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Repetition of words from dense and sparse phonological neighborhoods in children with hearing loss and normal hearing

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Main research questions

1. How is lexical access affected by hearing loss in young children? Are young hearing aid users sensitive to the phonological neighbors of words?

2. Does lexical access develop similarly in children with hearing loss and children with normal hearing?

3. Are standardized language tests (i.e., outcome measures) predictive in modeling the influence of lexical access performance?

Background

Neighborhood density (aka: *lexical density*. *lexical similarity;* see also *frequency weighted neighborhood density*) is the number of real words with similarity to a target word, varying by adding, subtracting, or substituting one phone. Effects on language have been shown to be inhibitory at the lexical level, facilitatory at the phonological level, and dependent on the task (Vitevitch & Luce, 1998; Vitevitch, 2002; Newman & German, 2002; Garlock, Walley, & Matsala 2001). That is, words from denser phonological neighborhoods may be less accurate when lexical competition is engaged, but more accurate when (only) phonological competition is engaged (possibly restricted to production; Storkel, Armbrüster, & Hogan, 2006).

Phonotactic probability is the frequency of bi/phone occurrence. It has facilitatory effects on lexical access (e.g., spoken word recognition, repetition latency, identification errors, resolution in noise, etc.). That is, higher phonotactic probability words are more accurate, faster, easier, etc., in a variety of language-use contexts.

***Probability & density are correlated,* and in this study confounded.

Age is almost always a facilitatory factor—but note that an older child's lexicon may be different in a number of respects that have been shown to affect accuracy (e.g., robustness of representations, fluency, number of lexical items and associated neighborhoods, etc.; Storkel, 2002; Edwards, Beckman, & Munson, 2004; Munson, Edwards, & Beckman, 2005).

Lexical frequency is the estimated usage frequency of a form. It is not possible for non-words. It is not correlated with phonological density or phonotactic probability in the lexical items used here. It has a facilitatory effect in many domains of perception and production, including accuracy (Vitevitch, 1997, 2002). Higher lexical usage frequency means more accurate reproduction.

Hearing loss (i.e., audibility) affects the lexicon:
► The lexicon may develop slower in children with HL (Mayne, Yoshinaga-Itano, & Sedey, 2000; Mayne, Yoshinaga-Itano, Sedey, & Carey, 2000; Moeller, Hoover, Putman, et al, 2007a, 2007b).
► Lexical competition may reduce lexical access ability (Jerger, Lai, & Marchman, 2002)
► Nonword repetition and phonological awareness performance may be decreased (Briscoe, Bishop, & Norbury, 2001; Moeller, Tomblin, Yoshinaga-Itano, Connor & Jerger, 2007)

♦ **Little is known about how childhood hearing loss affects the structure of, or access to, words from dense versus sparse neighborhoods in the lexicon.**

Method

Participants

		N	PTA dB HL (*M, SD*)	GFTA-II SS (*M, SD*)	EVT-II SS (*M, SD*)
Hearing Loss (*N* = 17)	**4 year olds**	9	45 (20)	103 (8)	104 (13)
	7 year olds	8	41 (11)	95 (21)	107 (20)
Normal Hearing (*N* = 30)	**4 year olds**	15	screened at < 15	109 (10)	111 (15)
	7 year olds	15	screened at < 15	102 (10)	114 (10)
	all pooled	47	—	103 (12)	110 (14)

Materials

► 100 monosyllabic word forms (68 words, 32 non-words)
► stimuli = citation-style, natural production, adult female voice
► to confirm naturalness of stimuli, open-set identification task (*N*=7 adult judges): 98.7% accuracy
► stimuli do not vary by overall size or lexical usage frequency
► stimuli selected are high probability/high density (confounded)
► phonological level of access is intended target of stimuli
► comparisons between Hoosier Mental Lexicon and the Child Corpus

