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A phonological, lexical, and phonetic analysis of the new words that young children imitate

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Abstract

As children learn language, they spontaneously imitate the speech of those around them. This article investigates the new words that five children imitated between 1 and 2 years of age. Children were more likely to imitate new words as they aged and as their productive language developed. After controlling for age, children also were more likely to imitate new words that were shorter and with high neighborhood densities, and that contained sounds the children had previously produced accurately. Together, the findings demonstrate that both the patterns of the target words and children's productive abilities are predictors of children's imitative speech. This supports models of language development where there are influences stemming not only from phonological and lexical representations, but also from phonetic representations.

Keywords: language development, speech production, lexicon, phonetics, imitation

Résumé

Au cours de leur développement langagier, les enfants imitent spontanément le discours des gens qui les entourent. La présente recherche s'intéresse à certains mots nouveaux imités par cinq enfants âgés de 1 à 2 ans. Les enfants imitent plus souvent les mots nouveaux avec l'avancée en âge et avec le développement de leurs compétences en production. Après avoir tenu compte du facteur 'âge', les enfants sont également plus enclins à imiter des mots nouveaux courts et avec une haute densité de voisinage, et contenant des sons que les enfants avaient produits correctement auparavant. Les résultats montrent que les modèles lexicaux des mots cibles et les capacités productives des enfants peuvent prédire leur discours imitatif.

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Cela soutient les théories de développement linguistique selon lesquelles les influences proviennent non seulement des représentations phonologiques et lexicales, mais également des représentations phonétiques.

Mots-clés: développement langagier, production de la parole, lexique, phonétique, imitation

1. Introduction

Research on imitation and language development has a long history (Kymissis and Poulson 1990).[1] Imitation has been analyzed at different linguistic levels, such as phonology, word learning, syntax, and pragmatics (Fraser et al. 1963, Macken 1975, Clark 1977, Goldinger 1998, Clark 2007). Imitation has been argued to have a number of diverse functions (Speidel and Nelson 1989), such as providing a pragmatic function (Clark 2007), as a means of internalizing language (Saville-Troike 1988), or with different functions across development (Lewis, 1936/1999). Imitation is such a pervasive behaviour in early development that it has been argued to be an innate ability (Meltzoff 2005), involving dedicated mirror neuron systems (Rizzolatti and Arbib 1998, Vihman 2002). Notwithstanding the wealth of research on imitation, the topic of imitation has received little attention in the past 50 years. This reflects the shift away from behaviourist theories (Skinner 1957, Olmsted 1971) to generativist theories (Chomsky 1957, 1959), although Chomsky himself did acknowledge that imitation does play a function in language acquisition (Speidel and Nelson 1989: 14). Moreover, within the body of research on imitative speech in language development that does exist, little work on imitation has examined the relative influence of phonological, lexical, and phonetic (output) factors on children's imitative speech. Our current research provides a corpus analysis of new words presented by parents to their children between the ages of 1;0 and 2;11, and examines different variables as possible predictors for patterns in children's imitative speech.

Young learners have substantial receptive knowledge about the phonological and grammatical structures of their language even before they begin producing speech (Werker and Curtin 2005, Curtin and Zamuner 2014). However, in typical language development, learners move beyond their initial comprehension skills to both comprehend and express language. We approach imitation as it relates to speech production and language acquisition. When children imitate, they produce speech. We investigate imitative speech productions for insights into children's developing language system, specifically, the relationship between language development and phonological, lexical, and articulatory factors. In the next section, we review the role that these factors have been found to play in previous research, focusing on children under 3 years of age.

