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Restricted consonant inventories of 2-year-old Finnish children with a history of recurrent acute otitis media

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Abstract
Many children experience recurrent acute otitis media (RAOM) in early childhood. In a previous study, 2-year-old children with RAOM were shown to have immature neural patterns for speech sound discrimination. The present study further investigated the consonant inventories of these same children using natural speech samples. The results showed that 2-year-old children with RAOM ($N = 19$) produced fewer words and had

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smaller consonant inventories compared to the healthy controls ($N = 21$). In particular, the number of consonants produced in the medial position of words was restricted. For places and manners of articulation, the most notable difference between the groups was observed for fricatives, which were produced less often by the children with RAOM than by the controls. These results further support the assumption that early and recurrent middle ear infections should be considered a risk factor for language development.

Keywords

Acquisition of Finnish, middle ear infections, otitis media, phonology, speech production

During the first years of life, many children are exposed to fluctuating hearing loss of 20–30 dB caused by otitis media (OM) (Koivunen, Uhari, Laitakari, Alho, & Luotonen, 2000; Teele, Klein, & Rosner, 1989). OM is a general term for different types of middle ear infections, for example, acute otitis media (AOM), otitis media with effusion (OME), and recurrent acute otitis media (RAOM) (Lieberthal et al., 2013). Several studies have discovered linguistic problems in children with various forms of OM (e.g., Friel-Patti & Finitzo, 1990; Luotonen et al., 1998; Nittrouer & Burton, 2005; Wallace et al., 1988; Winskel, 2006) and also the limited nonverbal strategies they use to overcome communication difficulties (Yont, Snow, & Vernon-Feagans, 2001). However, other studies have found no relationship between OM and language development (e.g., Johnson, McCormick, & Baldwin, 2008; Paradise et al., 2000, 2003; Serbetcioglu, Ugurtay, Kirkim, & Mutlu, 2008). The diagnosis of various forms of OM and monitoring of the disappearance of middle ear fluid is clinically challenging (Lieberthal et al., 2013), which has led to heterogeneity in OM populations in the literature. This inconsistency could also result in conflicting outcomes regarding the effects of OM on language development.

Recently, we reported results suggesting the presence of immature speech sound discrimination processes in the central auditory system of 2-year-old children with RAOM (Haapala et al., 2014). These children had atypical neural responses (mismatch negativity, MMN), reflecting difficulties in the preattentive discrimination of small speech sound contrasts such as consonants. Furthermore, the left hemispheric lateralization of consonant discrimination observed in the typically developing controls was not observed in the RAOM group. This suggests that their linguistic left hemisphere (see Locke, 1997), which typically is specialized for processing familiar phoneme category representations (Liebenthal, Binder, Spitzer, Possing, & Medler, 2005), is abnormally developed. It is important to connect these neural findings to their behavioral counterparts.

The development of phonology

Prelinguistic development plays an important role in language acquisition. Early phonological development, including consonant acquisition, is a predictor of ambient language and correlates with the development of other linguistic functions such as vocabulary and morphology (Stoel-Gammon, 2011; Vihman, 1996). Furthermore, early phonological impairments, even mild ones, have been suggested to lead to later problems in speech and/or literacy skills (Bishop & Clarkson, 2003; Lewis et al., 2006).

Together with linguistic-cognitive abilities and speech-motor skills, a well-functioning auditory system is vital for phonological development. Newborn children have an innate ability to categorize sounds (Kuhl, 2010); even fetuses are able to perceive sounds and speech (Huotilainen et al., 2005; Partanen et al., 2013). The language environment begins to influence phonetic discrimination during the second half of the first year, during which infants begin to specialize in their native language (Kuhl et al., 2008). Representations of native language vowels develop earlier than those of consonants, but already at the end of the first year the accuracy of foreign language consonant discrimination decreases and the accuracy of native language consonant discrimination increases (Kuhl et al., 2008).

Phonetic skills and motor practice create a basis for word production. Children begin to produce repeated CV syllables, referred to as canonical babbling, at the age of 6–10 months (Boysson-Bardies et al., 1992), and their first words are often constructed using these syllables (Stoel-Gammon, 2011). The phonetic structure of the native language also appears in children's vocalizations before the end of the first year (Boysson-Bardies et al., 1992) and in early words (Kunnari, 2003; Stoel-Gammon, 1985). Regardless of the language that the child is learning, the first consonants are often highly visible (Vihman et al., 1985). Phonemes with an anterior place of articulation are acquired earlier than phonemes with a posterior place of articulation (Locke, 2002). Jakobson (1968) proposed a universal developmental trajectory for consonant acquisition, from stops to nasals, and further to fricatives and liquids (laterals and trills). It appears that consonants that occur most frequently in a language are learned earlier than consonants with a low frequency (Locke, 2002). In addition, the rate of using a segment in an ambient language to differentiate one word from another, the so-called functional load, determines the acquisition order of consonants (van Severen et al., 2013).