Child Corpus is described in Storkel & Hoover (2010): Kolson (1960) + Moe, Hopkins, & Rush (1982)

STIMULUS WORDS (Munson, Swenson, Manthei, 2005; Storkel & Hoover, 2010)		dense	sparse	Pr(dense ≠ sparse)	z-val
Word size	**number of phonemes**	3.0 (0.2)	3.1 (0.3)	> 0.05	-1.007
Lexical frequency (N_{dense} = 34) (N_{sparse} = 34)	**word frequency – CC**	2.3 (1.7)	1.8 (1.5)	> 0.05	-0.488
	word frequency – HML	2.4 (1.0)	1.8 (0.9)	> 0.05	0.896
Phonotactic probability (N_{dense} = 50) (N_{sparse} = 50)	**segment frequency – CC**	0.060 (0.011)	0.050 (0.014)	** < 0.01	3.422
	segment frequency – HML	0.056 (0.012)	0.048 (0.016)	** < 0.01	2.617
	biphone frequency – CC	0.0051 (0.0031)	0.0035 (0.0026)	** < 0.01	3.203
	biphone frequency – HML	0.0041 (0.0034)	0.0032 (0.0027)	** < 0.01	2.581
Neighborhood density (N_{dense} = 50) (N_{sparse} = 50)	**number of neighbors – CC**	15.9 (4.9)	9.8 (6.0)	** < 0.01	-4.935
	number of neighbors – HML	23.3 (5.9)	16.1 (7.4)	** < 0.01	-4.973

Procedure

► All stimuli randomized as part of computer game with participants
► Listen-and-repeat **task**: "say what the lady on the computer says"
► Stimuli played in open field at about 68dB SPL
► Speech production was assessed via Goldman Fristoe-II
► Lexical probe was assessed via Expressive Vocabulary Test-II

Data analysis, Bayesian modeling

► Dependent variable
1. spoken word reproduction accuracy (correct, incorrect)

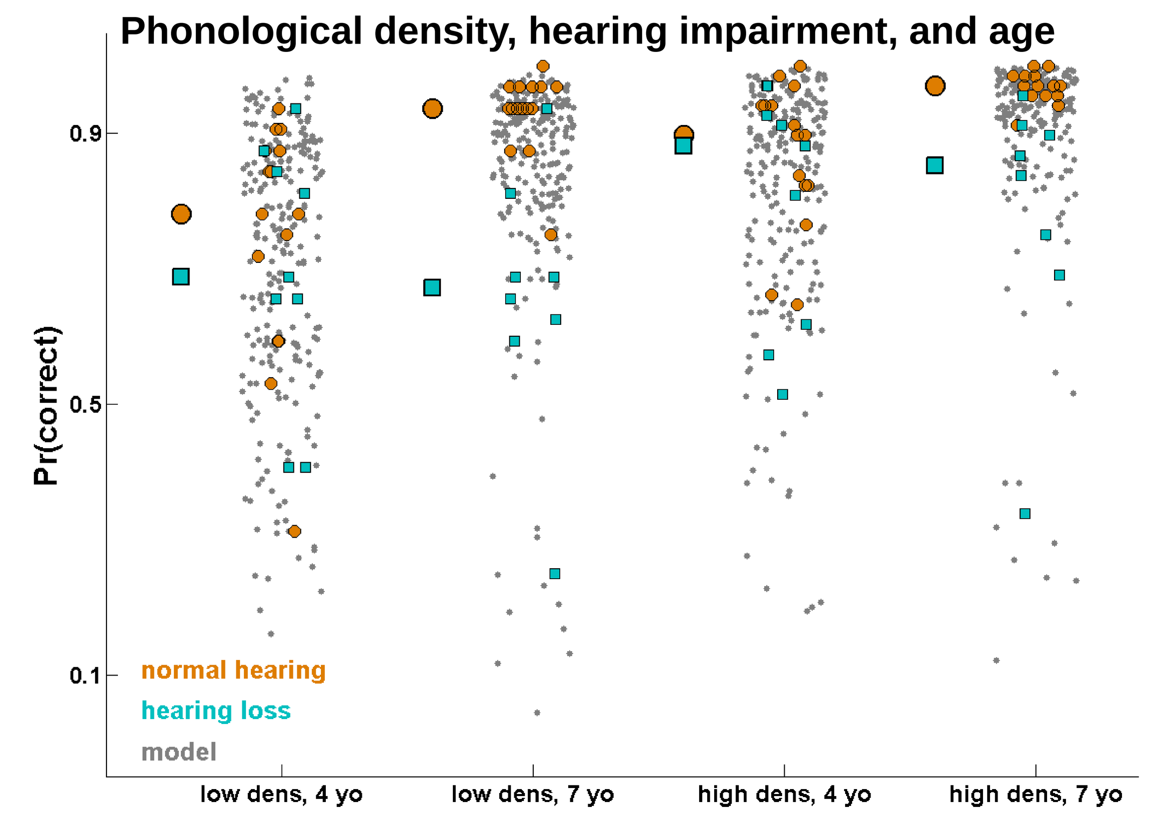
► Independent variables
1. Age (4 yrs, 7 yrs)
2. Hearing status (HL, NH)
3. Neighborhood density (dense, sparse)
4. Productive phonology (GFTA standard score)
5. Expressive vocabulary (EVT standard score)