[1]Abbreviations used: Accurate Inventory 10: size of the child's accurate phoneme inventory; CHILDES: Child Language Exchange System database; MLU: mean length of utterance; ND: neighbourhood density; PP: phonotactic probability; Relational Accurate 10: average accuracy of children's production for the consonants in the direct new offer;

2. Phonological, lexical, and phonetic factors in language development

Research on phonological, lexical, and phonetic (output) factors in language development spans the period in development before the onset of speech production to a stage where children have acquired productive language (approximately 3 to 4 years of age). One approach has been to examine the types of words that infants and young children can recognize or learn in a controlled experimental setting. There is also research using non-word repetition and picture-word elicitation tasks, to examine topics such as vocabulary development, production accuracy, and variability (e.g., Hoff et al. 2008, Johnson and Zamuner 2010, Sosa and Stoel-Gammon 2012, Macrae 2013, Zamuner and Kharlamov 2016). Other studies take a longitudinal approach, examining the words that are added to children's vocabulary over time based on spontaneous speech samples or lexical normative data (e.g., Maekawa and Storkel 2006, de Bree et al. 2014). We focus our discussion on these types of longitudinal research.

There has been a recent focus on phonological and lexical factors in language development, highlighted in a number of review articles (e.g., Saffran and Graf Estes 2006, Stoel-Gammon 2011, Curtin and Zamuner 2014). One commonly investigated phonological factor is phonotactic probability, which refers to the likelihood that sounds will occur in a given environment. Infants are better at learning words with common phonotactic patterns (Gonzalez-Gomez et al. 2013, though see Storkel 2009). Commonly investigated lexical factors are Word Length in phonemes and Neighborhood Density, which refers to the amount of phonemic overlap a word has with other words in the lexicon. Children are more likely to learn shorter words and words that reside in dense phonological neighbourhoods (Stoel-Gammon 1998; Coady and Aslin 2004; Storkel 2004, 2006; Maekawa and Storkel 2006).

Turning to phonetic factors, it has been argued that there is a tight link between articulation and development (Rvachew 1994, Vihman 2009). Researchers are beginning to investigate whether infant speech perception involves articulatory and sensorimotor representations, before the onset of meaningful speech (DePaolis et al. 2011, Yeung and Werker 2013, Bruderer et al. 2015). This is relevant for the emergence of speech production because the findings suggest that these representations are an early and integral part of language processing. There is continuity across the sounds found in infants' babbling repertoires and their first words (Vihman et al. 1985) and there is evidence in early child language for some children displaying lexical selection and avoidance (Ferguson and Farwell 1975, Leonard et al. 1979, Schwartz and Leonard 1982, Vihman et al. 2016). Schwartz and Leonard (1982) found that young children were more likely to imitate new words that contain sounds IN rather than OUT of the child's own production repertoire. However, the stimuli were confounded with other phonological and lexical factors. For example, the OUT words /uʃuʃ, ozotʃ/ contain infrequent English phonemes, have few phonological neighbours, have a less frequent English syllable structure, and have a less typical English stress pattern, etc. Thus, it is difficult to ascertain whether imitation patterns reported in Schwartz and Leonard's experiment stem from the child's own articulatory abilities or from other factors. Lexical avoidance and selection can be captured by an ‘articulatory filter’ (Vihman 1993, Vihman et al. 2014, Vihman 2017), which hypothesizes that sounds that the learner has produced are more salient in the learner’s input (also see Stoel-Gammon 2011 for her discussion of an auditory–articulatory loop). The result is that words consisting of produced sounds are facilitated by the learner’s previous production experience, which in turn supports the memory, recognition, and learning of word forms with those segments (Keren-Portnoy et al. 2010).

