New Measures to Chart Toddlers' Speech Perception and Language Development: A Test of the Lexical Restructuring Hypothesis

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Abstract

Language acquisition factors at work in toddlers between 2 ½ and 3 years of age were investigated in the first longitudinal study of this kind. New age-appropriate tasks were devised to measure the development of vocabulary size; articulation accuracy; sensitivity to the phonemic features of, in this case, Australian English; and the degree of specialisation towards the native tongue, as measured by language-specific speech perception; LSSP, with 45 Australian English learning toddlers (18 male, 27 female) at 30, 33, and 36 months of age. Results indicated (i) that nearly all measures improved linearly over age; (ii) that there were significant correlations between articulation ability and vocabulary size; and (iii) that, in confirmation of the lexical restructuring hypothesis, vocabulary size is significantly predicted by the broad range of native language abilities under the rubric of Phoneme Sensitivity, but not by the more specific measure of LSSP.

Index Terms: Early language acquisition, phoneme sensitivity, vocabulary development, Lexical Restructuring Hypothesis

1. Introduction

Speech perception bootstraps language acquisition. There are four stages of this development. During the first 6 months of life, the nonnative speech discrimination performance of infants equals their ability to discriminate sounds of their native language. Then, in the 2nd half of the first year, a perceptual shift occurs in favour of the native language, earlier for vowels than for consonants [1]: Infants' nonnative speech discrimination performance starts to decline [2], while they continue to build their native language skills. In fact, their ability to concentrate on native and to filter out nonnative speech contrast differences is positively related to their general cognitive development [2].

Following this, in 14-month-olds, semantic acquisition interferes with speech perception abilities, causing the toddlers to neglect fine-grained discriminations in favour of word meaning acquisition [3]. However, 20-month-olds overcome the difficulty of mastering word learning and contrast discrimination at the same time [3].

Once children start school at around 6 years, further interaction of a native language skill, in this case acquisition of orthography, with nonnative speech perception occurs. School children with good reading ability for their age are also those children with high language specific speech perception (LSSP) scores – they score relatively well on native (N) and relatively poorly on nonnative (NN) speech contrasts. LSSP is measured by subtracting discrimination scores for nonnative speech from native speech [4]. Thus, LSSP shows how much perceptual attention is paid towards native versus nonnative features of speech.

When reading is left out of the equation and 4-year-old pre-readers are compared to 6- and 8-year-olds, LSSP scores measured by N-NN are well-predicted by articulation ability for age. However, for school children, articulation ceases to be a significant predictor for LSSP, with reading, the major achievement in language development at school, taking over. In general, specialisation for the native language via abilities such as phonemic attunement in the first year, articulation abilities with 4-year-olds, and reading with school-aged children appears to be well-predicted by LSSP [4].

The major achievement in language development in toddlerhood is the acquisition of lexical meaning. The Lexical Restructuring Hypothesis has its origins in Shvachkin's [5] notion of semantic change, indicating a perceptual shift towards an emphasis on phonological representations at the onset of lexical acquisition. More specifically, the Lexical Restructuring Hypothesis states that once vocabulary has reached a size of 50 to 100 words, the child needs to represent lexical entries in a phonemically fine-grained manner as opposed to the holistic word storage applied to the very first lexical items [6, 7]. This process goes hand in hand with the vocabulary spurt, and toddlers' ability to acquire words referentially, not only in an associative manner. The referential acquisition mode leads to increased efficiency in word meaning acquisition as it reduces the number of required word-object mappings and hence gives rise to the vocabulary spurt [7]. There has, as yet, been no rigorous experimental test of the Lexical Restructuring Hypothesis. Here such a test will be conducted.

The first aim of this study is to comprehensively chart language development in toddlerhood on multiple dimensions, a task that has never before been undertaken. The factors under investigation are language-specific speech perception (LSSP), vocabulary size, articulation accuracy, and three measures of Phoneme Sensitivity. For all of these, existing methods were adapted for the specific needs of the younger age group of participants tested here. The second aim of the study is to provide the first longitudinal experimental test of the Lexical Restructuring Hypothesis, the proposed positive relationship between vocabulary size and speech perception ability. As this is the first test of its kind, two versions of this hypothesis are entertained: First, that focused native language ability, the language specific speech perception measure LSSP, will be significantly predicted by vocabulary size and; second, that general Phoneme Sensitivity, as measured by mispronunciation detection, nonword repetition, and rhyme detection, will be significantly predicted by vocabulary size.

