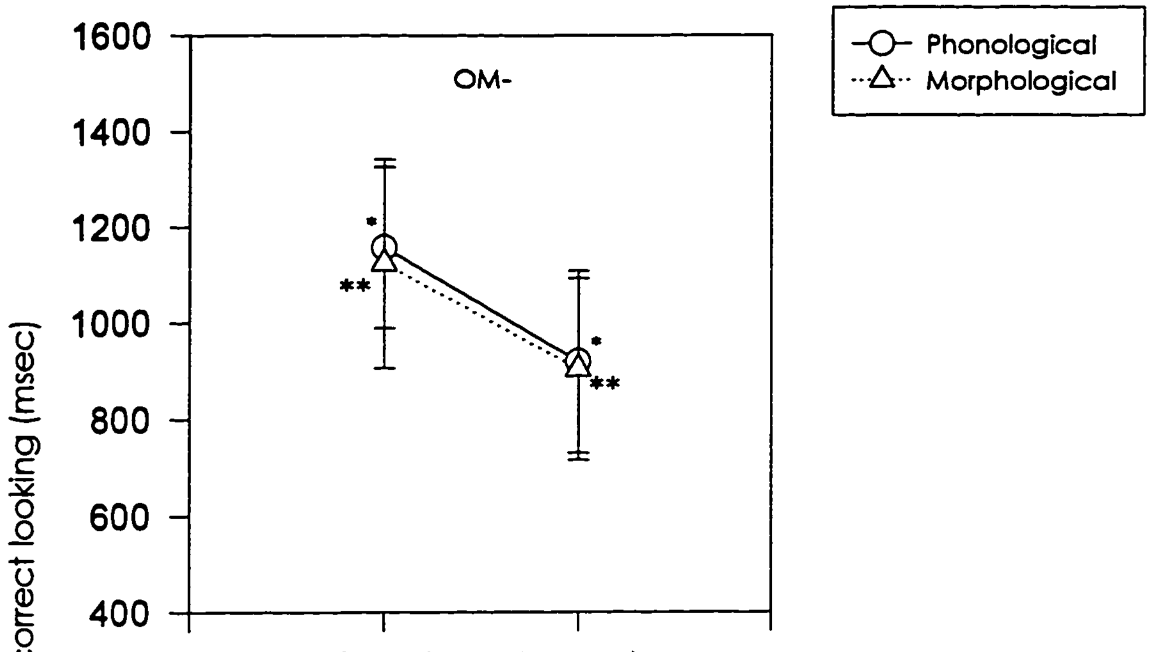

Figure 6a: Correct versus incorrect looking in OM- group for phonological and morphological categories (absolute values).

* p < .05; ** p < .01

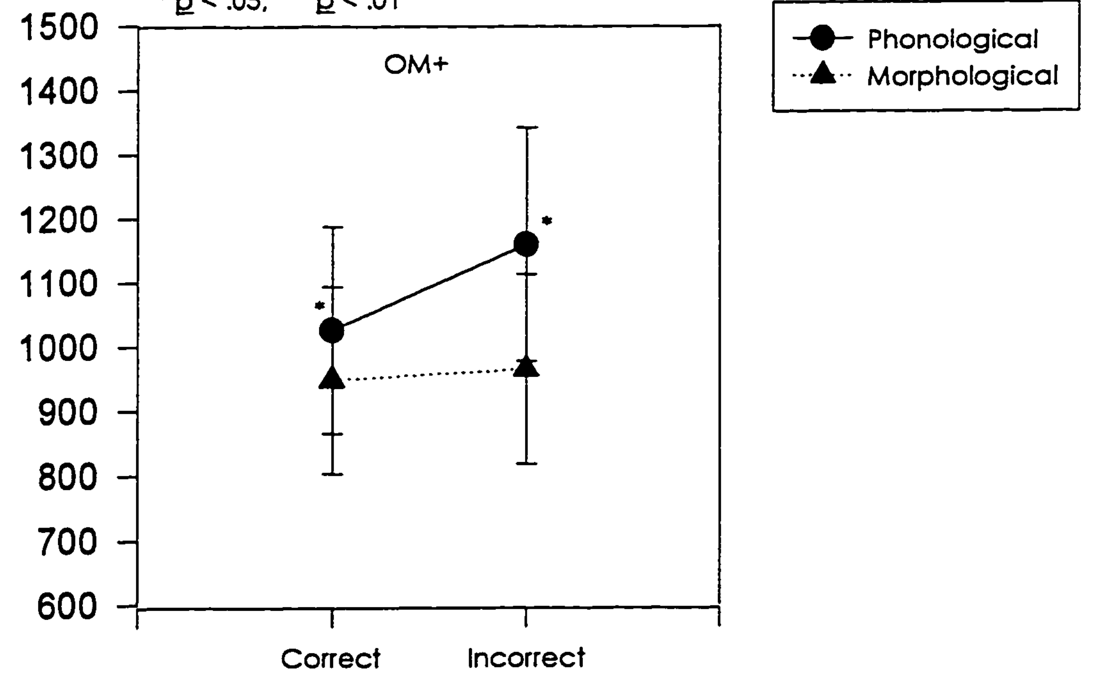

Figure 6b: Correct versus incorrect looking time in OM+ group for phonological and morphological categories (absolute values).

* p < .05

A two-way ANOVA with OM STATUS (positive vs. negative) as the between-subject factor and LINGUISTIC CATEGORY (phonological vs. morphological) as the within-subject variable, was performed with inattention time as the dependent variable. Inattention was measured in msec and corresponded to the amount of time children spent without looking at either correct or incorrect targets. Figure 7a and 7b present the duration of correct, incorrect, and inattention looking time in OM- and OM+ groups respectively. The analysis revealed a significant main effect for LINGUISTIC CATEGORY, $F(1, 14) = 4.3$, $p < .05$. All children, despite their OM status, exhibited more inattention for morphological ($M = 995$, $SD = 200$), than for phonological contrasts ($M = 870$ $SD = 238$). The OM STATUS main effect was not statistically significant, $F(1, 14) = .009$, $p > .05$. Collapsing over LINGUISTIC CATEGORY, inattention was the same in both OM+ ($M = 939$, $SD = 242$), and OM- children ($M = 942$, $SD = 233$). The significance of the LINGUISTIC CATEGORY main effect in relation to OM STATUS was tested by using post-hoc paired comparisons with Bonferoni corrections $p = .025$. For OM+ children inattention was significantly longer for morphological ($M = 1019$, $SD = 164$) than for phonological words ($M = 820$, $SD = 290$), $F(1, 14) = 5.2$, $p = .02$, whereas for the OM- group inattention was not significantly different between phonological ($M = 921$, $SD = 221$) and morphological words ($M = 972$, $SD = 258$), $F(1, 14) = .97$, $p = .612$.

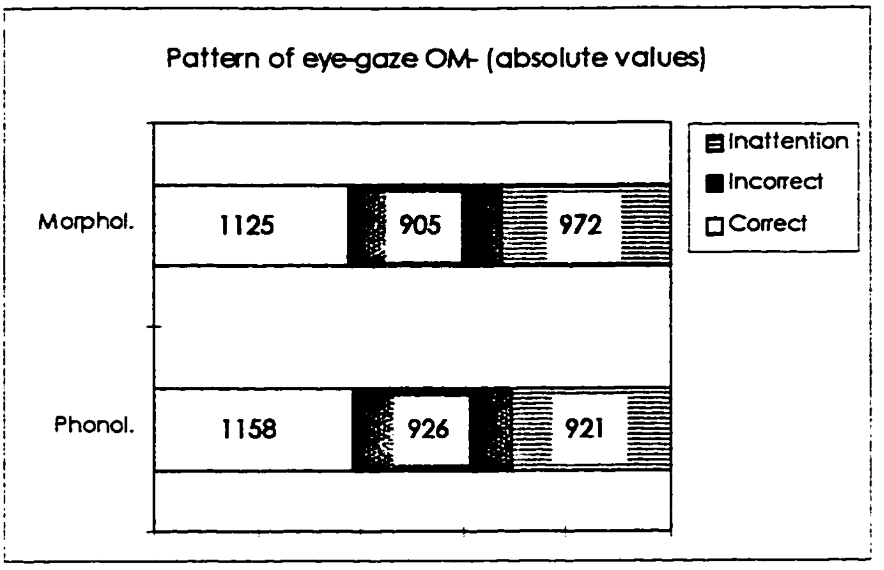

Figure 7a: Duration of correct, incorrect, and inattention looking time in OM- group (absolute values in msec).

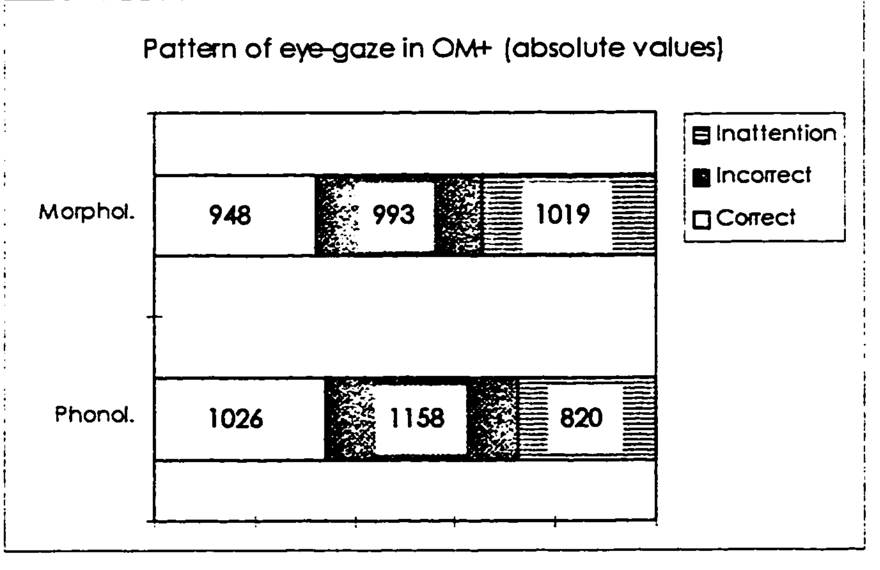

Figure 7b: Duration of correct, incorrect, and inattention looking time in OM+ group (absolute values in msec).

Comparison between the two groups on relative values. The performance of OM- children on the perception experiments was compared to that of OM+ by using the proportion correct looking time (PCLT). PCLT was calculated as the duration of correct responses divided by the total looking time (e.g., correct + incorrect/ looking time). Before performing any statistical analyses, all proportions were transformed to arcsines. The data from the three phonological and the three morphological word-pairs were collapsed to form the phonological and the morphological linguistic contrasts. Table 5 shows means and standard deviations for PCLT values for phonological and morphological contrasts in the two groups. A two-way ANOVA with OM STATUS (positive vs. negative) as the between-subject variable and LINGUISTIC CATEGORY (phonological vs. morphological) as the within-subject variable revealed a main effect for OM STATUS, $F(1, 14) = 7.32$, $p < .01$. PCLT for the OM- group ($M = .555$, $SD = .07$) was significantly larger than PCLT for the OM+ group ($M = .475$, $SD = .03$). The OM STATUS main effect is presented on Figure 8. A two-way interaction between OM STATUS X LINGUISTIC CATEGORY was not significant $F(1, 14) = .126$, $p > .05$. Figure 9 presents proportion correct and incorrect looking time for both groups on both linguistic contrasts. Within group looking performance suggested that each group did not respond differentially to phonological and morphological stimuli. The difference between the two groups was in the duration of preferential eye-gaze toward the correct targets. The OM STATUS main effect supported the first hypothesis; OM- children were better than OM+ children in making target distinctions. However, the data did not support the hypothesis that OM+ children as a group would have greater difficulty with morphological rather than with phonological contrasts. It should be noted that for the above analyses, the data for the individual phonological and morphological words were collapsed into their respective linguistic contrasts. It was possible thatthe effects of particular words were masked.