A subset of work has looked at a combination of phonological, lexical, and phonetic factors in children’s vocabulary development. Maekawa and Storkel (2006) performed backward regression analyses on longitudinal production data from three children in the CHILDES database between the ages of 1;4 and 3;1. Word length was a predictive factor for all children (children produced shorter words before longer words); however, phonotactic probability (PP), neighbourhood density (ND), and word frequency varied in their predictability across the children. They also found that for one child, a significant predictor for vocabulary development was the normative production accuracy for the words’ final consonants (but not the words’ initial consonants). That is, early-acquired words were more likely to contain final consonants that 3-year-olds typically produce accurately (based on norms established by Smit et al. 1990). This is similar to the approach taken in the current study; however, we examine individual children’s own production accuracy rather than using normative data. Carlson et al. (2014) conducted a study on longitudinal production data from 64 children between the ages of 1;2 and 4;2, and analyzed which factors, such as Age, Word Frequency, Word Length, Neighbourhood Density, Phonotactic Probability (but no phonetic factors), were significant predictors of when a new word entered the children’s productive vocabularies. They found that the words that emerged in children’s productive vocabulary were those that sounded similar to other words (high neighbourhood density), but which did not have a lot of interference from other words in the lexicon. Carlson et al. measured interference by two variables called ‘clustering coefficient’ and ‘coreness’. These measurements are argued to reflect lexical access during speech production.

Theories vary in the relative weight that is given to phonological, lexical, and phonetic (output) factors in language development, with phonetics typically having a more peripheral role. Exemplar Theories and Usage-Based Models propose that speech output representations are integrated into phonological and lexical representations (Pierrehumbert 2003, Sosa and Bybee 2008, Munson et al. 2011, Sosa and Stoel-Gammon 2012). In these models, the development of phonological, lexical, and phonetic representations is multidirectional, as all form part of the long-term representations. Acoustic-motor representations are the focus of the newly developed A-Map Model, which highlights the importance of the child’s own articulations in language development (McAllister Byun et al. 2016). While the A-Map Model was developed specifically to account for child-specific phonological patterns, the model can be adopted to make predictions for language development. Central to the A-Map Model is “the pressure to match adult productions of a given word […] and the pressure to attempt a pronunciation that can be realized reliably”

(McAllister Byun et al. 2016: 2). Given these pressures, one would predict that children would be more likely to produce and/or learn words that contain sounds that the child has previously produced accurately, because these items would both match the adult target and be more reliably produced by the child.

3. Corpus study

The broad aim of this research was to examine what children imitate, for insights on the developing language system. The more specific aim was to examine the relative contribution of phonetic factors on children's speech, while taking into account phonological and lexical factors. We conducted an analysis of imitation on longitudinal data from the Providence Corpus from CHILDES (MacWhinney 2000, Demuth et al. 2006). Following Clark (2007), we identified syntactic frames in which parents made direct offers of new words to their children. For example, 'It's called a *kid*' (Mother to daughter Lily, aged 1;5.21). Each direct new offer was coded for whether it was imitated by the child and for a number of predictor variables: phonological, lexical, and phonetic factors (phonetic was defined as children's sound inventory and children's production experience with the sounds in the direct new offers). Binary hierarchical logistical regressions were used to determine which variables were significant predictors for whether children would imitate a direct new offer, after taking into account the control variable of chronological age.

3.1 Methodology

Analyses were done on corpora of five mother-child dyads (Alex, William, Lily, Naima, and Violet), from monolingual English-speaking children from the Providence Corpus (MacWhinney 2000, Demuth et al. 2006). These data comprise spontaneous speech collected between the ages of 0;11 and 4;0, and were typically collected bimonthly. Separate analyses were done for each child, and analyses were restricted to nouns, as done by Maekawa and Storkel (2006), Zamuner (2009b), among others. Each session was analyzed to identify new words, which were defined as words not produced during the previous recording sessions by either the child or other people present. The set of new words from each session was then re-checked to ensure that the words did not appear in any previous transcript in the singular or plural form. Each new word was also checked to ensure that the child did not first produce the word before the direct offer within the concurrent session.