2. Method

45 Australian English learning toddlers (18 male, 27 female) were tested longitudinally at 30, 33 and 36 months on LSSP, their vocabulary, articulation, and Phoneme Sensitivity.

LSSP was measured with a go-no go computer task in which the toddlers were asked to press a red button for every perceived change in a series of continuously presented native (N), nonnative consonant (NN), or nonnative tonal (T) speech contrasts[1]. Correct responses (button press for a change trial or reject for a non-change trial) were rewarded by a short animated movie clip, frozen during trial stimulus presentation. During a familiarisation phase with animal sound contrasts, it was ensured the children understood the task – in an English vowel discrimination task, they were required to reach a criterion of 6 correct responses out of the last 8 trials in order to proceed to the experimental phase. In the experimental phase, separate native, nonnative and tone speech perception blocks were given (each with a demonstration phase followed by 2 sets of 8 trials), and separate N, NN, and T scores were derived.

Vocabulary production at 30 months was measured with the Australian English Communicative Inventory OZI, an adaptation of the well-known parental checklist MacArthur CDI [8] to Australian English, followed at 33 and 36 months with the Peabody Picture Vocabulary Test (PPVT) [9].

Articulation accuracy was tested with a subset of the Queensland Articulation Test [10], using only consonants in initial word position. The naming responses to the 22 target pictures were recorded on a DAT recorder.

To measure Phoneme Sensitivity (PS), three tasks were used: Mispronunciation detection, nonword repetition and rhyme detection. In the *mispronunciation task*, the child was asked to identify if the name for a picture was correctly or incorrectly pronounced. The 20 mispronounced words differed in one consonant on three levels of difficulty, either in initial or medial word position. The responses yielded a mispronunciation discrimination index (hits minus false positives). For the *nonword repetition task*, the child repeated 16 nonsense words from a puppet. The responses were recorded on a DAT recorder for later scoring. *Rhyme detection* with 14 rhyming and 14 non-rhyming word pairs proved to be the most demanding Phoneme Sensitivity task (many children did not perform past chance level). All three Phoneme Sensitivity tasks contained sufficient training items to ensure the child had understood the objective. Correct answers were rewarded by animated pictures displayed on a computer screen and accompanied by a recording of cheering and clapping children. All speech targets were pre-recorded and presented via loudspeaker at 60dB. Principal component analyses of the three Phoneme Sensitivity tests revealed a similar single component at each test age. Weighting and component coefficients for Phoneme Sensitivity are shown in Table 1.

PS Tests	30 months	33 months	36 months
Mispronunciation	.72 *(.61)*	.86 *(.51)*	.78 *(.47)*
Nonword	.53 *(.44)*	.87 *(.52)*	.81 *(.49)*
Rhyme	.63 *(.53)*	.42 *(.25)*	.63 *(.38)*

Table 1: Phoneme Sensitivity (PS) factor loadings *(and component coefficients)* per test age

At 36 months, a Stanford-Binet V subtest, Fluid Reasoning: Objects and Matrices, was used to measure nonverbal IQ.

3. Results

The results are presented in three parts: The first two parts concern the charting of language development, and consist of (i) a comparison of level ability for each language task over age, and (ii) correlations between language task measures. The third part concerns tests of the Lexical Restructuring Hypothesis, and consists of 2 sets of stepwise regression analyses in which vocabulary size is used to predict LSSP and Phoneme Sensitivity measures.

3.1. Language Development Measures over Age: Means

Descriptive analyses of the language measures generally showed normally distributed scores at each age, and consistent developments over age. This was true for all measures except the OZI, which was used at the limits of its validation range, 30 months.

Means of all language development factors at each age, 30, 33, and 36 months are shown in Table 2. The developmental changes in the data were tested via planned contrasts for linear and quadratic trends within Analyses of Variance (ANOVA).