Table 5

Means and standard deviations (in parentheses) for proportion correct values for phonological and morphological contrasts

Subject	Linguistic Category	
OM-	Phonological	Morphological
1	.59 (.05)	.51 (.05)
2	.57 (.04)	.51 (.06)
3	.57 (.03)	.62 (.04)
4	.58 (.14)	.55 (.06)
5	.46 (.07)	.47 (.08)
6	.51 (.15)	.44 (.03)
7	.52 (.06)	.54 (.02)
8	.67 (.07)	.71 (.02)
M	.56 (.07)	.55 (.07)
OM+		
9	.44 (.08)	.47 (.03)
10	.49 (.05)	.45 (.09)
11	.53 (.04)	.54 (.03)
12	.47 (.11)	.43 (.09)
13	.43 (.14)	.44 (.07)
14	.49 (.11)	.50 (.08)
15	.45 (.03)	.51 (.02)
16	.55 (.14)	.45 (.06)
M	.48 (.04)	.47 (.03)

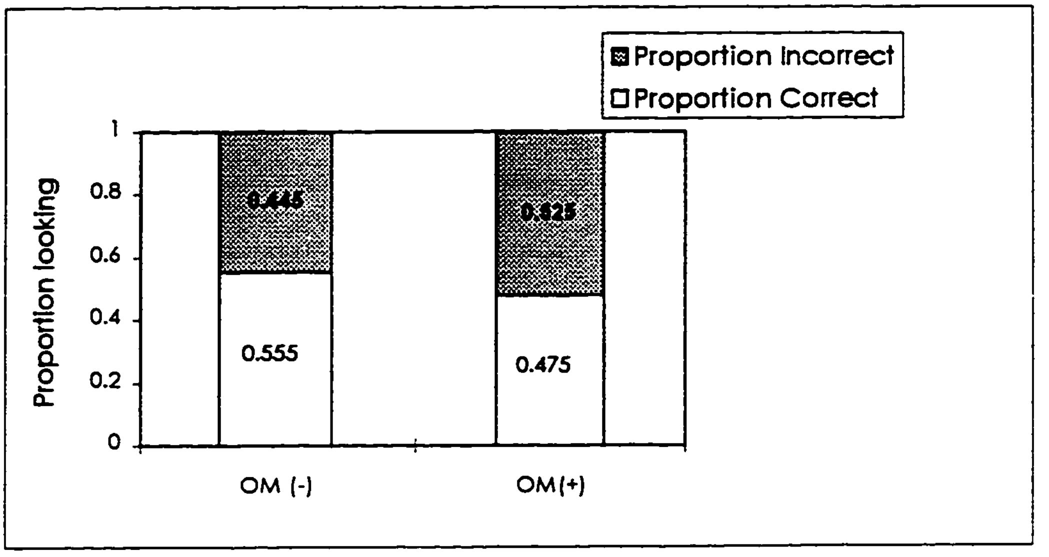

Figure 8: OM STATUS main effect for proportion correct looking time.

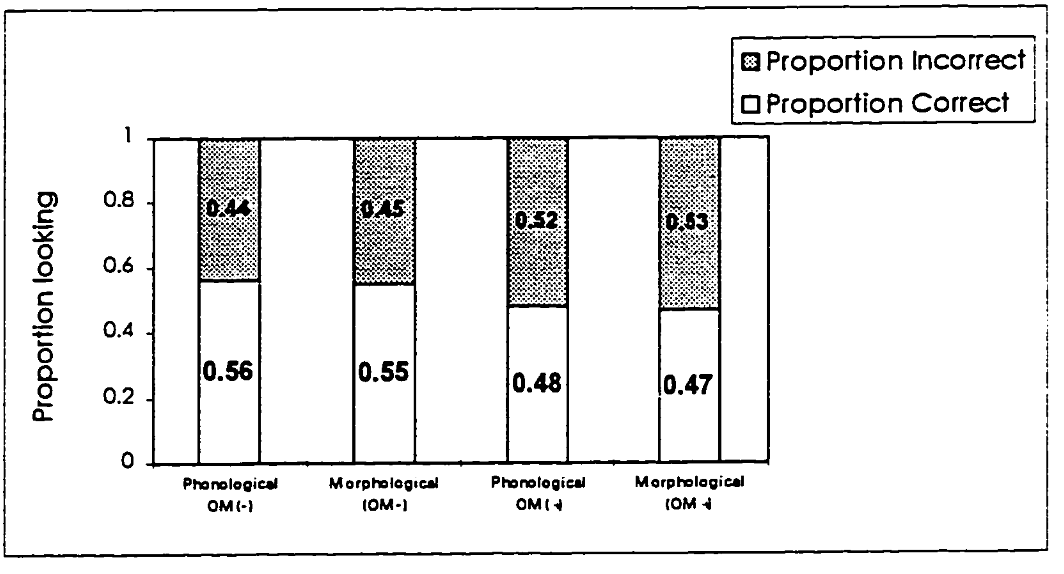

Figure 9: Proportion correct and incorrect looking time as a function of OM in the two linguistic contrasts.

Comparison of proportion correct looking between the two groups for each word-pair. Appendix I shows the means and standard deviations for PCLT for every child on individual word-pairs within each linguistic category. Table 6 shows the overall means and standard deviations for PCLT in the two groups for all phonological and all morphological targets. The performance of each group on each word-pair was analyzed using a 2 X 6 MANOVA. OM STATUS (positive vs. negative) was the independent variable, and WORD-PAIRS (six) were the dependent variables. Figure 10 presents means and standard deviations for PCLT in the two groups on individual word-pairs. The MANOVA was significant, Wilk's Lambda (6 , 9) = .224, $p < .01$. The results from the univariate analysis indicated that the two groups differed significantly on the following word-pairs: Phonological Pair 1 (P1) [gɔ]/[gɔs], $F(1, 14) = 20.33$, $p < .01$; Morphological Pair 1 (M1) [bok]/ [boks], $F(1, 14) = 7.05$, $p < .01$; and Morphological Pair 2 (M2) [dæp]/[dæps], $F(1, 14) = 10.49$, $p < .01$. PCLT for the OM- children was significantly greater when compared to PCLT in OM+ children, for P1 (OM-, $M = .60$, $SD = .09$; OM+, $M = .43$, $SD = .06$), M1 (OM-, $M = .54$, $SD = .09$; OM+, $M = .43$, $SD = .06$), and M2 (OM-, $M = .56$, $SD = .08$; OM+, $M = .48$, $SD = .07$). When compared to the OM- group, the OM+ children performed more poorly on two morphological and one phonological pair.

A visual inspection of Figure 10 indicated that OM+ children performed the worst on P1 and M1, and performed the best on P3 and M3. P1 and M1 were presented during the same session. The same was true for P3 and M3. This pattern of performance may have been the result of order effects, because presentation order could not be completely randomized or counterbalanced. During session 1, four children within the OM+ group received P1 and M1, two children received P2 and M2, and two received P3 and M3. During session 3 (last visit) four children received P3 and M3, two received P2 and M2, and two received P1 and M1. Thus, half of the OM+ children were presented with P1 and M1 during session 1, and half were presented with P3 and M3 during session

3. However, an order effect was ruled out , because PCLT as a function of each word did not always improve consistently from session 1 to session 3 (only two children showed improved performance from session 1 to session 3). Figure 11 presents the pattern of performance plotted as a function of each session. When compared to Figure 10 which shows performance as a function of each word, Figure 11 shows unremarkable differences among sessions.

Table 6

Means and standard deviations (in parentheses) for proportion correct values on all word-pairs in the two groups

		Phonological	
	P1	P2	P3
	[gɔ] vs. [gɔs]	[teɪ] vs. [teɪz]	[pʌk] vs. [pʌks]
OM-	.60 (.09)*	.55 (.09)	.52 (.09)
OM+	.43 (.06)*	.48 (.13)	.52 (.04)
		Morphological	
	M1	M2	M3
	[bok] vs. [boks]	[dæp] vs. [dæps]	[di] vs. [di z]
OM-	.54 (.09)**	.56 (.08)***	.54 (.1)
OM+	.42 (.06)**	.44 (.05)***	.54 (.03)

Note: Asterisks indicate statistically significant differences between the two groups.

* $p < .01$; ** $p < .01$; *** $p < .01$

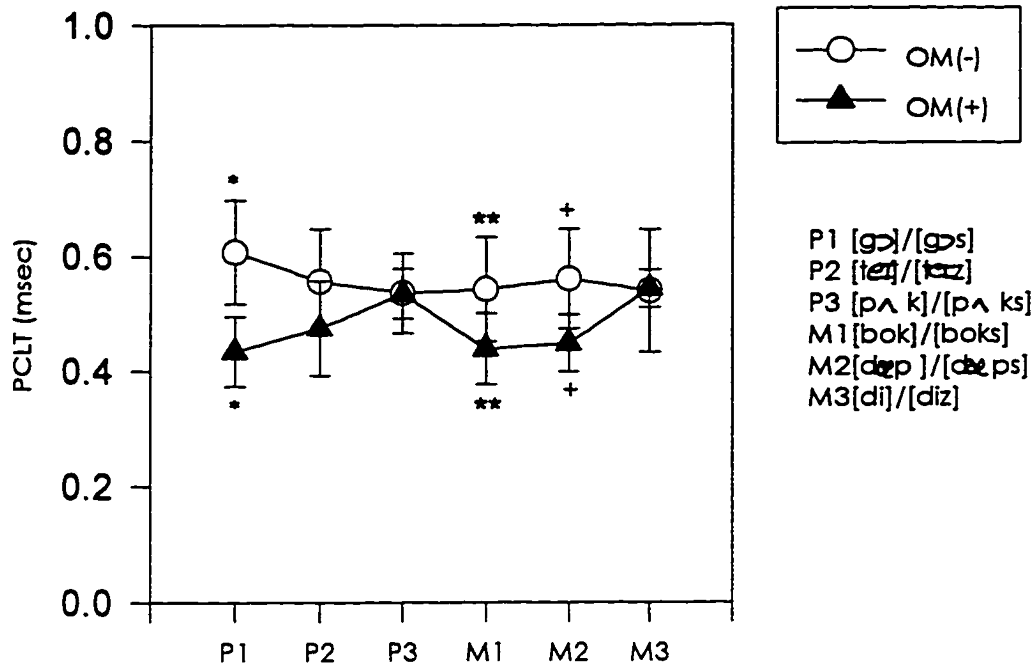

Figure 10: Proportion correct looking time in the two groups on all word pairs.
* p < .01; ** p < .01; + p < .01