The context for each new word was then coded, by checking the CHAT transcript for whether the new word was presented as a direct offer. Direct offers were defined by syntactic frames identified in Clark and Wong (2002), for example, "What is /what's …?, This is…, That is /that's…, and This is /that's called…" (Clark and Wong 2002: 185). Direct offers also included new words that were presented in isolation, for example, when a parent labeled an item in a book or in the immediate environment. The coding for the final set of direct new offers was additionally verified by checking the audio-video recordings. A subset of the words that were identified as direct new offers from the CHAT transcript were removed from the analyses after watching the audio-video recordings for a variety of reasons: for example, multiple people speaking at the same time; exchange was between two adults; mother talking to herself. In a few cases, words were excluded because the immediate context indicated that a word was not new to the child, such as discussing an event that occurred the day before. The final set of direct new offers were considered "unlikely to be already known to the child" based on the fact that the words did not previously appear in the corpus (Clark 2007: 164). Direct offers of new words were restricted to those that occurred in sentence-final position, to ensure that the new words were, relatively, of the same prominence. Past research has found that direct offers of new words are more likely to occur in sentence-final position (Clark and Wong 2002). Each direct new offer was coded for whether the child imitated the direct new offer (107 imitated, 454 not imitated), either immediately (n = 104) or within the next five conversational turns (n = 3). Six additional responses by the children were coded as unintelligible. Direct new offers that were coded as not imitated included a variety of responses, such as acknowledgments, continuation or change of the topic. See Clark (2007) who examines the pragmatic function of these different type of responses.

One difficulty in using spontaneous speech is that it can contain infrequent words, which can skew the results. To control for this, the direct new offers were searched for in the Child Mental Lexicon (Storkel and Hoover 2010), an English-language on-line corpus of child spoken language (4,832 types, 1,028,417 tokens). The assumption was that words found in the Child Mental Lexicon are more representative of child language. For example, some direct new offers not found in the Child Mental Lexicon were *dowel* (Naima 1;6.4), *reflection* (Alex 1;11.27), and *pimientos* (Lily 2;9.18). While the analyses focus on the subset of words found in the Child Mental Lexicon, when the analyses were repeated with the full set of direct new offers, similar results were found. Table 1 presents the number of direct new offers for each of the five children, broken down by chronological age, and whether or not the words were found in the Child Mental Lexicon.

The imitation rates by children in the Providence Corpus are lower (19%) than those reported by Clark (2007), who found that children imitate direct offers of new words on average of 54% of the time. Clark (2007) also reported that parents presented direct offers of new words in phrases 81% of the time, and as isolated words 19% of the time. In our data, direct new offers in phrases accounted for 54% of the new words, and those presented as isolated words accounted for 46% of the new words. Differences in imitation rates and the context of direct new offers could stem from situation contexts which vary across the recordings, such as playing games, meal times, and reading books. Data collection from the Providence Corpus was less dense after 3;0 (Table 1). For this reason, only the data from children between the ages of 1;0 and 2;11 were used for the analyses. A list of the direct new offers is given in Appendix A. The following sections contain analyses that examine phonological, lexical, and phonetic (output) variables, to determine which variables were significant predictors for whether a child imitated a direct new offer.

		All items			In Child Mental Lexicon		
Child	Age	Direct new offers	Imitated	Not imitated	Direct new offers	Imitated	Not imitated
Alex	1;0–1;11	58	1 (2%)	57	36	0	36
	2;0–2;11	94	32 (34%)	62	43	14 (33%)	29
	3;0–3;11	24	10 (42%)	14	6	2 (33%)	4
Lily	1;0–1;11	126	7 (6%)	119	71	5 (7%)	66
	2;0–2;11	36	9 (25%)	27	11	2 (18%)	9
	3;0–3;11	11	0	11	1	0	1
Naima	1;0–1;11	71	14 (20%)	57	35	7 (20%)	28
	2;0–2;11	6	1 (17%)	5	3	0	3
	3;0–3;11	1	0	1	–	–	–
Violet	1;0–1;11	56	11 (20%)	45	39	9 (23%)	30
	2;0–2;11	28	12 (43%)	16	9	2 (22%)	7
	3;0–3;11	10	5 (50%)	5	2	1 (50%)	1
William	1;0–1;11	20	1 (5%)	19	9	0	9
	2;0–2;11	19	4 (21%)	15	8	1 (13%)	7
	3;0–3;11	1	0	1	1	0	1
Combined	1;0–1;11	331	34 (10%)	297	190	21 (11%)	169
	2;0–2;11	183	58 (32%)	125	74	19 (26%)	56
	3;0–3;11	47	15 (32%)	32	10	3 (30%)	7
Total		561	107 (19%)	454	274	43 (16%)	232

