THE DEVELOPMENT OF PHONOLOGICAL SYSTEMATICITY: LATE TALKERS AND TYPICALLY DEVELOPING CHILDREN

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Abstract

Preliminary findings are reported from an ongoing study investigating the relationship of phonological systematicity to language delay or disorder in children who make a late start on word production. Based on formal testing at 2.6 years, we divided these children into 'true' (expressive) late talkers (LTs) and 'transitional' LTs (TLTs), depending on whether or not their expressive language falls at least 4.5 months below the norm at that age. An existing sample of 11 typically developing children (TDs) served as a comparison sample. All children are seen again one year after the first developmental milestone, with both naturalistic recordings and formal tests to assess linguistic advance.

Our hypothesis is that the LTs will fall into two groups identifiable from the earlier recordings: (i) children who are slow to make a start on word production but who show the same kind of systematization in their early word production as is found in the typically developing children and (ii) children whose word production displays little evidence of systematization. The prediction is that in the one-year follow-up recordings Group (i) will have caught up with the TDs, with their naturalistic recordings showing normal linguistic levels for their developmental level (i.e., a year after the first developmental milestone), as assessed for phonology, morphosyntax and lexical diversity as well as in age-based formal tests, while Group (ii) will continue to show language delay and will thus prove to be at risk of having Specific Language Impairment (SLI).

We have so far recorded only a few of the one-year follow-up sessions for the LTs, so that final outcomes cannot yet be reported. However, we have identified several differences in production between the (T)LTs and the TDs. In addition, the small sample of LTs do appear to fall into the two groups we expected to find, differing from the TDs in ways that correspond roughly to what we had predicted.

Introduction

Late talkers (LTs) are of interest for at least two quite different reasons. On the one hand, it is clinically important to identify children with language disorders as early as possible, with a primary challenge being the need to distinguish simple delay (which can have many causes, including both individual temperamental or motoric maturational issues and environmental or socio-familial issues) from disorder. On the other hand, from a theoretical point of view, such children may be able to shed some light on the basic sources and mechanisms of phonological system building, by providing clues as to what leads to delay or disorder.

Up until now, phonologically oriented studies of LTs have been largely restricted to lexical measures based on parental report (the Communicative Developmental Inventory, or CDI) along with transcription and analyses of the children's production, generally restricted to profiling of inventories (Thal, Oroz & McCaw, 1995; Rescorla & Bernstein Ratner, 1996). In this study we take a different approach, basing both lexical and phonological assessments on transcription of naturalistic home recordings. In addition, this study begins with a theoretical model of early word form learning (Vihman, 1996, Vihman & Velleman, 2000, Vihman & Croft, 2007, Vihman, DePaolis & Keren-Portnoy, 2008), which assumes that early word forms are produced relatively accurately as a result of an implicit match of the child's own vocal patterns (based on babbling practice) to input speech forms. According to this model, this early 'accurate' production is normally followed by a regression in accuracy. The regression is due to the development of one or more word-production routines or 'templates': The child extends patterns frequent in his or her own early word forms for use in producing more complex or less readily accessible words. These are the first signs of an incipient phonological systematicity. At the same time, phonetic advances are also taking place, but more gradually, eventually permitting a return to accuracy that will now include more complex adult targets as well. A side-effect of the formation of such templates is an increase in rate of lexical learning.

Here, we hypothesize that if systematicity is a general characteristic of typically developing children, then the majority of late talkers, who can be expected to catch up with those children in due course (Rescorla, Roberts, & Dahlsgaard, 1997), should show systematicity of a similar kind and extent at a comparable point in their lexical development. In contrast, a small number of LTs may fail to induce phonological patterning from their early words. The result would be a lack of systematicity despite attainment of a lexical level at which such patterning could be expected. In addition, these children would continue to show slow lexical growth, with each new word constituting a new challenge, since there would be little generalization from what has already been learned.

Theoretical preamble

As Ferguson & Farwell (1975) were the first to point out, first words tend to be accurate; they seem 'pre-selected' (Ferguson, Peizer & Weeks, 1973; see Table 1). But how does the child know what not to attempt? What mechanism lies behind this appearance of selectivity in the first words? It has long been established by production studies that individual children learning the same language differ in vocal patterns (Vihman, Ferguson & Elbert, 1986); furthermore, early word patterns resemble a given child's babbling or vocal practice (Vihman et al., 1985; McCune & Vihman, 2001). We have argued that the accuracy of the first words is due to grounding in

pre-existing (well practiced) motor patterns, with the addition of an implicitly experienced 'match' to 'selected' targets (via the 'articulatory filter': Vihman, 1991, 1993, 1996). Recent experimental studies support this conceptualization (Vihman & Nakai, 2003; DePaolis & Vihman, in submission).

target word & gloss	*child form*
/autoː/, /oːtoː/ 'car'	[at], [atə], [aut],[autoː], [oːt], [oːtoː]
/hap/, /hapjə/, /hapi/ 'a (little) bite'	[ap], [apə], [hap], [hapə], [hab], [habə]
/paːrt /, /paːrtjə/ 'horse, horsie'	[paːt], [paːtə], [baːt], [baːtə]
/pus/, /pusjə/ 'cat, kitty'	[pusj], [pəx], [bəx], [pux], [bux]