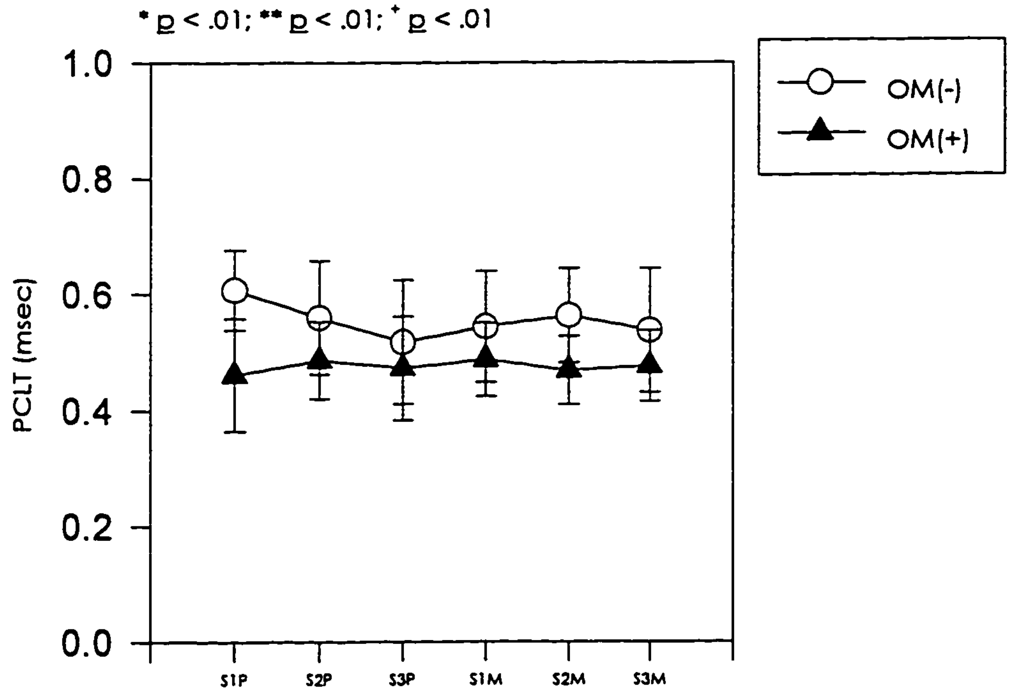

Figure 11: Performance in the two groups by session.

Paired comparisons were used to examine further within-group performance for the individual stimuli. In each group there were 15 paired comparisons corresponding to all possible word-pair combinations. Because these were post-hoc comparisons, the Bonferoni correction procedure was used at $p < .05$.

In the OM- group, none of the comparisons were significant within or between linguistic contrasts. OM- children performed similarly on all words regardless of linguistic category. The F ratios and corresponding probability levels for paired comparisons are reported in Table 7. Figure 12a presents PCLT on every word-pair within the OM- group.

OM+ children were more variable in their performance within and between linguistic contrasts. Figure 12b presents PCLT on every word-pair within the OM+ group. The F ratios and corresponding probability levels for paired comparisons are presented in Table 7. Within the phonological contrasts none of the comparisons approached significance. OM+ children performed similarly on all phonological pairs, even though Figures 10 and 12b present a trend towards better performance on P3. Within the morphological category, significant differences were revealed between M1 versus M3 $F(1, 14) = 20.2$, $p < .05$, and between M2 versus M3, $F(1, 14) = 12.7$, $p < .05$. PCLT for M3 ($M = .54$, $SD = .03$) was significantly larger than for M1 ($M = .42$, $SD = .06$) and M2 ($M = .44$, $SD = .05$). Comparisons between phonological versus morphological words were significantly different between P1 versus M3 $F(1, 14) = 12.9$, $p < .05$, between P3 versus M1 $F(1, 14) = 8.9$, $p < .05$, and between P3 versus M2 $F(1, 14) = 10.35$, $p < .05$. PCLT was larger for M3 ($M = .54$, $SD = .03$) than for P1 (M = .42, SD = .06), and larger for P3 ($M = .52$, $SD = .04$) when compared to M1 ($M = .42$, $SD = .06$) and M2 ($M = .44$, $SD = .05$) respectively.

Table 7

Paired comparisons between and within each linguistic category for every word-pair

Word-pair comparison	OM-		OM+	
	F	p	F	p
P1 versus P2	1.22	.29	1.30	.25
P1 versus P3	4.30	.03	7.40	.01
P2 versus P3	.540	.47	.95	.34
M1 versus M2	.457	.50	.50	.82
M1 versus M3	.011	.91	20.22	.0004 *
M2 versus M3	.592	.45	12.70	.003 *
P1 versus M1	5.44	.08	.056	.816
P1 versus M2	1.66	.21	.098	.758
P1 versus M3	4.80	.04	12.9	.002 *
P2 versus M1	.086	.77	1.12	.30
P2 versus M2	.012	.91	.97	.34
P2 versus M3	.155	.69	1.81	.198
P3 versus M1	.435	.51	8.90	.0027 *
P3 versus M2	2.04	.17	10.35	.003 *
P3 versus M3	.769	.39	.167	.698

Note: P1 = [gɔ]/[gɔs]; P2 = [teɪ]/[teɪz]; P3 = [pʌk]/[pʌks]; M1=[bok]/[boks];

M2 = [dæp]/[dæps]; M3 = [di]/[diz]

* p < .003 based on Bonferoni correction procedure (.05/15 = .003)

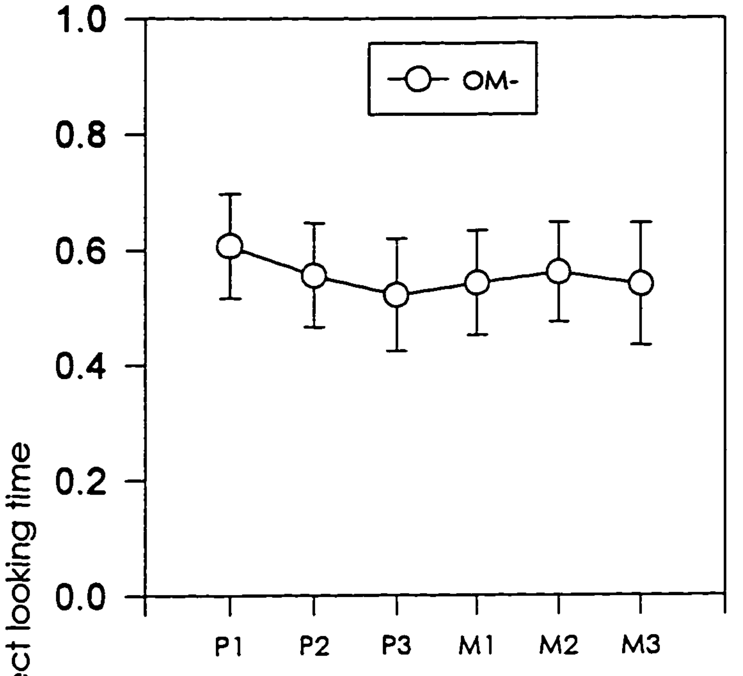

Figure 12a: Proportion correct looking time on every word pair within the OM- group.

P1 [gɔ]/[gɔs]
P2 [t[illegible]]/[tæz]
P3 [pʌk]/[pʌks]
M1 [bok]/[boks]
M2 [d[illegible]p]/[d[illegible]ps]
M3 [di]/[diz]

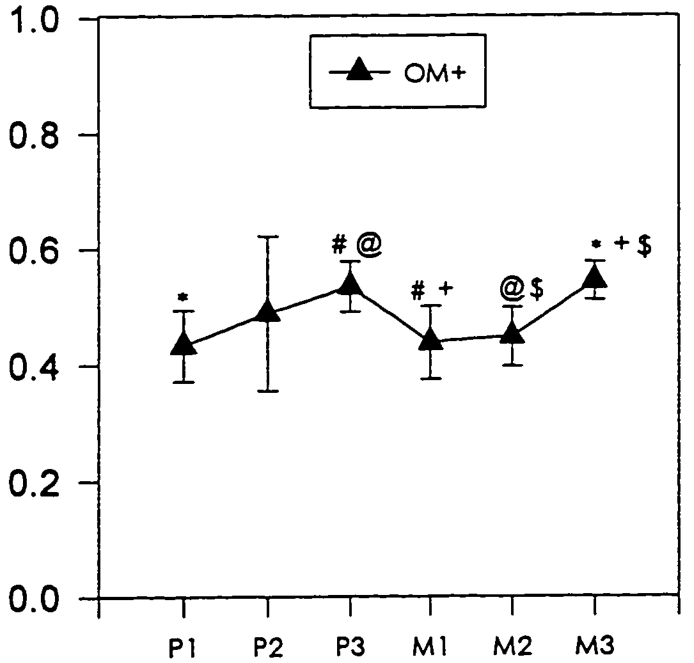

Figure 12b: Proportion correct looking time on every word pair within the OM+ group.
* p = .002; # p = .002; @ p = .003; + p = .0004; $ p = .003

Results based on each group's selective perception of members within a word-pair

The purpose of this analysis was to examine further each group's selective perception of non final fricative (NFF) (e.g., [di]) versus final fricative (FF) (e.g., [diz]) members within a word-pair. The analysis was a three-way ANOVA with STATUS (positive vs. negative) as the between-subject variable and WORD (six word-pairs) along with FINAL CONSONANT (final fricative vs. no final fricative) as the within-subject variables. Table 8 reports the means and standard deviations for PCLT for NFF and FF word-pair members in the OM- and the OM+ groups. The analysis yielded a significant STATUS X WORD X FINAL CONSONANT interaction, $F(5, 70) = 3.12$, $p < .05$. Within and between group paired comparisons between NFF and FF for all word-pairs was conducted with Bonferoni correction procedure at the .05 probability level. Table 9 reports the F ratio and p values for all between- group paired comparisons. As shown in Figure 13a, within the OM- group none of the comparisons between FF and NFF targets reached significance. OM- children spent equal amount of time looking towards no final and final fricative targets. For the OM+ children paired comparisons were significant for P2 [teɪ]/[teɪz], $F(1, 14) = 10.79$, $p < .05$, and M2 [dæp]/[dæps], $F(1, 14) = 3.08$, $p < .05$. The perceptual performance of OM+ children is shown in Figure 13b. On P2, OM+ children spent more time looking at targets with FF (e.g.,[teɪz]), ($M = .60$, $SD = .19$) than with NFF (e.g., [teɪ]), ($M = .37$, $SD = .18$). On M2, OM+ children spent significantly less time looking at FF targets (e.g.,[dæps]), ($M = .40$, $SD = .11$), than NFF (e.g.,[dæp]), ($M = .53$, $SD = .15$). The results indicated that OM+ children had difficulties in the selective perception of [s], at least on one morphological word-pair, but no difficulties in the selective perception of [z]. Between-group comparisons revealed significant difference on the PCLT FF on [gɔs], $F(1, 14) = 7.32$, $p < .05$, and PCLT for FF on [dæps], $F(1, 14) = 4.45$, $p < .05$. OM+ children spent less time looking at [gɔs] targets, ($M = .41$, $SD = .11$), and [dæps] targets ($M = .40$, SD =

10), when compared to OM- children for the respective targets (M = .6, SD = .16) and (M = .53, SD = .14). Table 10 indicates the F ratio and p values for between-group comparisons. Figure 14 shows the between-group selective perception for final fricative members. Collectively, the results suggested that the difference seen between the two groups on particular word-pairs (based on individual word analysis reported in previous section) could be attributed to the fact that OM+ children had difficulties in perceiving the fricative consonants. In addition, the perceptual difficulties seen in the OM+ group were greater for the voiceless final consonants.