Table 1: Direct new offers in the Providence Corpus, analyzed by child, child's age, and child's response. Computed for all direct new offers and subset of items found in Child Mental Lexicon

3.2 Expressive language measures

Imitation has been linked to other skills, such as chronological age and vocabulary growth (Snow 1989, Masur and Eichorst 2002). Five measures of each child's expressive language development were calculated. Cumulative type and token counts for each child's productive vocabulary were calculated for each session using the 'freq' command in CLAN (Computer Language Analysis program), transformed to logarithm form (Expressive Vocabulary Type, Expressive Vocabulary Token). Each child's consonant phoneme inventory was calculated using the phoneme accuracy tool in the *Phon* software <https://www.phon.ca>, Rose et al. 2006, Rose and MacWhinney 2014). This tool provides a list of the child's phoneme inventory, the phonemes' frequency, and how many times the phonemes were produced accurately. As with children's productive vocabulary, each child's phoneme inventory was calculated cumulatively, for example, at session 1, then at session 1 and 2 combined, etc. The Accurate Consonant Inventory measure was based on the number of accurately produced phonemes in the child's inventory, and a phoneme had to occur only a single time to be included. The measure Accurate Consonant Inventory 10 provided a more conservative estimate, which required that a phoneme be produced accurately a minimum of 10 times. We also calculated phoneme inventories independent of accuracy (e.g., a production of 'bottle' as 'mottle' could count as an instance of the child producing an /m/); however, these measures very quickly reached a ceiling and were not informative. Lastly, the child's mean length of utterance (MLU) was calculated for each session.

Correlations between chronological age (referred to as 'age' from this point forward) and the Expressive Language measures are given in Table 2. There were significant correlations between age and all measures. In addition, there were strong correlations (over .85) between expressive vocabulary and the children's accurate consonant inventories. This is problematic for the logistic regressions used in the following analyses, because of high multicollinearity. Therefore, only MLU and Accurate Consonant Inventory 10 were used in the analyses. It is important to keep in mind that because of the strong correlations, Accurate Consonant

Variable	1	2	3	4	5	6
1. Age	–	.78***	.80***	.75***	.81***	.67***
2. Expressive Vocabulary Type		–	**.98*****	**.96*****	**.97*****	.80***
3. Expressive Vocabulary Token			–	**.95*****	**.96*****	.79***
4. Accurate Consonant Inventory				–	**.96*****	.68***
5. Accurate Consonant Inventory 10					–	.74***
6. MLU						–

*$p < .05$ (two-tailed), **$p < .01$ (two-tailed), ***$p < .001$ (two-tailed), using Bonferroni adjusted alpha levels for multiple comparisons

Table 2: Correlations among Age and Expressive language measures (N = 264); correlations over .85 are in bold

Inventory 10 cannot be interpreted as referring only to the size of the child's accurately produced phoneme inventory; this is because the variable overlaps with other measures of expressive language.

Binary hierarchical logistical regressions were used for the analyses. Control variables are added in Block 1 and predictor variables are added in Block 2 (Reed and Wu 2013). A significant change in the model between Blocks 1 and 2 indicates that the predictor variables improves the membership of the dependent variable, after taking into account the control variable. The goal was to determine whether, after controlling for participants' age, Accurate Consonant Inventory 10 and/or MLU significantly accounted for whether children would imitate a direct new offer. The standard errors of the independent variables were below 2, indicating that there was no evidence of multicollinearity. The full model was statistically significant (χ^2(2, N = 164) = 7.75, $p < .05$) and explained 13% of the variance (Nagelkerke R^2) (Table 3). After controlling for age, only Accurate Consonant Inventory 10 was a significant predictor for distinguishing between the direct new offers that children did and did not imitate (χ^2(1, N = 164) = 8.32, $p < .01$). The value of Exp(B) or the Odds Ratio implies that direct new offers were 1.12 times more likely to be repeated by children with larger accurate phoneme inventories. The same results were found when Accurate Consonant Inventory 10 was replaced by Expressive Vocabulary Type. The analyses were also run using the full set of direct new offers with the same results as when based on the subset of words found in the Child Mental Lexicon.