Table 1. First words: Thomas (Dutch), aged 15-16 mos. (Elbers & Ton, 1985)

Once a few words have begun to be produced we see the emergence of a degree of systematicity. Implicit, distributional learning over first word forms leads to 'templates', based on repeated experience of patterns in production. In some cases, the result is regression in accuracy, with adult targets adapted to the child pattern in more or less radical ways, while in others we see instead extensive 'selection' on a single word form type found frequently in the input language (e.g., CVC word shapes in English), or a mix of 'selected' and 'adapted' words. Discussion and illustration of child word patterns or templates can be found in many studies published over the past 30-odd years (e.g., Menn, 1971, 1983; Waterson, 1971; Ferguson & Farwell, 1975; Priestly, 1977; Macken, 1979; Savinainen-Makkonen, 2007; Vihman & Croft, 2007). Here, accuracy is generally sacrificed to range - and to ease of representation as well as of production: The reuse of familiar motor routines facilitates memory for new forms and results in faster word learning; a simple match of production to perception can no longer account for child forms. Table 2 illustrates this stage of phonological advance from one of our typically developing children, Owen, who both selects and adapts words to fit his <…CVV> pattern.

Selected words		*Adapted words*	
ball	[pɔːə]	mine	[əmaɪ]
bear	[baːə]	owl (im.)	[əwaʊ]
drill	[dʲiːə]	Harri	[ɦəwaɪ]
sky	[kaːɪ]	Balamory	[mumʊi]
in there	[ənæːə]		

Table 2. Owen, 22 months.

At this point one or more internal templates can serve as a phonological source alongside the external pattern in the target word. We see this as a first step in phonological organization. In short, implicit pattern induction - based on repeated word production - leads to word templates, the beginnings of 'phonological system'.

The ‘adaptation’ of word forms reflects the dynamic power of emergent systematicity, a form of production-based perceptual categorization.

Is a lack of phonological abstracting the source of delay for LTs?
As a group, LTs later tend to fall at the lower end of a broad continuum for first language learning, with many of them nevertheless proving to be within the norm within a few months (Rescorla et al., 1997). The group of children identified as LTs at age 2-2.5 must then include both typically developing children who start late and children with genuine language problems. It is our goal to determine whether the two groups can be distinguished based on their phonology alone.

We hypothesize that some Late Talkers fail to induce patterns from their emerging lexicon - or do so only very slowly. Words are recognized and produced individually, each as a unique exemplar, but such item learning is inefficient. Each word is treated as a wholly new item, with little transfer of knowledge from what is already known. Some evidence that this is the case comes from earlier studies of older children with language disorders (SLI, dyslexia), who are found to have problems with phonological abstraction (and some - perhaps most or many? - began as LTs: Swan & Goswami, 1997; Beckman, Munson & Edwards, 2007; Bishop & Snowling, 2004). Furthermore, although LTs are identified by lexical and syntactic criteria (small lexicon, no combinations), they typically also show phonetic delays.

Among the phonetic characteristics reported for LTs we find the following: Less voluble vocalizing (Thal et al., 1995); smaller consonant and vowel inventories (Paul & Jennings, 1992; Rescorla & Bernstein Ratner, 1996); simpler syllable shapes (Pharr, Bernstein Ratner, & Rescorla, 2000); fewer codas (Thal et al., 1995; Pharr et al., 2000); and more use of word-medial glottal stops (Klein, 1985). In addition, previous research indicated that labial stops occurred in 90% of the late talker inventories, where no other ‘true’ or supraglottal consonants occurred as consistently (see Thal et al., 1995: Table 2; age-matched controls had that level of representation in their inventories for other true consonants as well while language-matched controls had no such consistently used consonant). Similarly, Rescorla & Bernstein Ratner (1996) show heightened use of [b] in initial position for LTs in comparison with TDs. Since McCune and Vihman (2001) also report a ‘special role’ for labial consonants in their first-word learners (TDs under age 16 mos.), we looked for heightened use of any labial consonants in words in all our groups.

Our first aim in the present study was to characterize any differences in the phonetic profiles of our three groups: TDs, TLTs, and LTs. In addition, we predicted that we would find two groups of LTs with different sources of delay:

> Group I: Limited production practice (babbling);
> Group II: Limited production practice plus a deficiency in pattern extraction or phonological abstraction.

For Group II phonetic knowledge would remain ‘hyper-detailed’ (Pierrehumbert, 2003); new words would be learned with difficulty. This group would be identified within the first year of word production, toward the end of the single-word period, by a lack of phonological organization or systematicity; this should prove a predictor of slower linguistic advance a year later.

Methods

Participants

We recruited LTs through newspaper ads, posters and brochures in nurseries and surgeries and sent the Oxford version of the CDI (developed for use in the UK: Hamilton, Plunkett & Schafer, 2000) to families that express interest in participating.[1] We followed children with home recordings from age 2 years if their parents reported that they were producing fewer than 50 words and few if any word combinations.