Table 8

Means and standard deviations (in parentheses) for selective PCLT of members within word-pairs for OM- and OM+ groups

	[gɔ]/[gɔs]		[teɪ]/[teɪz]		[pʌk]/[pʌks]		[bok]/[boks]		[dæp]/[dæps]		[di]/[diz]	
Group	NFF*	FF**	NFF	FF	NFF	FF	NFF	FF	NFF	FF	NFF	FF
OM-	.58	.6	.48	.51	.5	.47	.55	.51	.52	.53	.51	.56
	(.21)	(.16)	(.18)	(.13)	(.15)	(.18)	(.09)	(.18)	(.11)	(.14)	(.20)	(.13)
OM+	.43	.41	.37	.6	.52	.51	.4	.42	.53	.40	.47	.52
	(.09)	(.11)	(.18)	(.19)	(.10)	(.16)	(.13)	(.11)	(.15)	(.10)	(.11)	(.12)

Note: * NFF = no final fricative member

** FF = final fricative member

Table 9

Paired comparisons within OM- and OM+ groups for selective perception of no final and final fricative member of target word-pairs

	OM-		OM+	
	F	p	F	p
Word-pair				
P1 [gɔ]/[gɔs]	.10	.74	.42	.52
P2 [teɪ]/teɪz]	.02	.88	10.79	.005*
P3 [pʌk]/[pʌks]	.10	.74	.02	.87
M1 [bok]/[boks]	.44	.51	.19	.66
M2 [dæp]/[dæps]	.02	.87	3.08	.004*
M3 [di]/[diz]	.66	.42	.66	.42

Note: * p < .008 based on Bonferoni correction procedure (.05/6 = .008)

Table 10

Paired comparisons between OM- and OM+ groups for selective perception of final fricative members of target word-pairs.

	OM- versus OM+	
	F	p
Final fricative target		
[gɔs]	7.32	.001*
[teɪz]	1.1	.311
[pʌks]	.18	.67
[boks]	1.32	.26
[dæps]	4.4	.005*
[diz]	.57	.42

Note: * p < .008 based on Bonferoni correction procedure (.05/6 = .008)

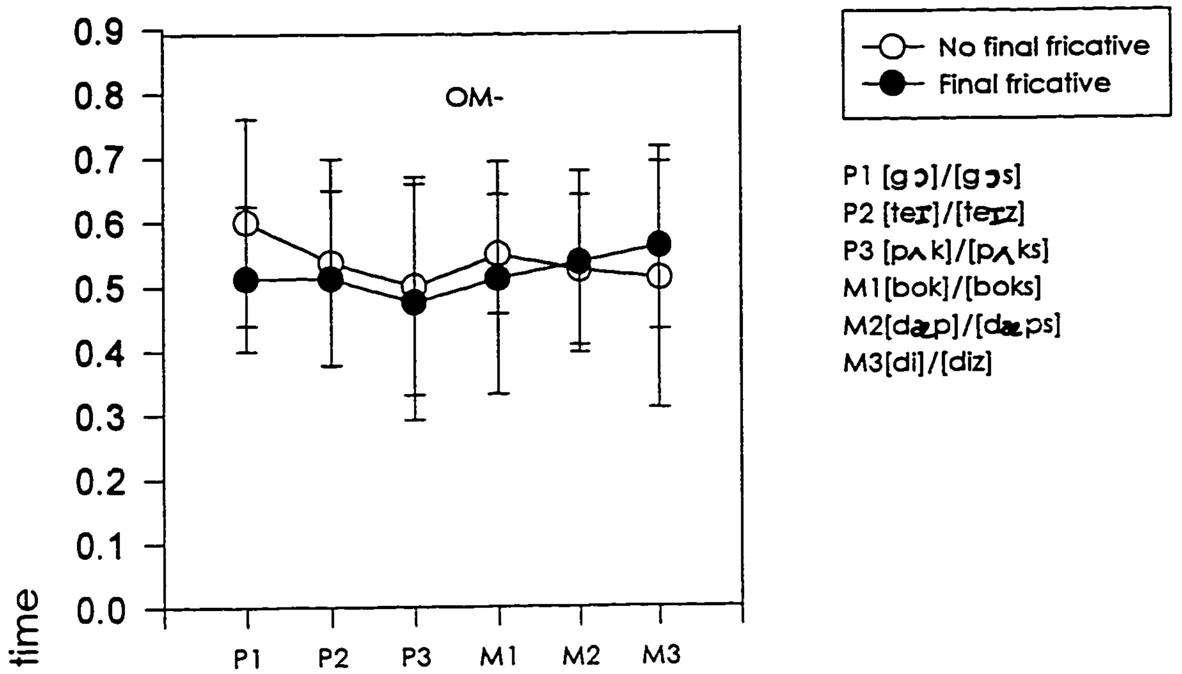

Figure 13a: Selective perception for no final and final fricative membesr within a word pair.

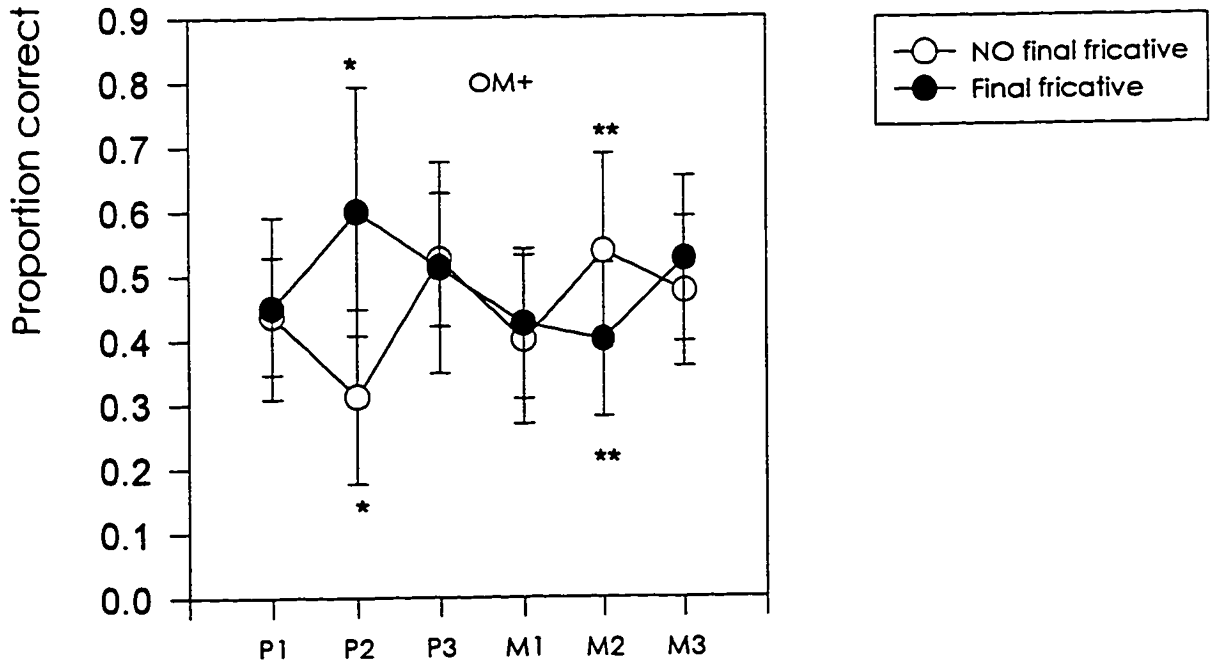

Figure 13b: Selective perception of no final and final fricative member within a word pair.

*$p < .05$

**$p < .05$

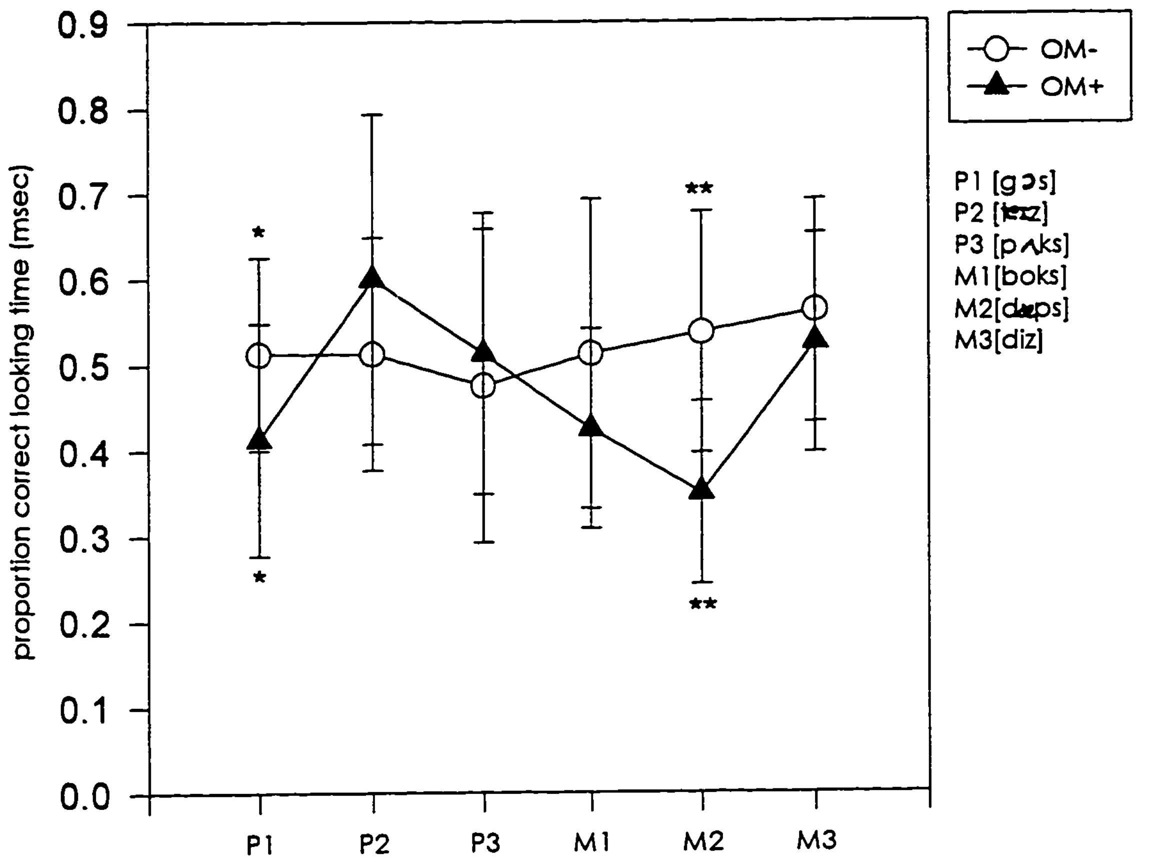

Figure 14: Selective perception of final fricative word pair member in the two groups.

* $p < .05$

** $p < .05$

Results based on second year OM history

A combination of first and second year OM history information yielded three subgroups. There were three children in each subgroup and documentation criteria included tympanometric and pneumatic otoscopy information along with hearing thresholds. Inclusion criteria in terms of OM history information were based on each individual child's status on every visit during the first two years of life. However, data analysis was based on group, rather than on individual subject performance. OM history for each individual child is reported in Appendix A. Table 11 reports OM history during both years of life for all three subgroups. Table 12 shows means and standard deviations of PCLT in the three subgroups on all word-pairs. Inter- and intra- subgroup comparisons for each linguistic category were based on PCLT. Figure 15a presents the mean PCLT of each subgroup for phonological and morphological contrasts. Figure 15b presents mean PCLT on all word-pairs. The small number of subjects within each subgroup precluded the use of any statistical analysis.