	30 months	33 months	36 months	F_{linear}	$F_{quadr.}$
N	.28 *(.30)*	.35 *(.34)*	.49 *(.25)*	**16.05**	.046
NN	.20 *(.21)*	.27 *(.30)*	.41 *(.28)*	**17.17**	.877
T	.22 *(.32)*	.36 *(.30)*	.50 *(.29)*	**30.56**	.016
N-NN	.08 *(.31)*	.11 *(.32)*	.08 *(.26)*	1.86^{-6}	.398
N-T	.06 *(.39)*	.02 *(.34)*	-.02 *(.28)*	1.584	-.003
PPVT		36.4 *(12)*	46.8 *(13.8)*	**71.19**	
QAT	.53 *(.16)*	.62 *(.14)*	.70 *(.12)*	**70.31**	.027
Mispr.	.24 *(.22)*	.39 *(.28)*	.55 *(.26)*	**60.69**	-.052
Rhym.	.49 *(.12)*	.51 *(.15)*	.53 *(.19)*	1.618	2.36^{-7}
NW	.55 *(.20)*	.61 *(.17)*	.65 *(.17)*	**10.35**	-.376

Table 2: Language factors at 30, 33, and 36 months: M *(SD)*
(if above critical F value (F = 4.064), marked with bold font)

All measures show the expected developmental increase trend between 30 and 36 months, most measures show significant linear trends over age, and none reveal quadratic age trends.
In particular, that two of the three subtests of Phoneme Sensitivity (PS), mispronunciation detection and nonword repetition, show a significant linear increase over age, suggests that PS is a sensitive, reliable and stable measure of fine-grained native language discrimination in toddlers.

Age trends for the other indicator of native speech perception, LSSP, are not as strong. The two LSSP measures, N-NN and N-T, do not improve significantly over age. On the contrary, toddlers' discrimination of nonnative tone improves and thus causes the LSSP score to decrease over age. This could be due to tone being both novel and salient, and therefore interesting and attention-capturing for the toddlers.

3.2. Correlations between Language Measures

Correlations between language measures are shown in Table 3. As expected, the nonverbal intelligence measure does not correlate with any of the other factors (Table 3) and did not significantly contribute towards explaining variance when factored into the stepwise multiple regression.

Pinpointing strong correlations between variables that remain stable across age is a way of determining general relationships in language development. The two LSSP measures, N-NN and N-T, do correlate with each other to some extent, but not consistently with other measures over age. On the other hand, vocabulary, OZI and PPVT, and articulation (QAT) correlate highly with each other, and Phoneme Sensitivity consistently correlates with both measures. This shows that there is a close relationship between vocabulary acquisition and perceptual attention toward phonemic detail in speech, and that this is also reflected in the articulation

		N-NN 30	N-NN 33	N-NN 36	N-T 30	N-T 33	N-T 36	OZI 30	PPVT 33	PPVT 36	QAT 30	QAT 33	QAT 36	PS 30	PS 33	PS 36
LSSP	**N-NN33**	.072														
	N-NN36	-.173	**.367**													
	N-T30	**.458**	**.351**	0.058												
	N-T33	.015	**.613**	.150	.260											
	N-T36	.052	.202	**.371**	**.312**	.153										
Voca-bulary	**OZI30**	.187	.188	.090	.135	.137	.086									
	PPVT33	**.314**	.225	-.119	.282	.158	.007	**.431**								
	PPVT36	.141	.67	.012	.038	.028	.189	**.364**	**.803**							
Artic.	**QAT30**	.051	.220	.046	-.002	.073	.154	**.536**	**.393**	**.419**						
	QAT33	.033	**.304**	.137	-.009	.282	.240	**.551**	**.523**	**.545**	**.737**					
	QAT36	.099	.266	.142	-.012	**.316**	.014	**.421**	**.321**	**.339**	**.576**	**.672**				
Phoneme Sensitiv.	**PS30**	-.023	**.408**	.041	.140	.274	.166	.290	**.484**	**.461**	**.372**	**.578**	**.371**			
	PS33	.214	.127	-.045	.117	.027	.237	**.419**	**.495**	**.516**	**.682**	**.680**	**.413**	**.460**		
	PS36	.207	.088	-.003	.234	.040	**.352**	**.568**	**.530**	**.555**	**.720**	**.634**	**.464**	**.369**	**.779**	
	IQ	.138	.140	.108	.102	.191	.130	.170	.005	-.018	.241	.165	.210	.037	.039	.084

Table 3: Pearson correlation coefficients for N-NN, N-T, vocabulary, articulation, PS and nonverbal IQ (Significant correlations marked bold)

measure. In order to compare the two phonemically-oriented measures - language specific speech perception measure (LSSP), and more general language perception measure, Phoneme Sensitivity (PS) - their relationship to vocabulary size is plotted below (Figures 1 and 2). As can be seen, the relationship with vocabulary size is stronger for PS than for both the LSSP measures, N-NN and N-T.