We saw 47 potential late talkers for one or more recordings. Of these, 13 were identified as LTs on the basis of the Reynell Scales administered at age 2.5 years by the following criteria: Within 3 months of the age norms on comprehension, but 4 months or more below age norms on production (see Table 3, which includes the 8 LTs whose early words have been fully analyzed to date). Children who fell within age norms on the test despite having had few words (or, in one case, no combinations) at the first recording, between age 2 and 2.5, were classified as 'Transitional' LTs (TLTs; N = 10; 3 are included in Table 3). Those who showed low comprehension were not followed further (N = 9). In addition, 9 children proved to have advanced to the end of the single word period before the first recording and were thus considered not really to have been 'late' at all and 6 children moved away or proved unable to continue in the study for other reasons. Our control sample of 11 typically developing children (TDs) were followed as part of an earlier study (Keren-Portnoy, DePaolis & Vihman, 2005; all are included in Table 3).

Child	Age in mos at 25wp	Total number of word shapes	Labials		Word-medial glottals		Codas	
I. Typically developing children (TDs)								
Jude	15	43	15	34.88%	1	2.44%	0	0.00%
Ian	19	42	24	57.14%	4	9.52%	22	52.38%
Rebecca	19	40	16	40.00%	1	2.50%	21	47.50%
Jennifer	21	64	35	54.69%	0	0.00%	40	62.50%
Martin	22	44	13	29.55%	0	0.00%	21	47.73%
Sylvia	22	29	17	58.62%	1	3.45%	7	24.14%
Andy	22	26	14	53.85%	1	3.85%	9	34.62%
Owen	22	37	22	59.46%	1	2.70%	5	13.51%
Helen	24	28	14	50.00%	1	3.57%	11	39.29%
Tomos	24	40	18	45.00%	5	12.50%	6	15.00%
Ali	25	29	15	51.72%	4	13.79%	13	44.83%
mean	21	38.36		48.63%		4.94%		34.68%

[1] The study was initiated in North Wales and completed in the area around York. All of our TDs, one TLT and four of our LTs come from North Wales, the rest from York.

II. Transitional Late talkers (TLTs)								
Jack	26	58	33	56.90%	13	22.41%	20	34.48%
Clarissa	27	49	26	53.06%	1	2.04%	19	38.78%
Julie	27	47	17	36.17%	12	25.53%	25	53.19%
mean	26.67	51.33		48.71%		16.66%		42.15%
III. Late talkers (LTs)								
Lewis	31	25	15	60.00%	3	12.00%	0	0.00%
Donagh	31	34	11	32.35%	6	17.65%	6	17.65%
Joel	31	30	11	36.67%	3	10.00%	5	16.67%
Nia	32	38	21	55.26%	8	21.05%	7	18.42%
Rowan	33	44	22	50.00%	2	4.55%	13	29.55%
Elise	33	52	31	59.62%	11	21.15%	37	71.15%
Mario	34	25	6	24.00%	3	12.00%	9	36.00%
Tony	35	36	22	61.11%	7	19.44%	6	16.67%
mean	32.5	35.5		47.38%		14.73%		25.76%

Table 3. Participants whose data are included in the analysis reported here, by group, ordered by age at 25wp. (All names are pseudonyms.) For 'labials', 'word-medial glottals', and 'codas', see Results.

Data collection and testing

We record the children in 30-minute play sessions at home with a parent, at intervals guided by parental report of linguistic advance, until they reach the '25-word-point' (25wp) - i.e., spontaneous production of 25 different word types in a session (corresponding to about 50-75 words of cumulative word use: Vihman & Miller, 1988), after which we record them twice more at biweekly intervals. We see the children again at 42 months for a spontaneous play recording and administration of the CELF (test for SLI) and the McCarthy Scales (a measure of cognitive development). In addition, all of the children are recorded 14 months after the age at which they reached the 25wp. These recordings will be analyzed for phonological, morphosyntactic and lexical advance as the LTs reach that point; analyses of the TDs and the first LTs to be seen at that lexically defined point are ongoing. All of the analyses reported here are based on a single session per child, at the 25wp.

Results

I. Phonetic characterization of the different groups

Our findings to date can be summarized as follows (see also Table 3 and Figures 1-3, which plot age at the 25wp against number of words with a word-medial glottal, a coda or a labial of any manner class, including the glide [w]).

A. *Word-medial glottal use* is seen in LTs and TLTs, but only rarely in TDs, as shown by the significant correlation between age at 25wp and word-medial glottal use ($r = .6$, $p = .014$ [one-tailed]).