Phonological and lexical development overlap in a compact, reciprocal manner (for a review, see Stoel-Gammon, 2011). First, the discrimination of native language phoneme contrasts creates a basis for learning word meanings (see Jansson-Verkasalo et al., 2010), and later a child's lexicon has a further impact on the phonological knowledge (Stoel-Gammon, 2011; Vihman, 1996). On the other hand, it has been suggested that children adopt word patterns in a holistic manner first and that phonemic patterns of words are built up incrementally (Locke, 1997). Development from phonetic discrimination to language-specific phonemic representations, however, begins before the end of the second year (Locke, 1997). In light of these theories, the age of 2 is an excellent time to study phonological development. Because phonological and lexical development go hand-in-hand it is important to also examine the size of the child's lexicon in addition to the phonological analysis (Kunnari, Savinainen-Makkonen, & Paavola, 2006; Stoel-Gammon, 2011).

Phonological aspects of Finnish

The current study was carried out on children whose native language is Finnish. Finnish has 11 consonants that occur in the initial positions of words: /p, t, k, n, m, l, r, s, h, v, j/, and occasionally /d/ (Sulkala & Karjalainen, 1992). In some dialects, /d/ is rare or even missing. Additionally, /ŋ/ occurs medially in words. In addition to these 13 consonants, /b, g, f, ʃ/ occur in loanwords. Consonants occur infrequently in the final positions of words; only /t, n, l, r, s/ occur in endogenous Finnish words. Hence, Finnish has relatively few consonants compared with the 24 consonants of English. On average, typically developing 2-year-old Finnish children produce six word-initial, seven word-medial, and only one word-final consonant (Kunnari et al., 2006), while English-speaking children produce about ten word-initial and six word-final consonants at that age (Stoel-Gammon, 2011). However, the variation in typical development is large (Kunnari et al., 2006), as is also the case in other languages (Vihman, 1996). Acoustically, Finnish phonemes are easy to distinguish because of the language's simple fricative system and lack of voiced/voiceless opposition (Karlsson, 1983).

Most words in the Finnish language are bisyllabic, but long words with three or more syllables are also very common (Karlsson, 1983, p. 217). Finnish morphology is rich and includes word formations with several suffixes, which further lengthens words (Helasvuo, 2008). In contrast, monosyllabic words are rare, and Finnish children typically attempt to produce longer, bisyllabic words as their first words (Kunnari, 2003). Essentially, Finnish words have one-, two- or three-mora syllables (consisting of the first vowel of the syllable and the following segments), with CV syllables being the most common (Helasvuo, 2008).

Finnish is a quantity language (Sulkala & Karjalainen, 1992), i.e., both the vowel and consonant phoneme lengths influence the meaning of words, for example: [tuli] 'fire' vs. [tulli] 'customs' vs. [tuuli] 'wind'. All consonants except for /d, h, v, j/ can appear as geminates (double consonants) in the medial position of words. The saliency of the medial positions of words in Finnish, especially for consonant geminates, may be one reason that Finnish children have more consonants in their word-medial inventories than their word-initial inventories (Kunnari, 2003; Kunnari et al., 2006; Savinainen-Makkonen, 2007). The omission of word-initial consonants is also a typical developmental feature in Finnish children (Kunnari, 2003; Savinainen-Makkonen, 2000). Universal characteristics are that stops and nasals are often acquired first and that word-final consonants emerge slowly and are rare during the early phases of development (Kunnari, 2003; Kunnari et al., 2006; for a more detailed description of Finnish phonological characteristics, see Saaristo-Helin, Kunnari, & Savinainen-Makkonen, 2011).

The consonant production of children with otitis media

Degraded auditory perception during the first years of life can affect linguistic development. It is known that phonological development in children with sensorineural hearing loss is delayed; for example, their consonant inventories are smaller than those of their normal hearing peers (Moeller et al., 2007). Fluctuating hearing loss due to middle ear effusion, even for short amounts of time, can also lead to challenges for the developing central auditory system. Stable, language-specific phonological representations may be hard to construct from the constantly changing and inaccurate auditory input. This can result in difficulties in discriminating speech sounds accurately (Petinou, Schwartz, Gravel, & Raphael, 2001), even years after the child's hearing has stabilized (Mody, Schwartz, Gravel, & Ruben, 1999; Zumach, Chenault, Anteunis, & Gerrits, 2011). Weak phonological representations can be reflected in expressive speech as small phonemic inventories, and further, as restricted lexicons.