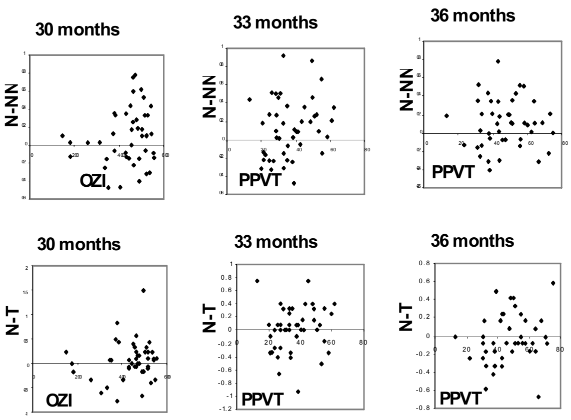

Figure 1: Scattergrams illustrating the correlation between LSSP (N-NN and N-T) and vocabulary at 30, 33, and 36 months

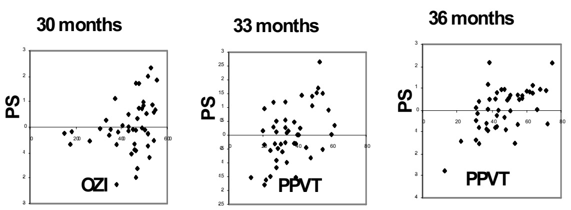

Figure 2: Scattergrams illustrating the correlation between Phoneme Sensitivity and vocabulary at 30, 33, and 36 months

3.3. Testing the Lexical Restructuring Hypothesis: Regression Analyses

Stepwise multiple regression analyses were conducted to test the hypothesis that vocabulary size influences phonemic perception, separately for children at 30 months, 33 months, and 36 months. To determine which of the two phonemic measures, LSSP or PS, proved to be more useful, two sets of stepwise multiple regressions were conducted. In the first set, the LSSP measures, N-NN and N-T (each in separate regression analyses), were predicted from vocabulary size (step 1), the Phoneme Sensitivity factor scores (step 2), and articulation ability (step 3). In the second set (Table 4), the Phoneme Sensitivity factors scores were predicted from vocabulary size (step 1), LSSP measures (step 2), and articulation ability (step 3). Again, separate regressions for the contribution of the LSSP measures N-NN and N-T were conducted. Nonverbal IQ did not significantly contribute when included in the multiple regressions, as suspected from the lack of correlations with any of the other factors. In this way, the Lexical Restructuring Hypothesis was tested with both a language-specific measure of native language ability (LSSP), and a language-general measure of native language ability (PS).

For LSSP, the only regression reaching significance was for N-T at 33 months – N-T was significantly predicted by articulation ability, measured by the QAT. It is possible that vocabulary mediates the influence of articulation on N-T, as articulation is positively correlated with vocabulary size at all ages (Table 3). This also is consistent with the finding that articulation predicts N-NN in pre-readers [4]. On the other hand, the regression analyses for PS shown in Table 4 indicate that the more general PS score was significantly predicted by vocabulary (OZI or PPVT) at all ages, and by articulation (QAT) at 33 and 36 months. Thus it appears that the Lexical Restructuring Hypothesis is supported for the language general measure of Phoneme Sensitivity, but not for the language specific measure, LSSP.

4. Discussion

In this longitudinal study, language development in 30- to 36-month-olds has been comprehensively charted for the first time with specifically adapted measures for this age group. The new measures work: They are normally distributed and generally show linear improvement over age. Particularly, the Phoneme Sensitivity factor score with its three component measures allows consistent measurement across age: Even the rhyme detection task, although the mean score improved just slightly beyond chance, still contributed positively to the PS factor.

Correlations illustrate the coherent relationship between vocabulary, articulation accuracy, and Phoneme Sensitivity. On the other hand, LSSP - in neither of its measures (N-NN, N-T) - correlated consistently over age with vocabulary, articulation, or PS. Possibly due to the attention span problems and affective variability difficulties that toddlers bring to the test sessions, the more general measure for native language attunement, Phoneme Sensitivity, seems to be more robust and hence effective.