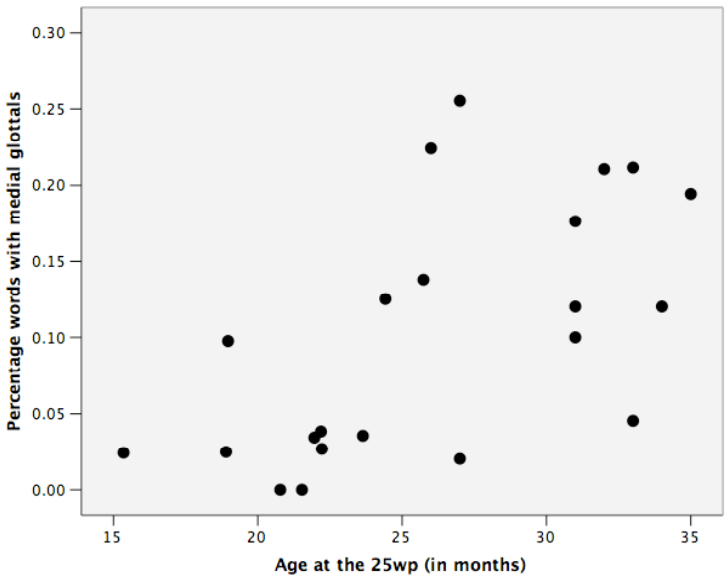

Figure 1. Glottal use by age at 25wp.

B. *Coda use* is similar in the three groups, occurring in about a third of the TD words (34.68%), slightly more in the TLTs (42.15%) and slightly less in the LTs (25.76%). There is thus no significant correlation with age (see Fig. 2).

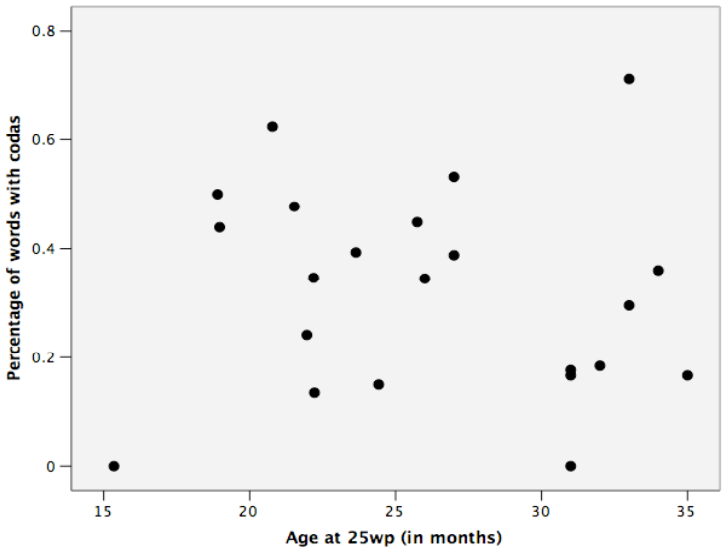

Figure 2. Coda use by age at 25wp.

C. *Labial use* also fails to show a statistically significant trend with age at the 25wp, although there is a tendency for children who reach the 25wp later to use more labials. Actually, we note that the children who reach the 25wp after age 2 (including one TD, Ali) fall into two groups in this respect, namely, (a) children who tend to make heavy use of labials (N = 8) and (b) children who make only sparing use of them (N = 4) (see Table 3). We will come back to this point below.

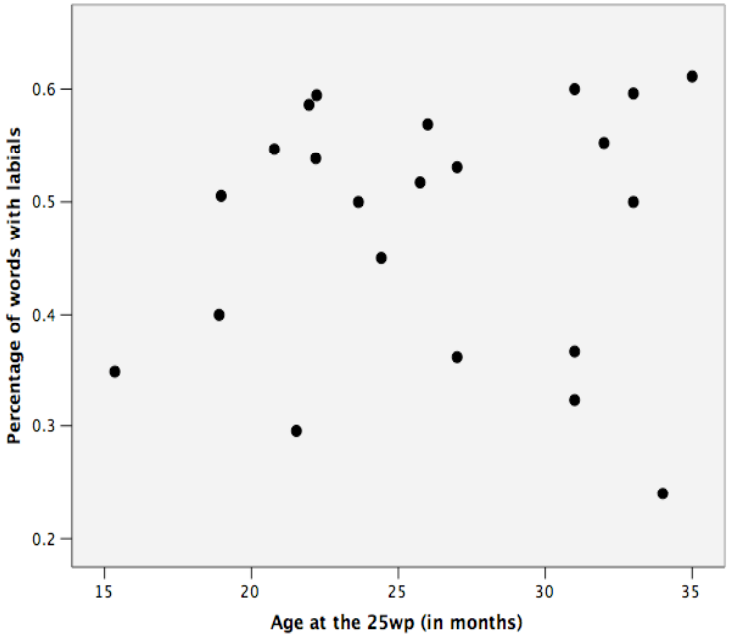

Figure 3. Labial use by age at 25wp.

II. Quantifying systematicity: A bottom-up procedure

In order to establish whether or not a subset of the LTs lack systematicity we needed to find a way to quantify the construct. The solution we arrived at was to make use of two bottom-up measures designed to characterise (a) similarity among a child's word forms and (b) distance of child form from adult target. The assumption is that children who have begun to develop phonological system or organisation, based on implicit induction of patterns latent in the word forms they produce, will have word forms that are both more similar to one another and less like the adult target forms than are the words of children who have made less of an advance in the induction of such patterns.