There are relatively few studies on consonant inventories in young children with OM. Nonetheless, these studies have indicated delayed or atypical phonological development. Petinou, Schwartz, Mody, and Gravel (1999) found that the babbling of 10- to 14-month-old children with OM during the first year of life differed from that of typically developing controls. These children showed a preference for bilabial plosives, which are highly visible when produced. Furthermore, delayed early phases of consonant acquisition were found in the case study of Miccio, Gallagher, Grossman, Yont, and Vernon-Feagans (2001). They followed six 12- to 48-month-old children with OM occurring for at least 2.5 months each year between the ages of 12 and 36 months. One child with the most severe hearing loss had problems with language acquisition throughout the entire study period, while the others reached typical levels by the end of the study. However, all of the children exhibited some abnormalities or delays in the acquisition of fricatives. Abraham, Wallace, and Gravel (1996), who studied 2-year-old children with bilateral OM during their first year of life, found that the children had difficulties with word-initial consonants and consonants with back-placed articulation. The consonant inventories of Finnish-speaking children with RAOM have not been studied specifically; however, in her comprehensive study of typical phonological development in Finnish-speaking children Kunnari (2000) reported that three of the ten children studied had experienced recurrent OM, which may have delayed word acquisition and phonological development.

Aims of the study

To date, studies of the effects of OM on consonant inventories have investigated small groups of English-speaking children with a heterogeneous background of middle ear infections. Therefore, more research is needed on the effects of unstable auditory signals resulting from RAOM on the acquisition of consonants. Recently, we showed that early childhood RAOM affected the central auditory discrimination of syllables in 2-year-old children (Haapala et al., 2014). In the present study, we investigated the consonant inventories of these same children. We compared the consonant inventory sizes of the children with RAOM and their typically developing peers. We also studied the association between the number of words produced in a speech sample and the consonant inventory size. Furthermore, we determined group differences in the quality of consonant inventories according to the place and manner of articulation.

Method

Participants

Nineteen 2-year-old (22–27 months; mean 24 months) children with a history of RAOM and 21 typically developing controls (22–26 months; mean 24 months) with a maximum of two AOM episodes in their medical history participated in the study. Families of target-aged children with RAOM (at least three AOM in 6 months or four AOM in a year) who presented to the Oulu University Hospital's Ear, Nose, and Throat Clinic for a tympanostomy tube insertion were invited to participate in the study. During a one-year period in 2009–2010, all children fulfilling the inclusion criteria participated in the study. A detailed AOM history of these children is presented in Haapala et al. (2014) (except for child number 19, who was excluded from the present study). The controls were recruited via public advertisements. Assessments were carried out at Oulu University Hospital's Neurocognitive Unit, where the children underwent electrophysiological recordings (Haapala et al., 2014; Niemitalo-Haapola et al., 2013; Niemitalo-Haapola et al., forthcoming). Fifteen Euros were paid to the families to compensate for transportation costs. The study was approved by the ethics committee of the Northern Ostrobothnia Hospital District (reference number 6/2009), and the children's parents gave written informed consent.

All the children came from monolingual Finnish-speaking families, were born full-term, and had normal birth weights. According to the parental questionnaires and assessments completed at family and health care clinics, where Finnish children regularly receive health care, the children were typically developing and had no signs of visual or hearing impairments. The parents reported no family histories of neurologic or severe neuropsychiatric diseases, including developmental language disorders. The Finnish standardized version of the Reynell III test (Edwards et al., 1997; Kortesmaa, Heimonen, Merikoski, Warma, & Varpela, 2001) was used to determine that all the children had age-appropriate language comprehension skills and to rule out any cases of specific language impairment (SLI). Sixteen children in the RAOM group and 14 in the control group passed the transient-evoked otoacoustic emission screening (TEOAE, MADSEN AccuScreen® pro, GN Otometrics; nonlinear click sequence 1.5–4.5 kHz, 73 dB SPL, pass result) at the time of the study. Although the other TEOAE measurements failed due to children not cooperating, all the children had passed the postnatal TEOAE screening. At the time of the study, an otolaryngologist reported that all the children had clinically healthy ears.