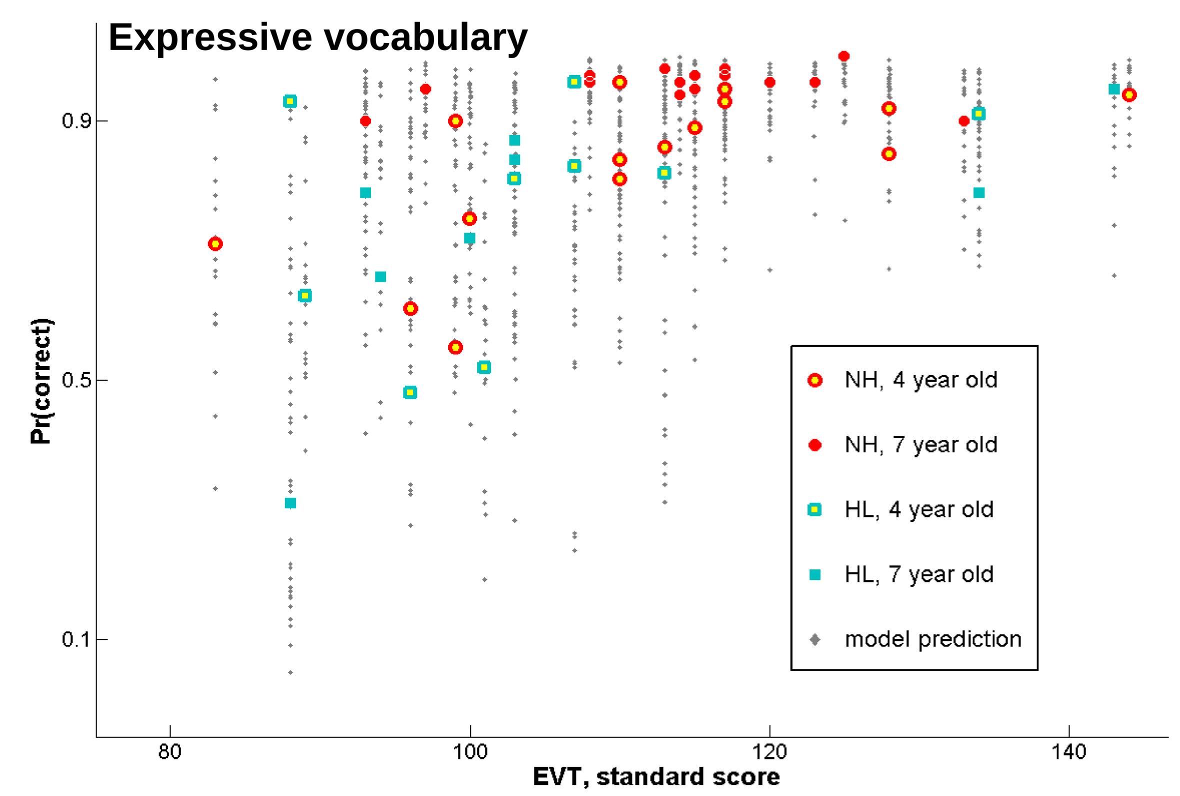
$$\beta_{0i} \sim \mathrm{N}(\mu_0, \sigma)$$