In addition, we define 'template consonants' (TC) and 'template vowels' (TV) to express the fact that, for some children, systematization includes the frequent use of a particular consonant or vowel, usually in a fixed word position, regardless of its occurrence in the target word. Examples of such usage have been reported many times in the child phonology literature (e.g., Priestly's 1977 description of his son Christopher's overuse of medial jod; cf. also Alice's palatal pattern, in Vihman, Velleman & McCune, 1999 and Claire's similar use of jod in early French words: Wauquiers-Gravelines, 2003; another example is the medial [l] of Laurent, reported in Vihman, 1993); we see this as highly characteristic of children's word templates, although not every child uses such a template segment. Thus we defined what can be considered 'overuse' of consonants or vowels in given word positions and gave extra similarity points for the production of word forms with any such segment and extra distance-from-target points for the inclusion of such a segment when it does not occur in the corresponding adult target. Thus, using these measures, high systematicity would be expressed as high similarity (among a child's own words) and high adaptation, i.e., a large distance between child forms and target forms.

A. Similarity score

This score is arrived at by ticking off potential 'similarity characteristics' over each child's sampled lexicon, based on one transcribed 30-minute session at the 25wp. Such characteristics include both general properties of syllable shapes (such as CV,

clusters, etc.) and occurrence of special features which are characteristic of either LTs (such as word-medial glottals) or of child word production in general (consonant harmony, reduplication). Labial use was not used as a characteristic in the similarity measure, but the presence of labials could influence the similarity score if one or more labials served as a TC. One point was assigned for each instantiation of any characteristic in a given word:

- occurrence of CV sequences
- coda
- cluster
- diphthongs
- word-medial glottals
- consonant harmony
- reduplication (in multisyllabic forms)
- 'template' C and/or V (TC, TV; the procedure for establishing 'templatic' or unusually high use of a C or V is detailed below)

The total of these points, calculated separately for monosyllables and disyllables and then added together, was then divided by the total words to give the child's *similarity score.*

An example of a similarity score sheet for one child's monosyllables is given in Table 4. Note that for the purpose of establishing similarity we evaluate only one variant shape per word, picking either the most frequent shape or, if there is no such form, the most adult-like. We reasoned that inclusion of more than one variant would increase similarity and would thus unjustifiably tend to make children who produce more varied word shapes appear to be more systematic.

Rebecca, 1.6 (TD)		Internal (between-word-form) similarity									
MONOSYLLABLES		CV sequence	CC cluster	VV or diphthong	syllabic consonant	medial glottal	CH – consonant harmony	Coda	TC – Template consonant	TV – Template vowel	Similarity score
arch (im.)	hatʃ							1	1		2
ball	baʊː	1		1							2
bath	baʃː	1						1	1		3
bug	bak^{h}	1						1			2
bye	baɪ	1		1							2
car	daː	1									1
choochoo	tʃəː	1									1
cow	daʊ	1		1							2
down	ʔaʊ			1							1
inside (im.)	ɬak^{h}	1						1			2
lots (im.)	latɬ	1						2			3
mat (im.)	mat:^{h}	1						1			2
moo	muː	1									1
no	naʊ	1		1							2
oh	əʊ			1							1
pat	pat^{h}	1						1			2
push	pʊʃ	1						1	1		3
put	bʊt^{h}	1						1			2
rocks	ɹaktʃː	1						2	1		4

Rebecca, 1.6 (TD)		Internal (between-word-form) similarity									
MONOSYLLABLES		CV sequence	CC cluster	VV or diphthong	syllabic consonant	medial glottal	CH – consonant harmony	Coda	TC – Template consonant	TV – Template vowel	Similarity score
star	saː	1									1
ta (im.)	t^haː	1									1
that	dæt	1					1	1			3
there	daː	1									1
two	tuː	1									1
up	ap							1			1
what's that?	ʃæt^h	1						1			2
yes	ɛːʃ							1	1		2
27 word shapes		24	1	6	0	0	1	19	5	0	49

Table 4. Similarity coding sheet (monosyllables)

B. Distance-from-target score (adaptation)

In order to calculate this score, similarly, we tally all the changes that the child has made to the target form for each word, including segment substitutions and also more holistic changes. The more numerous the changes to the target form, the less similar the child form is to the adult target. The changes we have identified include the standard phonological processes, e.g.,

- consonant and syllable omissions or additions;
- consonant harmony;
- vowel harmony;
- reduplication;
- metathesis;
- other developmental changes, such as velar fronting, gliding, etc.

In addition we allow a point for

- anomalous changes of various kinds;
- use of a template consonant which does not occur in the target form.

The total of these points, again tallied separately for monosyllables and disyllables and then added together, is divided by the total word shapes assessed to give the child's distance-from-target score. An example of a partial distance-from-target matrix for one child is given in Table 5 (some columns have been omitted to save space). Note that in this case we include all child variants of a word type and evaluate each variant shape separately.