Five children were excluded from the present study for the following reasons: one had a family history of dyslexia; one had a suspicion of SLI according the Reynell III Language Comprehension scale and an additional assessment by a speech and language therapist; two because the families did not arrive at the appointed time; and one because their sibling's speech masked their speech in a video recording. One child from the control group was excluded because of AOM diagnosed at the time of the study. The final groups did not differ significantly in gender (RAOM group: 8 girls, 11 boys; control group: 9 girls, 12 boys; χ^2 (1) = 0.002, p = .962) or maternal educational level (RAOM group: 4 low, 15 middle or high; control group: 2 low, 19 middle or high; Fisher's exact test, p = .398)

Data collection

The analysis was based on a semi-structured, free play situation between the child and a parent (all mothers, except for two fathers in the RAOM group and three in the control group). The parents were instructed to interact with their child in a natural way with an extensive variety of toys and picture books provided, which prompted the production of all the Finnish phonemes and elicited words from different word classes. A high-quality microphone (Sony ECM-55B) was placed on the floor near the child. Fifteen-minute video recordings were made after the EEG recording at the Neurocognitive Unit or, if a child was too tired, within a week at the family's home.

Analysis

The video data were transcribed using the International Phonetic Alphabet (IPA). The analysis of consonant inventories was limited to meaningful words in the samples. The criteria for identifying meaningful words were adopted from Vihman and McCune (1994). Inflected forms of the same word were counted as one word. Onomatopoeic words (for example, sounds of animals and vehicles) were accepted because they constitute a large proportion of a child's vocabulary at this age. Words immediately imitated after a parent's pronunciation were rejected because at 2 years of age, a child's ability to correct his/her output according to a model is already advanced. All the transcriptions were completed by a speech and language therapist (the first author). Additionally, a trained undergraduate student blinded for group membership made transcriptions for independent cross-checking. The inter-rater reliability was calculated from the transcriptions of 10 children (25% of the sample), and the agreement for consonant transcriptions was 82.83%.

Consonant inventories were defined separately for consonants in any word position (AWP) and for consonants in specific positions of words. Each consonant had to occur in two different words to be counted in the AWP inventory. In each word position – word-initial (WI), word-medial (WM), and word-final (WF) – the consonant was counted in the inventory if it occurred in two different words in that position. If a consonant only occurred once, it was counted as a marginal phoneme. This procedure has been used in previous studies of Finnish inventories (Kunnari, 2003; Kunnari et al., 2006). There is only one sibilant, /s/, and one trill, /r/, in the Finnish consonant system, which allows for a degree of variation among speakers in the production of these phonemes. These are known to be difficult for Finnish children to learn to produce correctly, and young children often produce these phonemes with alterations during a single sample (Saaristo-Helin, 2009). Nonetheless, higher phonological abilities exist when a child makes an allophonic distinction instead of omitting or substituting the sound with another phoneme. We accepted the consonants /s/ and /r/ in the inventory if the child clearly distinguished between these phonemes and others by using a common Finnish allophonic variant (e.g., /possu/ as [poʃʃu], 'pig'; /imuri/ as [imuʀi], 'vacuum').

The consonants were further classified into categories by place (labials, dentals/alveolars, palato-velars, and glottal) and manner (stops, fricatives, lateral, trill, nasals, and semivowels) of articulation. The numbers of produced words, consonant inventory sizes, and the correlations between these variables were calculated and compared between the groups. The places and manners of articulation were also studied. The consonant phonemes produced by 60% of the children in the groups were compared.

Statistical analyses were carried out with SPSS for Windows (21.0, SPSS Inc.); the level of significance was $p \leq .05$ with two-tailed tests. Non-parametric tests were used because of the small sample size and because not all the variables were normally distributed. Categorical variables were compared using the chi-square test and with Fisher's exact test if there was no prerequisite for chi-square testing. The Mann–Whitney U test was applied to compare the vocabulary and inventory sizes between the groups. A related-samples Wilcoxon signed rank test was used to study differences between the sizes of WI and WM consonant inventories within a group. The correlation between the sample vocabulary size and the consonant inventory size was studied with Spearman's rho correlation coefficient.

Results

Sizes of speech samples

The children with RAOM produced fewer words than the control children ($U = 118.00$, $p \leqslant .05$; Table 1). Furthermore, the children with RAOM were a homogeneous group, whereas the control children showed a large variation in vocabulary size (Figure 1; Table 1).

Sizes of consonant inventories

The children with RAOM had significantly smaller AWP inventories than the control children ($U = 108.50$, $p \leqslant .01$; Table 1). Furthermore, they displayed a trend of smaller WI inventories ($U = 131.50$, $p = .065$) and their WM inventories were found to be significantly smaller ($U = 109.00$, $p \leqslant .01$) than those of the controls (Figure 2). In both groups, few consonants were produced in the WF position with no significant difference between the groups. Nearly all the children, with no significant group differences, had some marginal phonemes in their consonant inventories.