Subgroup 1. This group consisted of three children who were negative of OM during both years of life (N1N2). Based on tympanometric or pneumatic otoscopy results, the subjects were free of the disease for 100% (5/5) of the visits, and had hearing thresholds of less than 15 dB HL on all 10 visits during both years. As a group, their average hearing thresholds ranged from 12 to 13 dB HL (M = 12.3, SD = .57) during the first year, and from 7 to 9 dB HL (M = 8.7, SD = 1.1) during the second year. These were subjects 2, 5, and 6 (Appendix A). A visual inspection of Figure 15a showed that within N1N2 group, PCLT on phonological (M = .50, SD = .06) was slightly larger than for morphological (M = .47, SD = .03) category. When compared to subgroups 2 (P1N2) and 3 (P1P2), N1N2 had larger PCLT on phonological category. PCLT on morphological category was isometric to PCLT in P1N2 and P1P2 subgroups.

Subgroup 2. This group consisted of three children who were OM positive during the first year and OM negative during the second year of life (P1N2). During the first year the subjects were positive for OM for 60% (3/5) of the visits and their average hearing thresholds ranged from 23 to 27dB HL (M = 25.6, SD = 2.3). During the second year, tympanometric and otoscopic results suggested presence of the disease for only 17% (1/6) of visits, with average hearing thresholds ranging from 8 to 15 dB HL (M = 12.2, SD = 3.9). From Appendix A, subgroup 2 included subjects 9, 11, and 13. Within this group, mean PCLT was slightly smaller for the phonological (M = .46, SD = .05) than for the morphological contrast (M = .48, SD = .06). P1N2 group did slightly better on the phonological than on the morphological contrast, a pattern opposite to the one seen on subgroups 1 and 3. The difference among the three subgroups was mainly in favor of phonological category on which P1N2 children performed more poorly when compared to the other two subgroups. No differences were seen among subgroups in regard to morphological category.

Subgroup 3. The third subgroup included three children who continued to be positive for OM during the second year of life (P1P2). Tympanometric and otoscopic results during the first year indicated presence of the disease on 3 out of 5 visits (60%). This pattern continued as audiological results in the second year suggested OM episodes for 3 out of 6 visits (50%). As a group, the subjects did not show any improvement in terms of hearing thresholds. During the first year, average hearing thresholds ranged from 21 to 25 dB HL (M = 23, SD = 2), and during the second year from 17 to 24 dB HL (M = 21, SD = 3.6). As indicated in Appendix A, this group included subjects 14, 15, and 16. Mean PCLT was slightly larger for phonological (M = .49, SD = .04) than for morphological contrasts (M= .48, SD = .03), a pattern similar to the one seen for N1N2 group. As mentioned previously, when compared to subgroup 2, children in subgroup 3 had larger PCLT for phonological category, but on morphological perception PCLT was the same.

The main difference seen among subgroups was in terms of the phonological category. N1N2 children had the largest PCLT. The most remarkable difference was the smaller PCLT seen in P1N2 children as opposed to P1P2 group. This result that contradicted the prediction stating that P1N2 children would show better performance than P1P2 children. A more detailed observation of children's performance on individual word-pairs showed that the difference seen between subgroup 2 and subgroup 3 was due to one word-pair including P2 [teɪ]/[teɪz].

Performance of subgroups on individual word-pairs. According to Figure 15a, there was remarkable performance variability among subgroups on the different word-pairs. Particular focus was given on PCLT between P1N2 and P1P2 subgroups who presented with similar performance on all word-pairs except P2. On [teɪ]/[teɪz] P1N2 subgroup had smaller PCLT attribuTable to one child's (subject # 13) poor performance (M = .31). On the same pair, one child within P1P2 group (subject # 16) had large PCLT (M =.71). On morphological category PCLT was the same for all subgroups. In addition, the pattern of performance within morphological category for P1N2 and P1P2 groups was similar to the pattern seen in the larger data set analysis when OM children (n= 8) were defined according to OM history based only on the first year of life.

Table 11

Otitis media information in the three subgroups during the first and second year of life

	OM status Year 1		OM status Year 2	
	AHT[a]	Visits free of OM	AHT[a]	Visits free of OM
Subgroup 1	12.3	5/5(100%)	8.7	6/6(100%)
Subgroup 2	27	2/5(40%)	12.2	5/6(83%)
Subgroup 3	25	2/5(40%)	23	3/6(50%)

[a] Average hearing thresholds in dB HL

Table 12

Mean proportion correct looking time in the three subgroups on target word-pairs (standard deviations in parentheses)

Subgroup	Phonological			Morphological		
N1N2	P1	P2	P3	M1	M2	M3
Subject 2	.55	.62	.55	.46	.50	.58
Subject 5	.54	.41	.43	.44	.57	.42
Subject 6	.62	.48	.33	.48	.44	.42
M	.57 (.04)	.50 (.10)	.43 (.11)	.46 (.02)	.50 (.06)	.47 (.06)
P1N2	P1	P2	P3	M1	M2	M3
Subject 9	.42	.37	.53	.47	.45	.51
Subject 11	.40	.31	.6	.42	.38	.52
Subject 13	.51	.58	.5	.54	.50	.60
M	.44 (.05)	.42 (.14)	.54 (.05)	.47 (.06)	.44 (.06)	.54 (.05)
P1P2	P1	P2	P3	M1	M2	M3
Subject 14	.53	.37	.58	.42	.50	.58
Subject 15	.41	.48	.47	.50	.50	.54
Subject 16	.44	.71	.56	.4	.43	.52
M	.46 (.06)	.52 (.17)	.53 (.05)	.44 (.05)	.47 (.04)	.54 (.03)

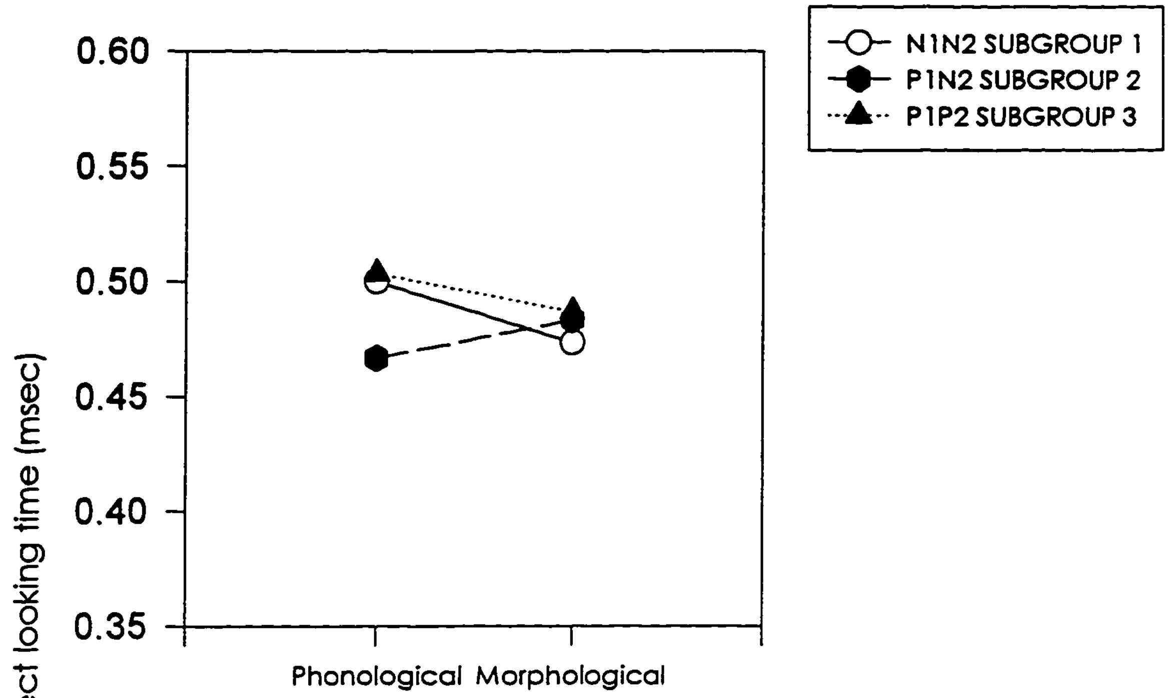

Figure 15a: Proportion correct for phonological and morphological categories in the three subgroups.

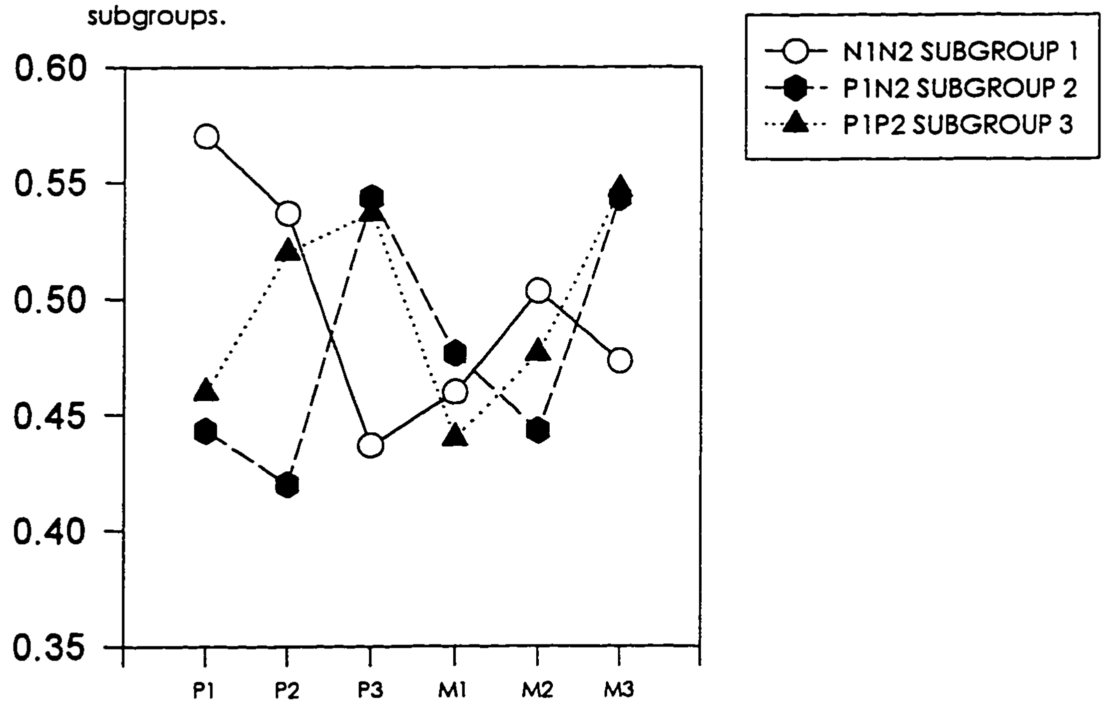

Figure 15b: Performance of the three subgroups on individual word pairs.

Chapter 4: Discussion

The current study examined the effects of otitis media on the perception of phonological and morphophonological markers. The focus was on the comprehension of final position [s] and [z] in three phonological and three morphological nonsense word-pairs. In morphological words emphasis was on plural {-s}. The investigation employed an experimental word-learning procedure. Perception was tested by using a cross-modal preferential looking, speech perception paradigm. The major set of analyses was based on data from two groups of children, the OM+ (n=8) and the OM- (n=8) with age range between 26 to 28 months. Otitis media documentation included results from frequent tympanometric, otoscopic, and audiometric examinations collected during the first and second year of life. A smaller set of analyses included three subgroups of children differing in OM history during the second year of life.