Table 5. Distance-to-target coding sheet (monosyllables)

Tony, 35m (LT)		Distance to Target											
MONOSYLLABLES		Omit Coda	Reduce Consonant Cluster	Add Vowel	Add Syllable	Include Medial Glottal	CH – Consonant harmony	Reduced Diphthong	Develop-mental Change	Anomalous Change	Include TC	Include TV	Adaptation Score
ball	ɒːbɔː	1		1									2
beep	biːpʰ												0
bike	æʔbaː	1		1		1		1				1	5
bum	awʌm			1							1	1	3
bye	baɪː												0
car	hægaː				1							1	2
car	aːgaː			1								1	2
dig	hɛgɪg				1		1				1		3
fly	ɒʔwaɪːː		1	1		1			1		1		5
fly	əbaɪː		1	1						1			3
four	əgɔːː			1							1		2
four	gɔː									1			1
go	gəuːː												0
go	gʊ							1					1
more	mɔː												0
no!	ŋəuːː									1			1
please	biː	1	1										2
soil	hawaʊ	1			1					1	1	1	5
stuck	gɒkʰ						1						1

Tony, 35m (LT)		Distance to Target											
MONOSYLLABLES		Omit Coda	Reduce Consonant Cluster	Add Vowel	Add Syllable	Include Medial Glottal	CH – Consonant harmony	Reduced Diphthong	Develop-mental Change	Anomalous Change	Include TC	Include TV	Adaptation Score
stuck	ɒʔgʊk^{h}			1		1	1				1		4
stuck	æːgɔːk^{h}			1			1				1	1	4
tom	əwɒm			1							1		2
tom	^{h}ɒʔwɒm			1		1					1		3
train	ɒgeɪːːː	1	1								1		3
wee	wiːː												0
whoa	wəuː												0
yeah	jɛ												0
yeah	jɛʔ					1							1
28 word shapes		5	4	11	3	5	4	2	1	4	10	6	55

C. Template consonants and vowels (TC, TV)

In order to determine which of the segments that a child produces should be counted as TCs or TVs we calculated how frequently any given phoneme is used by a child in relation to its occurrence in the target forms attempted by all of the children in the group (dividing the children into two groups, TDs and (T)LTs). Thus, if a child showed a marked preference for a given segment over that shown by the group as a whole, we considered that child to have a 'template segment'. A cumulative lexicon of all of the words attempted by the children in each group was created and the relative frequency of each phoneme within the sample was calculated, based on the adult pronunciation of those words. The frequency of each phoneme used was also calculated for each of the children, but only within the child's own word sample and based on the child's phonetic realisation of those words. When the frequency score for any of a child's segments amounted to three or more times the frequency of the same phoneme in the target sample, the phoneme in question was deemed to be a TC or TV.

In the examples given above, Rebecca (TD, Table 4) makes unusually high use of the fricative [ʃ] and the affricate [tʃ] in her word forms (regardless of whether the sound occurs in the adult form or not: cf. *arch, bath, push, rocks, yes*), while Tony (LT, Table 5) includes both [g] and [w] in words which have no such sound in the adult model (cf. *four, stuck* and *train* for /g/, *bum, fly, soil* and *Tom* for /w/; see the qualitative linguistic analysis of Tony's templates in Vihman et al., 2008, where the templates of two other LTs are also described).

D. Similarity plotted against distance from target

Once both the mean similarity and the mean distance-from-target scores had been calculated the two scores were plotted on a matrix with Similarity on the x-axis and Distance-from-target on the y-axis (Fig. 4; each child's status is indicated by a circle (TDs), square (LTs) or triangle (TLTs)). Neither similarity nor distance-from-target can serve as a measures of systematicity on its own, but we consider the combination of high similarity AND high distance-from-target to be a reasonable way to model systematicity for present purposes. We therefore do not analyze these separately but only as they intersect on the matrix (see Fig. 4).