A WM position advantage for consonant production typically observed in Finnish children (Kunnari, 2003; Kunnari et al., 2006) was not clearly observed in the children with RAOM, while it was in the control children. The controls had significantly more consonants in their WM than in their WI inventory ($W = 138.00$, $p \leq .01$), which was, however, also a trend in the RAOM group ($W = 72.00$, $p = .057$).

Association between the speech sample size and the consonant inventory size

The number of words in the speech sample correlated significantly with the AWP consonant inventory size in both groups (RAOM $\rho = .817$, $p \leq .001$; controls $\rho = .743$, $p \leq .001$; Figure 3) as well as with the WI, WM, and WF inventories (RAOM $\rho = .928$, $p \leq .001$, controls $\rho = .769$, $p \leq .001$; RAOM $\rho = .859$, $p \leq .001$, controls $\rho = .797$, $p \leq .001$; RAOM $\rho = .588$, $p \leq .01$, controls $\rho = .893$, $p \leq .001$, respectively).

Places and manners of articulation

Within the category of *place of articulation*, dentals/alveolars were produced significantly less frequently by the children with RAOM than by the controls ($U = 88.00$, $p \leq$

Table 1. Total word and consonant inventories in the sample for the RAOM group and control group.

		RAOM	Controls
N		19	21
Words in sample			
Mean		33	51
SD		16.3	26.4
Min–Max		6–65	0–103
Inventory size			
AWP	Mean	6.9	8.8
	SD	2.6	2.7
	Min–Max	1–11	0–11
WI	Mean	5.2	6.5
	SD	2.1	2.4
	Min–Max	1–9	0–10
WI_m	Mean	1.5	2.0
	SD	0.8	1.9
	Min–Max	0–3	0–7
WM	Mean	5.8	7.8
	SD	2.6	2.7
	Min–Max	0–9	0–11
WM_m	Mean	2.5	1.7
	SD	1.5	1.3
	Min–Max	0–6	0–4
WF	Mean	0.8	1.5
	SD	1.0	1.2
	Min–Max	0–2	0–4
WF_m	Mean	0.8	1.3
	SD	0.6	1.0
	Min–Max	0–2	0–4

Notes: RAOM: recurrent acute otitis media; AWP: any word position; WI: word initial position; WM: word medial position; WF: word final position; subscript m: marginal phonemes.

.01; Table 2). Regarding the *manner of articulation*, fricatives were produced less frequently by the children with RAOM than by the controls (U = 104.00, $p \leq .01$). Furthermore, nasals tended to be used less frequently by the children with RAOM than by the controls (U = 135.50, p = .083). Using the 60% criterion, the children with RAOM used six consonants /p/, /t/, /k/, /l/, /m/, and /n/, while 60% of controls used nine consonants /p/, /t/, /k/, /l/, /m/, /n/, /h/, /s/, and /ʋ/ in at least one word position.

In the WI position, the group difference was nearly significant for dentals/alveolars (U = 129.50, p = .057; Table 3), which were produced less frequently by the children with RAOM than by the controls. In the WM position, fricatives and dentals/alveolars were significantly less likely to occur in the children with RAOM than in the controls (U = 113.50, $p \leq .05$; U = 101.50, $p \leq .01$, respectively). In the WF position, a significant

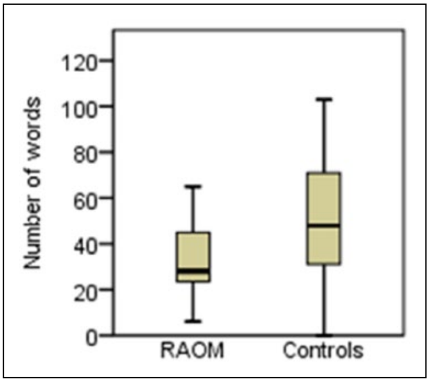

Figure 1. Distribution of expressive vocabulary sizes for the recurrent acute otitis media (RAOM) group and control group.