Phoneme Sensitivity at 30 months

Step	N-NN	Beta	t	N-T	Beta	t
1	OZI	.29	**2.0***	OZI	.29	**2.0***
2	OZI	.31	**2.0***	OZI	.28	1.9
	N-NN	-.08	-.53	N-T	.10	.69
3	OZI	.14	.81	OZI	.10	.60
	NNN	-.06	**-.42****	N-T	.13	.88
	QAT	.30	1.8	QAT	.32	1.9

Phoneme Sensitivity at 33 months

Step	N-NN	Beta	t	N-T	Beta	t
1	PPVT	.50	**3.7****	PPVT	.50	**3.7****
2	PPVT	.49	**3.6****	PPVT	.50	**3.7****
	N-NN	.02	.12	N-T	-.05	-.39
3	PPVT	.20	1.6	PPVT	.20	1.5
	N-NN	-.10	-.88	N-T	-.18	-1.6
	QAT	.61	**4.6****	QAT	.63	**4.8****

Phoneme Sensitivity at 36 months

Step	N-NN	Beta	t	N-T	Beta	t
1	PPVT	.56	**4.4****	PPVT	.56	**4.4****
2	PPVT	.56	**4.3****	PPVT	.51	**4.1****
	N-NN	-.01	-.08	N-T	.26	**2.1***
3	PPVT	.45	**3.5****	PPVT	.39	**3.2****
	N-NN	-.05	-.44	N-T	.27	**2.4***
	QAT	.32	**2.5***	QAT	.33	**2.7****

Table 4: Stepwise multiple regression predicting PS from vocabulary (step 1), from vocabulary and LSSP (N-NN and N-T) (step 2), and from vocabulary, LSSP and articulation (step 3) at 30, 33, and 36 months (significant t-values are bold, significance level <.05 marked with *, <.01 marked with **)

Given these strong correlations, it comes as no surprise that support for the Lexical Restructuring Hypothesis was found when predicting Phoneme Sensitivity rather than LSSP. At 30, 33, and 36 months, vocabulary size is a significant predictor for Phoneme Sensitivity (Table 5). This means that the perceptual attention paid to phonemic details in speech is influenced by the number of entries in the toddlers' vocabulary. In other words, how well children listen to fine-grained detail in spoken words, depends on how many words they already know. This leads to the legitimate assumption they use the referential acquisition mode when acquiring new vocabulary [7]. According to Shvachkin [5], toddlers then truly are at the so-called phonemic stage. It is of interest here that in addition to vocabulary, articulation ability also predicts PS. Thus it is not only the words the child knows, but how well they produce them that determines phoneme sensitivity.

Although the vocabulary spurt should have leveled out by the ages tested here, nevertheless, the prediction of Phoneme Sensitivity and articulation by vocabulary tightens over age. This could be due to an ongoing phonemic restructuring of the lexicon, originally initiated by the vocabulary spurt. This suggests that toddlers become more efficient in identifying phonemic detail when acquiring words and make good use of this skill as exponentially growing vocabulary acquisition rates even past-spurt demonstrate. If vocabulary measures taken at an earlier age turn out to be predictive of Phoneme Sensitivity in 3-year-olds, there would be additional support for the Lexical Restructuring Hypothesis. The OZI, validated for 16- to 30-months-olds, would be a good measure to put this idea to the test.

5. Conclusions

For the first time in 30- to 36-month-olds, language development has been charted comprehensively on multiple dimensions, implementing new age-appropriate measures for LSSP, vocabulary, Phoneme Sensitivity, and articulation.

Significant correlations were found between the factors, especially between vocabulary size, articulation, and Phoneme Sensitivity.

In multiple regression analyses, vocabulary size significantly predicted Phoneme Sensitivity at 30, 33, and 36 months, providing the first longitudinal experimental support for the Lexical Restructuring Hypothesis.

6. Acknowledgements

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7. References

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8. Footnotes

1) English and Thai contrasts used in LSSP task:

N:	[ba-p^{h}a]; [da-t^{h}a]
NN:	[ba-pa]; [da-ta]
T:	[ka^2-ka^4]; [ka^1-ka^4]