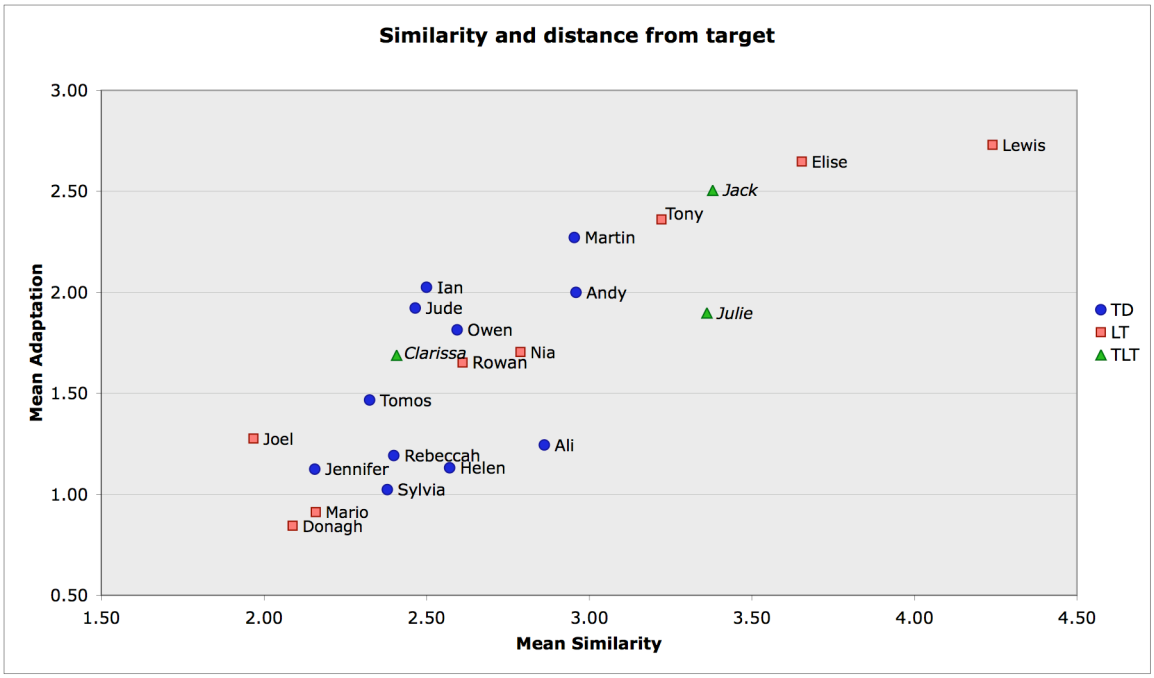

Figure 4. Similarity and distance from target.

Figure 4 shows a near linear mapping with a spread of TD scores from relatively low on both measures (Jennifer, Sylvia, Rebecca) to relatively higher scores on both (Andy, Martin). The three TLTs showed no low scores but ranged from middle-level on both (Clarissa) to high on both (Jack). The LTs, in accordance with our prediction, fell into two groups with extreme scores on both measures (Donagh, Mario and Joel on the low end, Tony, Elise and Lewis on the high end); the scores of two more LTs (Rowan and Nia) fell in the middle range, close to Clarissa. Neither TDs nor TLTs proved to have quite such extreme scores as the three low- and three high-scoring LTs (although one TLT, Jake, had scores that fell close to the highest end of the scale).

Interestingly, the three LTs at the low end of the matrix – Joel, Mario and Donagh – are the three LT children who fail to show the high use of labials that might be expected, given their late start on word use (see Table 3 and Figure 5). Their use was well below the mean of nearly 50% of words including a labial, ranging from Mario's 24% (the lowest figure of any of the 21 children) to Joel's 37%, which ranked sixth lowest. Note that the average age at the 25wp in the group of LTs at the high-systematicity end of the matrix (triangles in Figure 5) is highly similar to that of the low-systematicity LTs (diamonds in Figure 5), but use of labials in the former group is very high (in fact, Tony's 61% is the highest use of labials of all). If the three low-systematicity children are excluded from the analysis there is a strong correlation between age at the 25wp and percentage of words containing labials ($r = .45$, $p = 0.026$ [one-tailed]), such that children who reach the 25wp at an older age tend to base more of their words on labials (see Fig. 5).

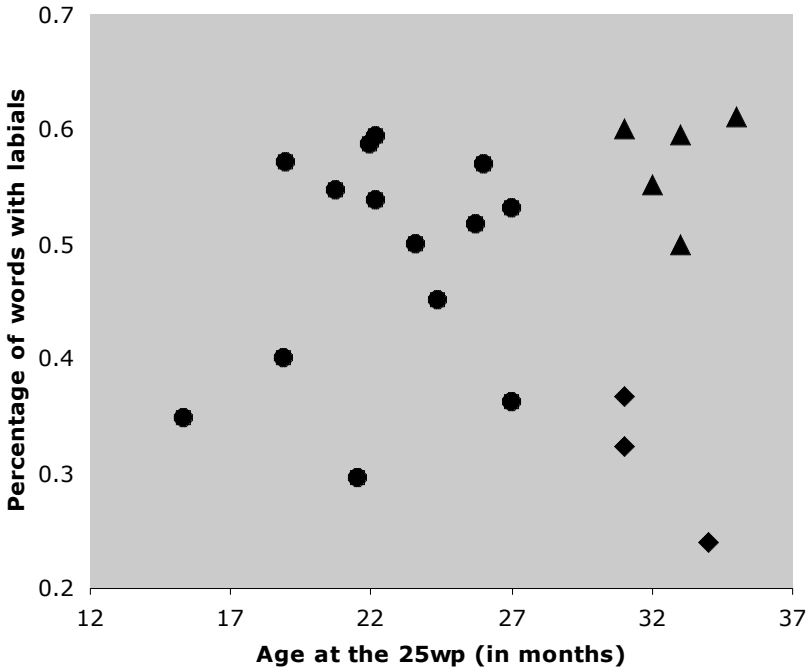

Figure 5. Labial use and age at 25wp by systematicity status. (Dots: TDs and TLTs. Triangles: High systematicity LTs; Diamonds: Low systematicity LTs.)

Discussion and conclusion

We have analyzed phonetic and phonological characteristics of early word use toward the end of the single-word period in three groups of children, as identified at age 2;6 by the Reynell Scales: TDs, transitional LTs (or apparent late talkers who had already begun to make rapid progress with language by that age) and LTs. Analysis of the word forms produced by the children in each of the three groups showed higher use of word-medial glottals by the two late-talker groups than by TDs but no significant group differences in coda use. Labial use, on the other hand, showed a tendency to increase with age at the end of the single-word period, although there were exceptions to this trend in each group.