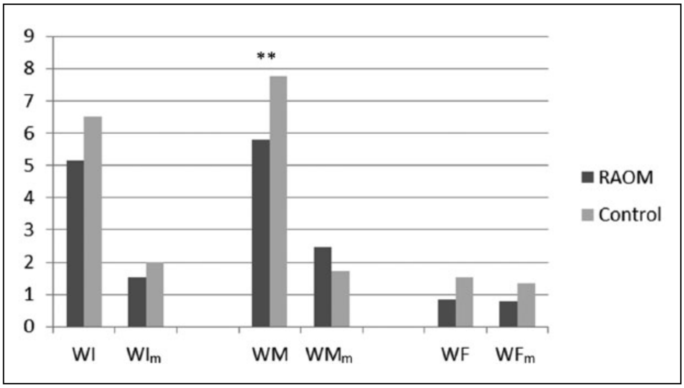

Figure 2. Mean sizes of consonant inventories in word initial (WI), word medial (WM), and word final (WF) positions for the recurrent acute otitis media (RAOM) group and control group. The bars marked with subscript m represent the number of marginal phonemes.
** = a significant difference, $p \leq .01$.

difference was found for fricatives ($U = 115.50$, $p \leq .05$). With the 60% criterion, the children with RAOM produced the consonants /p/, /t/, /k/, and /m/, while 60% of the controls produced /p/, /t/, /k/, /m/, and /n/ in the WI position. In the WM position, 60% of the children with RAOM produced /p/, /t/, /k/, /l/, and /n/, while 60% of the controls produced /p/, /t/, /k/, /l/, /m/, /n/, /h/, and /s/. In the word final position, the 60% criterion was only realized by the controls with one consonant /n/.

Discussion

Our main findings suggest a limited production of words and restricted consonant inventories in 2-year-old Finnish children with RAOM. These results support the existing

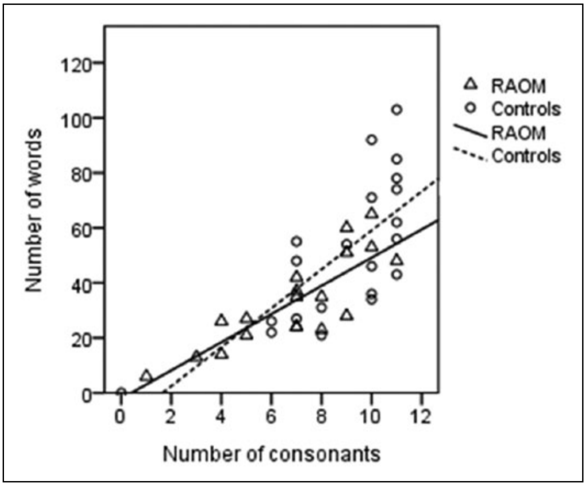

Figure 3. Correlation between the speech sample vocabulary size and consonant inventory size for the recurrent acute otitis media (RAOM) group and control group. The inventory size is counted for consonants occurring in any word position. The correlation was significant in both groups.

Table 2. Percentages of the RAOM group and control group producing each Finnish consonant in at least one word position.

Manner of articulation	Place of articulation							
	Labials		Dentals/alveolars		Palato-velars		Glottal	
	RAOM	Control	RAOM	Control	RAOM	Control	RAOM	Control
Stops								
Voiceless	p 94.7%	p 95.2%	t 94.7%	t 95.2%	k 89.5%	k 90.5%		
Voiced	(b) 5.3%	(b) 4.8%	d 0%	d 9.5%	(g) 0%	(g) 0%		
Fricatives	(f) 0%	(f) 4.8%	s, (ʃ) 26.3%	s, (ʃ) 76.2%			h 52.6%	h 71.4%
Laterals			l 68.4%	l 81.0%				
Trill			r 5.3%	r 23.8%				
Nasal	m 84.2%	m 95.2%	n 73.7%	n 90.5%	ŋ 10.5%	ŋ 28.6%		
Semivowels	ʋ 52.6%	ʋ 71.4%			j 31.6%	j 42.9%		

Notes: RAOM: recurrent acute otitis media. Phonemes in parentheses occur in loan words in Finnish. In this sample, /s/ and /ʃ/ were counted as one phoneme because /ʃ/ is a phonetic variant of /s/ in many 2-year-old children and very rare in Finnish. In all cases, the target phoneme was /s/. The shaded boxes indicate a significant group difference with regard to place or manner of articulation. The darker-colored boxes present a significant group difference in individual phonemes, χ^2 (1) = 9.950, $p \leqslant .01$.

findings of restricted consonant production in children with OM in early childhood (Abraham et al., 1996; Miccio et al., 2001; Petinou et al., 1999), a time in which phonological development is critical for further language development. Delayed and/or limited

Table 3. Percentages of the RAOM group and control group producing each Finnish consonant in word initial (WI), word medial (WM), and word final (WF) positions.