Unlike other studies, this was a prospective investigation and reported audiometric data. All children in the OM+ group had elevated thresholds, whereas children defined as OM- had normal hearing (less than 15 dB HL). Furthermore, the focus was on a specific linguistic area (perception of phonological and morphological forms) and examined developmentally young children. In addition, by employing a preferential looking paradigm, perception was directly tested. This eliminated the need to infer perception data from production.

Several predictions were made regarding the effects of OM on phonological and morphological perception. The first hypothesis was that OM- children would make all target distinctions and overall OM- performance would be superior to that of the OM+ children. The second hypothesis was that for OM+ group morphological distinctions would be more difficult than phonological distinctions. Overall, the findings supported both hypotheses advanced by the current study. OM- children made all target distinctions and performance was superior to that of the OM+ children. Furthermore, OM+ children had greater difficulties in perceiving target pairs in which one member ended with the voiceless sound [s], especially in the morphological category.

Group performance based on OM history during the first year

Perceptual distinction abilities in OM- and OM+ children based on correct versus incorrect looking time (absolute values). The accuracy of perceptual distinctions within each group was examined in terms of the difference between correct and incorrect looking time. The two groups were different in terms of bimodal eye-gaze behavior. OM- children looked significantly longer at the correct than the incorrect targets, a pattern that was consistent for both phonological and morphological contrasts. For the OM+ group, the difference between correct and incorrect looking time was not significantly different, despite a trend towards longer incorrect looking time. OM- children were able to make consistent target distinctions, whereas their OM+ counterparts were less consistent in making these distinctions. The ability of the OM- children to identify correct targets more often than the OM- children supported the first hypothesis of the study.

Within the OM+ group, a more detailed analysis as a function of each individual linguistic category showed that the tendency towards longer incorrect looking time occurred on phonological contrasts. For morphological targets, there was no significant difference between correct versus incorrect looking time. This group's differential performance on the two linguistic contrasts suggested a greater effect of OM on morphological than on phonological perception. It was evident that, regardless of eye-gaze direction, overall looking time was longer for phonological than for morphological pairs. The differential effect of OM on the two linguistic contrasts is also supported by the significantly greater amount of inattention looking time in favor of the morphological category. The results lead to certain speculations concerning the effects of OM on the development of phonological and morphological perception skills. One likely possibility is that the phonological perception of segments necessary to create a complete, accurate, and stable representation is prerequisite to the perceptual establishment of that segment as a morphological marker. The pattern of longer looking time for the phonological contrasts may be indicative of an effort from the child's part to perceive the target distinctions. However, because of incomplete underlying representation for phonological units, OM+ children were less certain of the picture/auditory stimulus match. The lack of preferential looking time suggests that the morphological marker for plurals is not yet established. Experience with OM during the critical years for language development may delay the perceptual establishment of phonological representations and consequently inhibit the development of morphological rules concerning the same segment. This is consistent with Pinker's (1984) description of morphological rule development: children not only need to perceive [s] or [z] as phonological units, but they also recognize them as morphological entities. Experience with an inconsistent speech signal caused by the hearing loss associated with OM has an effect on phonological perception and a greater effect on morphological perception. The scope of this effect could not be discerned from the initial analysis because the phonological and the data from the morphological word-pairs were collapsed.

Perceptual distinction abilities in OM- and OM+ children based on proportion correct looking time. The two groups were compared for proportion correct looking time (PCLT). PCLT corresponded to the time children spent looking at the correct targets (PLCT = correct time/ total correct + incorrect). Within each group the mean PCLTs for phonological and morphological contrasts were isometric. However, the OM- children had significantly larger PCLT than OM+ children on both linguistic contrasts. OM- children were more accurate in their perception skills than their OM+ counterparts. The lower PCLT in the OM+ group may reflect the child's uncertainty in terms of target distinctions. This observation is based on a PCLT critical range .42 to .58 determined from trial-by-trial analysis. Schwartz and Pollock (1983) examined the eye-gaze responses from 40 children and determined the critical range of .42 to .58 as the cut-off point for considering the child's looking as preferentially correct at .95 confidence level. Proportion correct looking values above .58 were considered as preferentially correct, below .42 were considered as preferentially incorrect, and anything between .42 to .58 were considered to be by chance. The mean PCLTs for the OM- children on phonological and morphological contrasts were .56 (SD = .07) and .55 (SD = .07) respectively. For the OM+ group the counterpart means were .48 (SD = .04) and .47 (SD = .03). For both groups, PCLT means fell within the "by chance" range. However, the OM+ children's means were closer to the .42 critical value suggesting a pattern towards preferentially incorrect. For the OM- children, the PCLT fell closer to the .58, suggesting eye-gaze behavior towards the preferentially correct cut-off critical value. We know from other studies (e.g., categorical perception) a difference in this range may reflect the degree of uncertainty in making target distinctions or may be the result of variation across stimulus pairs (e.g., [gɔ]/[gɔs], [bok]/[boks], [dæp]/[dæps]). The results from this analysis provided converging evidence regarding the negative effects of OM on phonological and morphological perception and supported the first hypothesis of the study. Further analyses of performance on individual word-pairs revealed that OM+ children had more difficulty with morphological than phonological contrasts. Analyses including individual word-pairs revealed that the OM+ children were able to make some of the distinctions such as phonological [teɪ]/[teɪz] and [pʌk]/[pʌks], as well as morphological [di]/[diz]. Specifically, OM+ and OM- children were significantly different on three word-pairs including one phonological and two morphological. The two groups were not significantly different from each other on two phonological and one morphological word-pair.

Performance of OM- and OM+ children on individual word-pairs. PCLT was examined between and within groups for each individual word-pair in the two linguistic contrasts.

Between group performance. The difference in PCLT between the groups was stronger for morphological than for phonological category. OM+ children performed more poorly than OM- children on one phonological word-pairs including P1 [gɔ]/ [gɔs], and on two morphological pairs including M1 [bok]/[boks] and M2 [dæp]/[dæps]. Pairs on which the two groups performed similarly included P2 [teɪ]/teɪz], P3 [pʌk]/[pʌks], and M3 [di]/[diz].

Three word-pairs that appeared to be most problematic for the OM+ children (P1, M1, M2) ended with the voiceless fricative [s], whereas words that were less problematic (P2, M3) ended in voiced [z]. One exception was the word-pair P3 [pʌk] /[pʌks] on which OM+ children seemed to have the least trouble. This word-pair will be discussed later.

An s/z effect could explain the differences seen between the two groups. Two prominent acoustic features characterizing [s] and [z] in syllables and words include voicing and duration of frication (Borden, Harris, & Raphael, 1994). In addition, vowels preceding a consonant are longer when compared to vowels preceding a voiceless consonant (Raphael, 1972). Thus, it is possible that [z] may have been more salient than [s]. However, in the present study duration of frication was edited so that it was equal across all word-pairs. Furthermore, the examiner examined the ratio of the vowel to the final voiceless and voiced fricative. For [gɔs], [teɪz], and [diz], the vowel ration was 2.0, 2.6, and 1.9 respectively. It appears that [teiz] might have been more salient to perception when compared to [gɔs] and [diz], due to the longer vowel/final consonant ratio. However longer vowel/final consonant ratio as a perceptual cue does not account for the differential performance of OM+ children between [gɔs] and [diz], because these two words had similar vowel ratios, 2.0 and 1.9 respectively.

It is possible that OM+ children did better with [z] because its voicing made it more audible than [s]. OM+ children in this study experienced transient hearing loss because of OM, with pure tone thresholds (PTA) averaged across speech frequencies of 500, 1000, 2000, and 4000 Hz. However, examining only the pure-tone average does not provide sufficient information in determining the source of differential treatment of voiced-voiceless fricatives. The configuration of the audiogram provides a more accurate description of the impairment. The audibility of [z] versus [s] might be determined by the frequencies affected. Although hearing loss associated with OM has been described as flat (Bess, 1986), the distribution of air conduction thresholds is qualitatively different across test frequencies (Fria, Cantekin, & Eichler, 1985). However, configuration of the hearing loss could not totally account for the differences seen between the two groups. The s/z effect does not appear to explain the results fully, because OM+ children were not different from OM- children on P3 [pʌk]/[pʌks], a word-pair that ended with a voiceless fricative.

A more plausible explanation is the interaction of [s] and [z] with the phonological/morphological nature of the stimuli. OM+ children performed less well than OM- children on both final [s] word-pairs that were morphological and on only one final [s] stimulus that was phonological. Overall, perceptibility of [s] was more difficult when this segment was morphological that when it was phonological.

Within-group performance. Performance on the word-pairs was also examined within each group as a function of each linguistic category. OM- children performed similarly on all word-pairs irrespective of segmental and/or linguistic category. However, in the OM+ group there was variability in performance on both the phonological and the morphological contrasts. Paired comparisons within phonological category did not reveal significant differences among target word-pairs, despite a trend seen between P1 [gɔ]/[gɔs] and P3 [pʌk]/[pʌks]. On P3 PCLT was larger than P1, even though the difference did not approach statistical significance. On the other hand, for the morphological category PCLT was significantly smaller on the word-pairs M1 [bok]/[boks] and M2 [dæp]/[dæps] when compared to M3 [di]/[diz]. One plausible speculation is that OM+ children did have some difficulties with voiceless fricatives when these occur as phonological entities, but their problem was exacerbated when [s] occurred as a morphophonological entity. Within the phonological category, perception of [s] was inconsistent. PCLT on P1 was smaller that PCLT for P3, even though this pattern was merely a trend and failed to reach statistical significance. Within the morphological category perception of [s] was non-existent, children did not perceived it on any of the words. Contrary to [s], [z] was accurately identified when it was phonological and morphological. From a developmental framework, the perceptual pattern seen in the OM+ children suggested that comprehension was emerging in phonological, but not in morphological category. From a theoretical perspective, this finding is consistent with Pinker's learnability theory (1984) stating that the formation of morphological rules involves not only the perception of a target segment, but also its placement in the corresponding morphological cell paradigm. Thus, morphological comprehension involves complex cognitive tasks that demand more that just a phonological distinction. The differential performance on the pairs [pʌk]/[pʌks] (phonological) versus [bok]/[boks] and [dæp]/[dæps] (morphological), supported the difficulty OM+ children had with two word-pairs that were phonologically similar, but linguistically different. It appears that s/z effect alone could not account for the patterns seen in the OM+ children. If children were paying more attention to [z] than to [s], irrespective of linguistic category, OM+ children would have shown a better performance on all final [z] word-pairs when compared to final [s] stimuli. Apparently this was not supported by the current results, because sometimes OM+ children performed similarly on word-pairs that consisted of final [s] and final [z] (e.g., no differences were seen between [gɔ]/[gɔs] and [teɪ]/[teɪz] or [pʌk]/[pʌks] and [di]/diz]).

Rather, the results from this investigation can be explained from a phonological /morphological framework in combination with the s/z effect. If we were to form a hierarchy of segmental/linguistic perceptual saliency, for OM+ children [z] was the easiest sound to perceive in both linguistic contrasts and [s] was more difficult especially when it occurred as a morphological marker. OM+ children had the most difficulty with morphological {-s}, because of its greater linguistic load as a plural marker.