In order to test the idea that some LTs might be showing a lack of systematicity in their early phonological organization we made use of a bottom-up procedure to gauge both similarity among child words (based on one token or variant per word type) and distance from target, or adaptation (based on all variant shapes produced for a given word type). We also established for each of the children whether or not there was 'over-use' of one or more consonants or vowels, based on the frequency of occurrence of those sounds in the child's word forms as compared with use in the full sample of target words attempted by the children in the group to which the child belongs (TD or (T)LT); where such use was identified, the 'template consonant/vowel' was included in both similarity and distance-from-target scores. The intersect of the similarity scores with the distance-from-target scores was then plotted in a matrix to evaluate relative systematicity, based on the finding established in previous work that advances in phonological organization are expressed in an increase in similarity among the child's word forms, often accompanied by a relative increase in distance from the target word (decrease in accuracy, or regression; cf.

Vihman, 1993; Vihman & Velleman, 2000; Vihman & Croft, 2007); one often observed index of this advance is the overuse of a given segment.

We saw that the TDs range from relatively low on systematicity, as defined by the intersect of the two scores, to medium; the TLTs range from medium to relatively high; and the LTs split into two groups, one at the very low end of the intersecting scores, the other ranging from middle to very high. Thus, as predicted, we are seeing two subgroups of LTs, those who appear to show little systematicity and those who show high systematicity, defined as high similarity among their word forms and a large distance from the adult targets, which we assume to be the result of the word form being fitted into the child's own pattern or template.

In earlier work (Vihman et al., 2008) we undertook a qualitative phonological description of the same data on which the quantitative analysis is based for three of the children who score at the highest end of this scale (Tony, Jack and Elise) and found strong evidence of template use; informally we have also analysed the data for the children who scored very low on systematicity and found that too to be a plausible result. This gives us confidence that our effort to quantify systematicity with a maximally objective 'bottom-up' procedure is providing the kind of information that we were looking for.

We also note that the LTs (and TLTs) who do show systematicity on the matrix tend to fall higher on the scale than any of the TDs. A likely reason for this is that, reaching the point of producing 25 or more words in a session at a much later age than the TDs at a comparable lexical level (and with age-appropriate comprehension), they are attempting to express more complex words with a phonetic inventory that is the same as or smaller than that of the lexically matched TDs, presumably leading them to experience a stronger need to adapt target forms to fit within their very limited phonetic capacities. It is our intention to incorporate a measure of size of phonetic inventory into our overall analysis in further work with these data.

On the other hand, the three LTs who fell at the low end of the matrix were also found to make relatively low use of labials. We assume, with Locke (1983) and others, that high use of labials reflects the visual advantage that they afford: Labials can be seen as well as heard, providing the child in transition into language with an important additional production cue. Thus while failure to make high use of labials is not in itself a sign of disorder, it suggests a striking 'blindness' to a useful cue in the production of children as old as 31-34 months at the end of the single-word period.

The idea that a domain-general processing deficit that is not purely auditory (as in the well known Tallal hypothesis: Tallal & Piercy, 1973; Tallal et al., 1996) might lie behind the various aspects of difficulty with language seen in children with SLI has been suggested in several recent studies, including Bishop (1997) and Bishop and Snowling (2004). Ullman and Pierpont (2005) specifically hypothesized that the underlying problem in SLI is a deficit in procedural learning. Since then Tomblin, Mainela-Arnold and Zhang (2007) reported use of a visual Serial Reaction Time task involving implicit sequential pattern learning to test (at about age 15) their longitudinal sample of 38 children diagnosed with SLI in Kindergarten, with a control group of 47 classmates with normal language skills. They found strong evidence of a weakness in procedural learning of sequences in the children with SLI. By hypothesis,

a weakness in procedural or implicit learning, generally speaking, could account for both lack of phonological systematicity and low reliance on labials: Systematicity depends on distributional learning of early word patterns, based on the representations of the first words produced (Vihman & Croft, 2007), while use of labials supports learning through implicit cross-modal association (McCune & Vihman, 2001).

This study is based on an original theoretical framework with respect to phonological development, which is seen as neither purely 'phonetic' nor purely 'phonological' but as a process of transformation that moves from the vocal precursor of speech, babbling practice, through first word production, to systematization as a result of the implicit discovery of patterning in early word forms. This discovery is expressed in each child's idosyncratic word production patterns or templates, often resulting in child word forms that bear no simple one-to-one 'rule-like' relationship to the adult forms.

The application of this approach to the study of late talkers is new and seems promising, but our study is still on-going; the results from the children's later follow-up sessions, which will reveal whether any of them show serious deficits in phonological, morphosyntactic or lexical learning at age 3 to 4 years, are not yet available. Nevertheless, we believe that our preliminary results have already confirmed the interest of our approach, in that it provides a way of identifying potentially important differences in the process of phonological development itself among the late talkers. Furthermore, the finding that a subgroup of our older LT learners, who reach the 25wp only at age 30-35 months, are proving unusually systematic for that lexical level is interesting in itself and will be the basis of further investigation.

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