Consonant phoneme	WI		WM		WF	
	RAOM	Control	RAOM	Control	RAOM	Control
p	84.2%	90.5%	68.4%	81.0%	–	–
t	94.7%	95.2%	94.7%	95.2%	15.8%	23.8%
k	84.2%	81.0%	78.9%	85.7%	–	–
(b)	5.3%	4.8%	–	–	–	–
d	–	–	–	9.5%	–	–
(g)	–	–	–	–	–	–
(f)	–	4.8%	–	–	–	–
s, (ʃ)	15.8%	42.9%	26.3%	71.4%	15.8%	57.1%
h	26.3%	38.1%	42.1%	61.9%	–	4.8%
l	26.3%	47.6%	68.4%	76.2%	–	4.8%
r	–	4.8%	5.3%	23.8%	–	–
m	73.7%	90.5%	57.9%	71.4%	5.3%	–
n	52.5%	71.4%	63.2%	85.7%	47.4%	61.9%
ŋ	–	–	10.5%	28.6%	–	–
ʋ	31.6%	47.6%	36.8%	57.1%	–	–
j	21.1%	33.3%	26.3%	28.6%	–	–

Notes: RAOM: recurrent acute otitis media. Phonemes in parentheses occur in loan words in Finnish. In this sample, /s/ and /ʃ/ were counted as one phoneme because /ʃ/ is a phonetic variant of /s/ in many 2-year-old children and very rare in Finnish. In all cases, the target phoneme was /s/. The shaded boxes indicate a significant difference in individual phonemes between groups, WM: χ^2 (1) = 8.120, $p \leq .01$; WF: χ^2 (1) = 7.278, $p \leqslant .01$.

use of consonants and a limited production of recognizable words may indicate later problems with language development (Moeller et al., 2007).

We found that the children with RAOM had significantly fewer words in their speech samples than the controls. The results for the control group were consistent with the findings of Kunnari et al. (2006), who reported that 2-year-old Finnish children produced 47 different words on average (range 5–121) during 15-minute speech samples. The variation in the sizes of their lexicons, however, was large in the controls (see also Kunnari, 2003), whereas the children with RAOM were a more homogeneous group and fell at the lower end of the typical range of development. This may be due to altered auditory input inhibiting optimal development.

Difficulties in consonant acquisition in the children with RAOM were indicated by smaller AWP inventories compared to the controls. Based on the consonants produced by 60% of children, the RAOM group was delayed compared to the controls overall. In contrast to Abraham et al. (1996), who reported problems with WI consonants in 2-year-old English-speaking children with recurrent OM during the first year of life, we found no significant difference in the WI inventories between the groups. However, we found that the children with RAOM had smaller WM inventories than the controls. In

Finnish children, omission of WI consonants is a typical developmental feature (Savinainen-Makkonen, 2000). Consistent with our results regarding the controls, previous studies have shown that typically developing Finnish children have more WM than WI consonants in their early inventories (Kunnari, 2003; Kunnari et al., 2006; Savinainen-Makkonen, 2007). This preference for WM consonants may be explained by the Finnish obtrusive WM geminate template, which is a common template for the first words that Finnish children produce (see Saaristo-Helin et al., 2011).

However, the children with RAOM did not produce significantly more WM than WI consonants, suggesting that they had particular difficulties with WM consonants. Consonants in the WM position are probably harder to discriminate because other phonemes might mask them more than consonants in the WI position. A similar effect of the acoustic environment was observed in a study of auditory processing in dyslexic adults (Kujala et al., 2000), who typically have auditory processing difficulties (Ramus et al., 2003). The study found that they had difficulty with the neural discrimination of changes in the middle of tone patterns, but this was not observed when the same changes were presented without surrounding sounds. Furthermore, the neural discrimination of sound-order reversals was affected in dyslexic participants when an additional sound followed the tone pair but not when the sound preceded the pair (Kujala, Belitz, Tervaniemi, & Näätänen, 2003).

Minimally small inventories of WF consonants were found in both groups. The acquisition of WF consonants is slow in both English (Abraham et al., 1996; Stoel-Gammon, 2011) and Finnish (Kunnari, 2003; Kunnari et al., 2006), and 2-year-olds using these languages have only developed small inventories of WF consonants. Therefore, comparisons between the groups are difficult to make.