Although, the study did not provide robust evidence for a lower acoustic weight corresponding to [s] as opposed to [z], intensity measurements from final [s] and final [z] revealed that final [z] was approximately 8 dB more intense than final [s]. This difference in intensity might have facilitated perceptibility of [z] versus [s]. However, differences in intensity levels could not support the differential perception seen between OM+ and OM- children, and within OM+ children group. On some word-pairs differing in intensity levels as a function of [s] and [z](e.g., [di]/[diz] vs. [pʌk]/[pʌks]), OM+ children had identical PCLT. Although not supported by the current investigation, a combination of parameters (lack of voicing cues, lower intensity levels) may constitute [s] as a sound of low acoustic weight. Cross linguistic studies with SLI children indicated that not all morphological markers are vulnerable to misperception (Leonard, 1989). The presence or absence of different acoustic properties corresponding to morphological inflections make particular markers either more or less salient to perception. The difference in the perception of [s] versus [z] may be attributed partly to subtle acoustic differences inherent in these two consonants.

In summary, OM+ children were shown to have greater difficulties with morphological and with phonological word-pairs. The source of this difficulty could be attributed to a synergistic relationship between the low acoustic and the high linguistic weight of the segment [s].

Selective perception of the final fricative within members of target word-pairs

A more detailed analysis of selective perception of no final versus final fricative members within word-pairs indicated that OM+ children preferred looking at members within a word-pair that contained a voiced fricative (e.g., [diz]), but had difficulty with one morphological pair ending in a voiceless fricative. This selective perceptual pattern seen in the OM+ children, provided some support in terms of the difficulty this group had with the perception of position final [s]. Selective perceptual difficulty with [s] was seen for the final fricative target of only one morphological word-pair, but for none of the phonological counterparts. Although not a robust effect, this perceptual pattern seen within OM+ children provides some evidence of the exacerbated perceptual difficulty of [s] as a morphological, but not as a phonological entity.

Group performance based on first and second year OM history

This part of the investigation examined the effects of OM on subgroups of children who were defined according to the persistence and/or absence of the disease during the second year of life. Each subgroup consisted of three children: three children free of OM during both years of life (N1N2), three children positive in the first and negative in the second year (P1N2), and three children positive during the first and second year of life (P1P2). This was a preliminary analysis and an attempt was made to identify any differential, if any, effects of OM as a function of the particular year the disease occurs. The general speculation was that children with no OM history during the second year of life would perform better than children who remained positive during the second year. The prediction was non-directional. No specific hypotheses were made in terms of phonological or morphological perception between the two OM+ subgroups. Based on descriptive analysis as a function of PCLT on specific word-pairs, the difference seen between the two subgroups on phonological category was attributed to one word-pair including [teɪ]/[teɪz]. One child belonging to the P1N2 group presented with low PCLT, whereas one other child in P1P2 group did remarkably well despite his OM+ status during both years of life. If one excludes this word-pair on which there was great variability, the P1N2 and P1P2 groups were similar in their performance on all word-pair in both phonological and morphological contrasts. In fact the patter of performance within the morphological category was comparable to the pattern seen when data analysis included the larger OM+ group (n = 8), discussed earlier in the paper.

General conclusion and directions for future research

The current investigation examined the effects of OM on phonological and morphological perception. The results indicated that OM, and its associated hearing loss, had a negative effect on phonological and morphological perception. Children with no significant history of OM performed better on perceptual identification tasks including novel word-pairs. Thus, experience with OM during the first year of life may have a negative impact on the development of speech perception. The negative effects of OM on speech perception were supported by analyses that focused on individual word-pairs. OM+ children were shown to have difficulties with phonological targets and greater difficulties with morphological final position [s] targets.

The effects of OM on phonological and morphological perception was not an all-or-none phenomenon. The sound [s] appeared to be more difficult than [z] especially when the former occurred as a morphophonological entity (e.g., {-s} for plural). Some of the acoustic characteristics of [s] could account for this differential treatment of [s] versus [z]. Nevertheless, this study suggested that the first year in life is critical for the development of stable and consistent speech perception.

Currently, there is converging evidence suggesting that, for some children with early histories of OM, the negative effects of the disease persist during preschool and school years. These persistent effects appear as atypical phonological patterns (Shriberg & Smith, 1983), verbal memory deficits (Mody, Schwartz, Gravel, Wallace, et al., 1995), attention and auditory processing difficulties during tasks requiring higher signal-to-noise ratio (Gravel & Wallace, 1992), and difficulties with perception of voicing (Eimas & Clarkson, 1986; Groenen et al., 1996).

Questions remain whether OM+ children continue to have problems later in life and what variables might influence the persistence of these problems. Future research should address this issue by isolating and controlling certain variables (e.g., MLU, parental language input, degree and configuration of hearing loss) in identifying children who have persistent difficulties. In addition, future studies should, ideally, be designed as prospective cohort investigations, and, if possible, examine the same children at different stages critical to language development. Because this was a cross-sectional investigation, we do not know if the deficits seen in OM+ children will persist beyond the time of testing. However, we do have additional information regarding the immediate effects of OM on children's performance during experimental tasks. Four OM+ children who failed tympanometric screening on the day of the experiment, performed more poorly than on days they passed tympanometric screening.

Another important issue pertains to the effects of OM during a particular chronological age. Preliminary data from subgroups of children with and without OM in the second year of life indicated no significant differences between the two subgroups. The results should be interpreted with some caution, because of the small number of subjects included within each subgroup. Studies examining the effects of OM during critical periods for language development, should expand on the number of subjects within subgroups of children who experience OM only during the first or second year of life, as well as children positive during both years.

Overall, the current investigation suggested that auditory deprivation and experience with an inconsistent speech signal as a result of OM, even as early as the first year of life, is sufficient to create speech perception difficulties at age 2. Within the OM+ group the examiner looked at subject performance as a function of hearing thresholds during the first year of life. Results suggested that two children with the highest thresholds (M = 27 dB HL) performed more poorly when compared to children with the lowest thresholds (M = 20 dB HL). This pattern suggests that the degree of hearing loss seen within OM+ children, may play a crucial role in determining the severity of the impact. The results should be interpreted with some caution, because of the small number of subjects as well as the limited choice of stimuli. Future research needs to expand on the number of stimuli and also examine any long term deficits of OM beyond the age of 2 years. Furthermore, additional work is needed to separate the effects of fluctuating conductive hearing loss from OM and help us determine whether OM is a disease or a disorder.

Appendix A

Otitis media history on all children in first and second years.

Subject	Children defined as OM - Year 1 AHT	SD	B+	B-	U+	Same children Year 2 AHT	SD	B+	B-	U+
1	20	14	0	5	0	19	6	0	5	1
2	12	6	1	4	0	10	5	0	6	0
3	16	10	0	4	1	18	9.5	0	4	1
4	5	.8	0	5	0	6	2.9	0	4	1
5	13	9	0	5	0	11	7	0	6	0
6	12	5	0	5	0	8	5	0	6	0
7	12	6	0	5	0	10	4	0	6	0
8	12	4.5	0	4	1	13	1.7	0	6	0
M	12.7	8.5	.12	4.6	.2	11.8	5.2	0	5.3	.3
SD	4.2	5.3	.3	.5	.46	4.8	2.1	0	.9	.5

	Children defined as OM + Year 1 AHT	SD	B+	B-	U+	Same children Year 2 AHT	SD	B+	B-	U+
9	27	21	2	2	1	8.3	4.4	0	5	1
10	20	13	2	3	0	10	2.8	3	2	0
11	20	17	2	2	1	16.2	6.1	1	5	0
12	23	3	2	3	0	12.3	5.5	2	3	1
13	27	9.5	2	2	1	9	2	0	6	0
14	25	3.5	1	3	1	24	5.1	4	2	0
15	23	7	2	3	0	22	14	3	0	3
16	21	8	1	1	3	16	5	5	0	1
M	23	10	1.7	2.3	.8	15.5	5.7	2.2	2.8	.78
SD	2.5	7.3	.46	.74	.9	5.9	3.9	1.8	2	1

Note: AHT = average hearing thresholds in dB HL; S =D, standard deviations of hearing thresholds; B+ = number of visits bilaterally positive; B- = number of visits bilaterally negative; U+ = number of visits unilaterally positive.

Appendix B

Duration in msec of each experimental word on different acoustic dimensions with parentheses indicating the ratio of vowel to final consonant

Word-pair 1	Initial Stop closure	VOT	Vowel duration	Final stop Closure	Final stop Burst	Final fricative	Total word duration	Amplitude in dBA
[gɔs]	160	18	400(2)	n/a	n/a	200	778	51
[gɔ][a]	170	26	580	n/a	n/a	n/a	776	52
[gɔ][b]	170	26	410	n/a	n/a	n/a	606	52
Word-pair 2								
[boks]	124	9	290(1.4)	138	22	200	783	51
[bok][a]	154	9	300	246	32	n/a	741	52
[bok][b]	134	9	300	146	32	n/a	621	51
Word-pair 3								
[dæps]	141	9	240(1.2)	240	20	200	850	52
[dæp][a]	143	9	300	350	20	n/a	822	51
[dæp][b]	143	9	240	250	20	n/a	662	52
Word-pair 4								
[teɪz]	140	120	520(2.6)	n/a	n/a	200	980	58
[teɪ][a]	140	120	710	n/a	n/a	n/a	970	57
[teɪ][b]	140	120	540	n/a	n/a	n/a	800	55
Word-pair 5								
[pʌks]	126	60	213(1.6)	205	7	130	741	51
[pʌk][a]	136	70	278	219	17	n/a	720	51
[pʌk][b]	136	70	223	215	17	n/a	661	49
Word-pair 6								
[d i z]	144	2	380(1.9)	n/a	n/a	200	726	52
[d i][a]	150	7	578	n/a	n/a	n/a	735	51
[d i][b]	150	7	390	n/a	n/a	n/a	547	50

[a] Token matched to its counterpart member for total word duration

[b] Token matched to its counterpart member for vowel duration

Appendix C

Speech perception sequence of phonological pair 1. Underlined words refer to the audio presentation (the correct answer). The stimuli refer to unfamiliar object 1 [gɔ], unfamiliar object 2 [gɔs], familiar foil 1 (dog) and familiar foil 2 (car).

TRIAL	LEFT	RIGHT	LEFT	RIGHT
1	gɔ (learning trial)	gɔ (learning trial)	unfamiliar 1	unfamiliar 1
2	gɔ (learning trial)	gɔ (learning trial)	unfamiliar 1	unfamiliar 1
3	gɔ s (learning trial)	gɔ s (learning trial)	unfamiliar 2	unfamiliar 2
4	gɔ s (learning trial)	gɔ s (learning trial)	unfamiliar 2	unfamiliar 2
5	gɔ	gɔ s	unfamiliar 1	unfamiliar 2
6	car	gɔ s	familiar 2	unfamiliar 2
7	gɔ s	gɔ	unfamiliar 2	unfamiliar 1
8	gɔ	gɔ s	unfamiliar 1	unfamiliar 2
9	gɔ	dog	unfamiliar 1	familiar 1
10	gɔ s	gɔ	unfamiliar 2	unfamiliar 2
11	gɔ s	gɔ	unfamiliar 2	unfamiliar 1
12	gɔ s	gɔ	unfamiliar 2	unfamiliar 1
13	gɔ s	gɔ	unfamiliar 2	unfamiliar 1
14	gɔ	gɔ s	unfamiliar 1	unfamiliar 2
15	dog	gɔ	familiar 1	unfamiliar 1
16	gɔ	gɔ s	unfamiliar 1	unfamiliar 2
17	gɔ	gɔ s	unfamiliar 1	unfamiliar 2
18	gɔ s	gɔ	unfamiliar 2	unfamiliar 1
19	gɔ s	car	unfamiliar 2	familiar 2
20	gɔ	gɔ s	unfamiliar 1	unfamiliar 2

Appendix D

Speech perception sequence of morphological pair 1. Underlined words refer to the audio presentation (the correct answer). The stimuli refer to unfamiliar object 1 in its singular [bok] and plural [boks] form, and familiar foil 1 in its singular (cup) and plural form (cups).