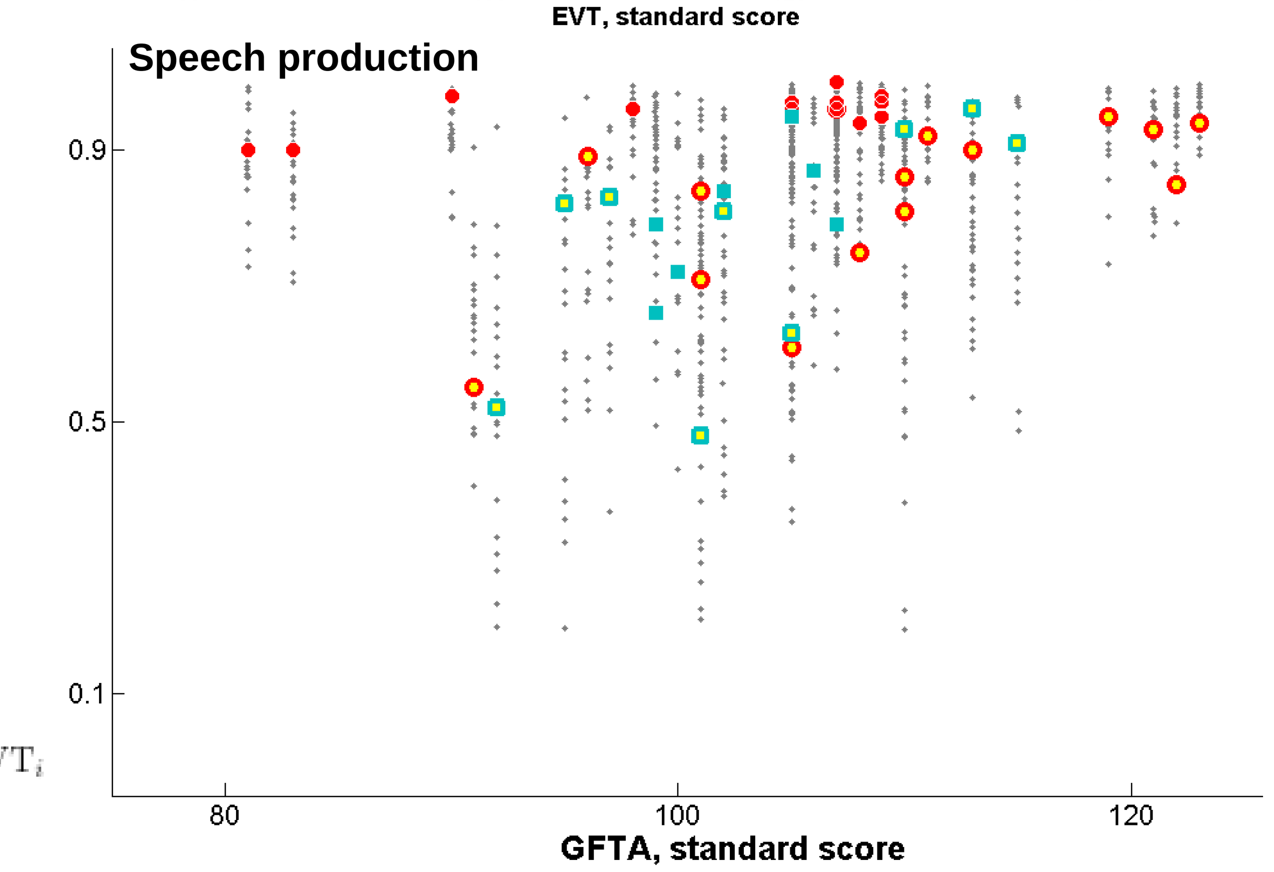
$$\beta_{1ij} \sim \mathrm{N}(\mu_j, \sigma)$$