Our results for the consonant inventories of the controls are highly consistent with Kunnari et al. (2006), while the RAOM group lagged behind those results. Kunnari et al. reported that 2-year-old typically developing Finnish children ($N = 24$) had the following consonant inventories: WI mean 5.79 (range 0–12), WM mean 7.08 (range 0–15), and WF mean 1.42 (range 0–5). There are two possible reasons for the control children in our study being slightly more advanced than in the study of Kunnari et al. (2006). First, in that study, the OM history of the children was not reported. Therefore, some children with earlier RAOM might have affected the results. Second, it was not reported whether onomatopoeic words were included in the analysis. If not, it is reasonable that they found somewhat smaller mean numbers of words and consonants produced than our study.

The number of words in the speech sample was positively correlated with the size of the consonant inventory both overall and in all word positions, which is in accordance with earlier studies (Kunnari et al., 2006; for a review Stoel-Gammon, 2011). The restricted number of words produced by the children with RAOM may be explained by the size of their consonant inventories, as small repertoires of phonemes do not support the production of a large number of words (Stoel-Gammon, 2011). However, the association between early phonological and lexical development is bi-directional. Possibly, delayed word acquisition leads to delayed consonant acquisition (Locke, 1997). The children in the present study were 22–27 months old, thus generally at an early stage of lexical development. Onomatopoeic words, which are very common among children's first spoken words, were included in the analysis to obtain the maximal consonant inventories, even from children with restricted lexicons.

The quality of consonant inventories was found to be different between the RAOM and control groups. Dentals and alveolars occurred less frequently in the AWP and WM inventories for the RAOM group. The largest difference was found for fricatives, which occurred less frequently in the AWP, WM, and WF inventories in the RAOM group. Fricatives may be harder to perceive and discriminate because their acoustic energy is weak and occurs mostly in the high frequencies. It should be noted, however, that consonants are not isolated in speech; changes in the vocal tract shaped by adjacent vowels appear as formant transitions, modifying the perception of consonants (e.g., Coez et al., 2010). Problems in the production (Miccio et al., 2001) and in the discrimination (Petinou et al., 2001) of fricatives in children affected by various forms of OM have also been established in earlier studies. Finnish only has three fricatives; /s/ is often the first to be acquired in typical development (Kunnari et al., 2006), and it has a notable role in the Finnish lexicon and morphology. The only significant difference in the use of single consonants between the groups was for the production of /s/ in the WM and WF position. However, there was no significant difference between the groups for the number of fricatives in their WI inventories. It is possible that the friction in the WI position may be more audible than in the WM or WF positions, where it is masked by other phonemes. Additionally, the common developmental feature of WI consonant omission (Savinainen-Makkonen, 2000) may have influenced our results.

Some important factors need to be considered for a cautious interpretation of these results. Natural speech samples can be problematic because they might not show the full capacity of a child's spoken language (Edwards & Beckman, 2008). However, the ecological validity of spontaneous speech samples is better than that of samples elicited by isolated word-naming tests in toddlers (Stoel-Gammon, 1987). The 15-minute play situation used was the same across the groups and similar to the method used in earlier studies (e.g., Kunnari et al., 2006). Because of the limited cooperation skills of 2-year-old children, audiometric testing was not included. At the time of the study, hearing levels were assumed to be within the normal range because the children with RAOM had had tympanostomy tubes inserted and severe hearing impairments were excluded by TEOAEs and parental reports. In our study, the children's RAOM histories were collected from their medical records, but we had no detailed information on their hearing during OM episodes. When comparing the results with those of other studies of phonological development in children with OM, it should be noted that studies differ in their definitions of the history of middle ear infections and that the duration of middle ear effusion varies greatly among children (Tapiainen et al., 2014). This variation presumably influences language outcomes.

Children with RAOM typically suffer from continuously and asymmetrically fluctuating hearing impairments as their middle ear statuses change with OM episodes. However, it is not known whether it is more detrimental to have hearing fluctuate due to numerous shorter or a few longer OM episodes. This clinically important aspect should be taken into account in future studies through intensive monitoring of the timing, frequency, and duration of OM episodes. Furthermore, it should be determined whether these early phonological problems result in literacy skill deficits in school-age children.

To conclude, 2-year-old children with RAOM were found to have restricted consonant inventories, which may be explained by the immature neural mechanisms for speech sound discrimination found in the MMN recordings reported in Haapala et al. (2014).

They also produced fewer words than the typically developing controls, which might be due to restricted consonant inventories. These results may be indicators of later language problems (Moeller et al., 2007). Our results suggest that Finnish children with RAOM are particularly prone to problems with consonants produced in the medial position of words and in fricative production. Clinically, early childhood RAOM should be taken as a risk factor for language deficits. It is important to counsel parents and other people working with young children with OM to support language development and to request assessment early enough to prevent delayed speech.

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