TRIAL	LEFT	RIGHT	LEFT	RIGHT
1	bok (learning trial)	bok (learning trial)	unfamiliar 1	unfamiliar 1
2	bok (learning trial)	bok (learning trial)	unfamiliar 1	unfamiliar 1
3	boks (learning trial)	boks (learning trial)	unfamiliar 1 plural	unfamiliar 1 plural
4	boks (learning trial)	boks (learning trial)	unfamiliar 1 plural	unfamiliar 1 plural
5	bok	boks	unfamiliar 1	unfamiliar 1 plural
6	cups	boks	familiar 1 plural	unfamiliar 1 plural
7	boks	bok	unfamiliar 1 plural	unfamiliar 1
8	boks	bok	unfamiliar 1 plural	unfamiliar 1
9	boks	bok	unfamiliar 1 plural	unfamiliar 1
10	bok	boks	unfamiliar 1	unfamiliar 1 plural
11	bok	boks	unfamiliar 1	unfamiliar 1 plural
12	bok	boks	unfamiliar 1	unfamiliar 1 plural
13	boks	bok	unfamiliar 1 plural	unfamiliar 1
14	bok	boks	unfamiliar 1	unfamiliar 1 plural
15	boks	cups	unfamiliar 1 plural	familiar 1 plural
16	boks	bok	unfamiliar 1 plural	unfamiliar 1
17	cup	bok	familiar 1	unfamiliar 1
18	bok	cup	unfamiliar 1	familiar 1
19	bok	boks	unfamiliar 1	unfamiliar 1 plural
20	boks	bok	unfamiliar 1 plural	unfamiliar 1

Appendix E

Speech perception sequence of morphological pair 2. Underlined words refer to the audio presentation (the correct answer). The stimuli refer to unfamiliar object 1 in its singular [dæp] and plural [dæps] form, and familiar foil 1 in its singular (book) and plural form (books).

TRIAL	LEFT	RIGHT	LEFT	RIGHT
1	dæp (learning trial)	dæp (learning trial)	unfamiliar 1	unfamiliar 1
2	dæp (learning trial)	dæp (learning trial)	unfamiliar 1	unfamiliar 1
3	dæps (learning trial)	dæps (learning trial)	unfamiliar 1 plural	unfamiliar plural
4	dæps (learning trial)	dæps (learning trial)	unfamiliar 1 plural	unfamiliar 1 plural
5	dæps	dæp	unfamiliar 1 plural	unfamiliar 1
6	dæp	dæps	unfamiliar 1	unfamiliar 1 plural
7	dæps	dæp	unfamiliar 1 plural	unfamiliar 1
8	dæps	book	unfamiliar 1 plural	familiar 1
9	books	dæp	familiar 1 plural	unfamiliar 1
10	dæps	dæp	unfamiliar 1 plural	familiar 1
11	dæps	dæp	unfamiliar 1 plural	unfamiliar 1
12	dæp	dæps	unfamiliar 1	unfamiliar 1 plural
13	dæp	dæps	unfamiliar 1	unfamiliar 1 plural
14	dæp	dæps	unfamiliar 1	unfamiliar 1 plural
15	dæp	books	unfamiliar 1	familiar 1 plural
16	book	dæps	familiar 1	unfamiliar 1 plural
17	dæp	dæps	unfamiliar 1	unfamiliar 1 plural
18	dæp	dæps	unfamiliar 1	unfamiliar 1 plural
19	dæps	dæp	unfamiliar 1 plural	unfamiliar 1
20	dæps	dæp	unfamiliar 1 plural	unfamiliar 1

Appendix F

Speech perception sequence of phonological pair 2. Underlined words refer to the audio presentation (the correct answer). The stimuli refer to unfamiliar object 1 [teɪz], (unfamiliar object 2 [teɪ], familiar foil 1 (cup) and familiar foil 2 (sock).

TRIAL	LEFT	RIGHT	LEFT	RIGHT
1	teɪ (learning trial)	teɪ (learning trial)	unfamiliar 2	unfamiliar 2
2	teɪ (learning trial)	teɪ (learning trial)	unfamiliar 2	unfamiliar 2
3	teɪ (learning trial)	teɪz (learning trial)	unfamiliar 1	unfamiliar 1
4	teɪz (learning trial)	teɪz (learning trial)	unfamiliar 1	unfamiliar 1
5	teɪ	sock	unfamiliar 2	familiar 2
6	teɪ	teɪz	unfamiliar 2	unfamiliar 1
7	teɪz	teɪ	unfamiliar 1	unfamiliar 2
8	cup	teɪz	familiar 1	unfamiliar 1
9	teɪz	teɪ	unfamiliar 1	unfamiliar 2
10	teɪ	teɪz	unfamiliar 2	unfamiliar 1
11	teɪz	cup	unfamiliar 1	familiar 1
12	teɪz	teɪ	unfamiliar 1	unfamiliar 2
13	teɪ	teɪz	unfamiliar 2	unfamiliar 1
14	teɪ	teɪz	unfamiliar 2	unfamiliar 1
15	sock	teɪ	familiar 2	unfamiliar 2
16	teɪ	teɪz	unfamiliar 2	unfamiliar 1
17	teɪz	teɪ	unfamiliar 1	unfamiliar 2
18	teɪz	teɪ	unfamiliar 1	unfamiliar 2
19	teɪz	teɪ	unfamiliar 1	unfamiliar 2
20	teɪ	teɪz	unfamiliar 2	unfamiliar 1

Appendix G

Speech perception sequence of phonological pair 3. Underlined words refer to the audio presentation (the correct answer). The stimuli refer to unfamiliar object 1 [pʌks], unfamiliar object 2 [pʌk], familiar foil 1 (dog) and familiar foil 2 (car).

TRIAL	LEFT	RIGHT	LEFT	RIGHT
1	pʌ k (learning trial)	pʌk (learning trial)	unfamiliar 2	unfamiliar 2
2	pʌk (learning trial)	pʌk (learning trial)	unfamiliar 2	unfamiliar 2
3	pʌks(learning trial)	pʌks (learning trial)	unfamiliar 1	unfamiliar 1
4	pʌks(learning trial)	pʌks (learning trial)	unfamiliar 1	unfamiliar 1
5	pʌ ks	pʌk	unfamiliar 1	unfamiliar 2
6	cup	pʌk	familiar 2	unfamiliar 2
7	pʌ k	pʌks	unfamiliar 2	unfamiliar 1
8	pʌk	pʌks	unfamiliar 2	unfamiliar 1
9	pʌk	pʌ k s	unfamiliar 2	unfamiliar 1
10	pʌks	pʌk	unfamiliar 1	unfamiliar 2
11	pʌks	pʌk	unfamiliar 1	unfamiliar 2
12	pʌks	pʌk	unfamiliar 1	unfamiliar 2
13	pʌk	pʌks	unfamiliar 2	unfamiliar 1
14	pʌks	pʌk	unfamiliar 1	unfamiliar 2
15	pʌk	cup	unfamiliar 2	familiar 2
16	pʌk	pʌks	unfamiliar 2	unfamiliar 1
17	dog	pʌks	familiar 1	unfamiliar 1
18	pʌks	dog	unfamiliar 1	familiar 1
19	pʌks	pʌk	unfamiliar 1	unfamiliar 2
20	pʌk	pʌks	unfamiliar 2	unfamiliar 1

Appendix H

Speech perception sequence of morphological pair 3. Underlined words refer to the audio presentation (the correct answer). The stimuli refer to unfamiliar object 1 in its singular [di] and plural [diz] form, familiar foil 1 in its singular form (doll) and familiar foil 1 in its plural form (dolls).

TRIALS	LEFT	RIGHT	LEFT	RIGHT
1	di (learning trial)	di (learning trial)	unfamiliar 1	unfamiliar 1
2	di (learning trial)	di (learning trial)	unfamiliar 1	unfamiliar 1
3	diz (learning trial)	diz (learning trial)	unfamiliar 1 plural	unfamiliar 1 plural
4	diz (learning trial)	diz (learning trial)	unfamiliar 1 plural	unfamiliar 1 plural
5	di	diz	unfamiliar 1	familiar 1 plural
6	doll	diz	familiar 1	unfamiliar 1 plural
7	diz	di	unfamiliar 1 plural	unfamiliar 1
8	di	diz	unfamiliar 1	unfamiliar 1 plural
9	di	dolls	unfamiliar 1	familiar 1 plural
10	diz	di	unfamiliar 1 plural	unfamiliar 1
11	diz	di	unfamiliar 1 plural	unfamiliar 1
12	diz	di	unfamiliar 1 plural	unfamiliar 1
13	diz	di	unfamiliar 1 plural	unfamiliar 1
14	di	diz	unfamiliar 1	unfamiliar 1 plural
15	dolls	di	familiar 1 plural	unfamiliar 1
16	di	diz	unfamiliar 1	unfamiliar 1 plural
17	di	diz	unfamiliar 1	unfamiliar 1 plural
18	diz	di	unfamiliar 1 plural	unfamiliar 1
19	diz	doll	unfamiliar 1 plural	familiar 1
20	di	diz	unfamiliar 1	unfamiliar 1 plural

Appendix I

Means and standard deviations for proportion correct looking time for all children on phonological (P) and morphological (M) word-pairs

Subject		Phonological				Morphological		
OM -	P1	P2	P3	Mean	M1	M2	M3	Mean
1	.56	.66	.57	.59	.51	.51	.52	.51
2	.55	.62	.55	.57	.46	.50	.58	.51
3	.61	.55	.57	.57	.61	.67	.58	.62
4	.75	.49	.50	.58	.62	.55	.49	.55
5	.54	.41	.43	.46	.44	.57	.42	.47
6	.62	.58	.33	.51	.48	.44	.42	.44
7	.50	.48	.60	.52	.52	.55	.56	.54
8	.73	.66	.62	.67	.70	.70	.75	.71
M	.60	.55	.52	.56	.54	.56	.54	.55
SD	(.09)	(.09)	(.09)	(.07)	(.09)	(.08)	(.10)	(.08)
OM+	P1	P2	P3	Mean	M1	M2	M3	Mean
9	.42	.37	.53	.44	.47	.45	.51	.47
10	.42	.53	.53	.49	.42	.38	.56	.45
11	.51	.58	.50	.53	.54	.50	.60	.54
12	.34	.56	.51	.47	.34	.45	.52	.43
13	.40	.31	.60	.43	.42	.38	.52	.44
14	.53	.37	.58	.49	.42	.50	.58	.50
15	.41	.48	.47	.45	.50	.50	.54	.51
16	.44	.71	.56	.55	.40	.43	.52	.45
M	.43	.48	.52	.48	.43	.44	.54	.47
SD	(.06)	(.13)	(.04)	(.04)	(.06)	(.05)	(.03)	(.03)

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