$$\ln\left(\frac{p_i}{1-p_i}\right) = \hat{\beta}_{0i} + \hat{\beta}_{1ij}\mathrm{ND}_j + \hat{\beta}_2\mathrm{A}_i + \hat{\beta}_3\mathrm{HS}_i + \beta_4\mathrm{ND}_j\mathrm{A}_i + \beta_5\mathrm{ND}_j\mathrm{HS}_i + \hat{\beta}_6\mathrm{GFTA}_i + \hat{\beta}_7\mathrm{EVT}_i$$

Results







Correlations between outcome measures (EVT & GFTA) and Hearing status and Age

	EVT		GFTA	
	$\rho_{SPEARMAN}$	*p*	$\rho_{SPEARMAN}$	*p*
All pooled	0.556	0.001	0.383	0.001
HL	0.559	0.019	0.661	0.003
NH	0.376	0.040	0.022	0.907
4 yr old	0.579	0.003	0.680	0.001
7 yr old	0.490	0.017	0.459	0.007
HL 4yo	0.343	0.364	0.633	0.076
NH 4yo	0.670	0.006	0.593	0.019
HL 7yo	0.795	0.022	0.728	0.046
NH 7yo	0.218	0.434	0.311	0.258

The model:

1. ...predicts Hearing and Age effects reasonably well.

2. ...consistently predicts accuracy as a function of both EVT and GFTA scores, and shows the interaction between hearing loss and lexical access.

3. ...may be improved with more data (better informed weighting parameters).

Summary of results

Repetition accuracy:

1. ...improves with increased expressive vocabulary scores.

2. ...improves with increased speech production ability scores.

3. ...reveals sensitivity to phonological and lexical density for all children.

4. ...for older children (7 yr olds) with NH is at ceiling, but older children with HI perform more like younger children.

5. ...improves at older ages for children with NH, but is about the same for children with HI.

6. ...seems to distinguish those children with hearing loss in 7 yr olds but not 4 yr olds.

Conclusions

1. For children with NH, repetition accuracy is at ceiling at older ages and for high-density words at younger ages.

2. For children with HL, repetition accuracy is poorer for low-density words at both test ages (in contrast to children with NH who improve accuracy of low-density words at the older test age).

3. The effects of (1) and (2) may be explained by more impoverished representations in younger children with HL (evidenced by the relationship between EVT and percent-correct).

Future directions

1. Collect more data.

2. Look at independent effects of *density, phonotactic probability, lexical frequency,* and *lexicality*. (See Garlock, Walley, & Metsala, 2001; Bailey & Hahn, 2001; Luce & Large, 2001; Munsen, Swensen, Manthei, 2005; Storkel, Armbrüster, & Hogan, 2006; Storkel & Hoover, 2010).

3a. Look at response latency as additional dependent factor.
3b. Look at phoneme-level error patterns (already coded).

4. Look at acoustic characteristics of the children's productions (with reference to child and stimulus acoustic features).

5. Improve statistical modeling procedure to better predict real performance; more data will help inform priors.

6. Investigate results with respect to lexical processing models (e.g., NAM, TRACE, PARSYN, Shortlist, MERGE).