The relationship between children's age in months, Accurate Consonant Inventory 10, and children's imitation of direct new offers is illustrated in Figure 1. Children were more likely to imitate a direct new offer as the size of their accurately produced consonant inventory grew larger.

						95% CI	
Variable	B	S.E.	Wald	p	Exp(B)	Lower	Upper
Block 1							
Age	.003	.001	12.92	.000	1.10	1.00	1.01
Block 2							
Age	.002	.001	2.85	.091	1.00	1.00	1.00
MLU	.021	.24	.008	.93	1.02	.64	1.63
Accurate Consonant Inventory 10	.11	.04	8.32	.004	1.12	1.04	1.21

Block 1: Nagelkerke R^2 = .08, χ^2 = 13.10, df = 1, $p < .001$; Block 2: Nagelkerke R^2 = .13, χ^2 = 7.75, df = 2, $p < .05$.

Table 3: Binary hierarchical logistic regression models predicting probability of child imitating direct new offer, age, and expressive language measures

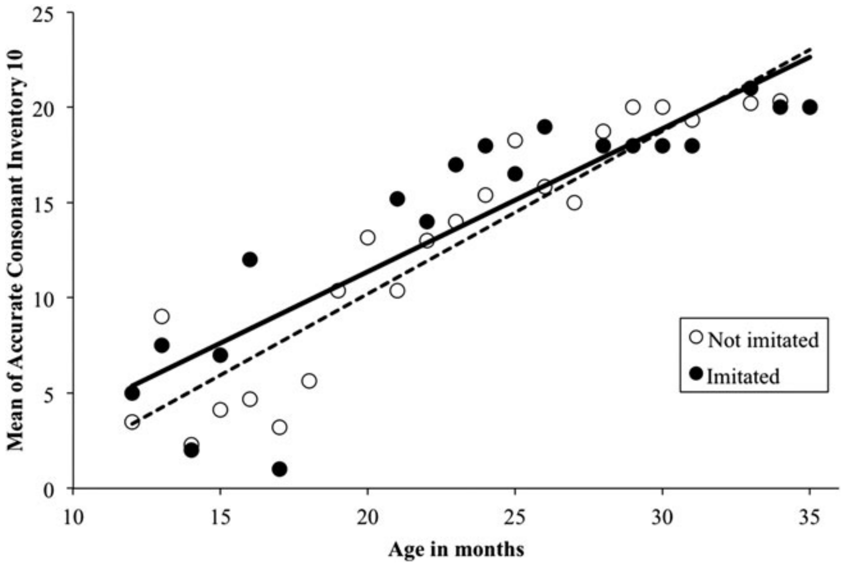

Figure 1: Relationship between direct new offers imitated, children's age in months, and Accurate Consonant Inventory 10

3.3 Target word measures

The second set of analyses examine whether children were more likely to imitate direct new offers based on the words' phonological and lexical properties, using values obtained from the Child Mental Lexicon (Storkel and Hoover 2010). This child-based corpus was used because comparative analyses have found differences in phonological and lexical patterns between child- and adult-based corpora (Storkel and Hoover 2010). The four Target Word measures were all based on logarithm forms and were as follows: Word Length, Phonotactic Probability, Neighbourhood Density, and Word Frequency. Word Length in phonemes and ND were chosen because they have been established in the literature as being significant predictors of vocabulary development (Storkel 2004, Stokes 2010, Carlson et al. 2014). We also included phonotactic probability because it has been shown to be a factor in the accuracy of children's speech productions (e.g., Zamuner et al. 2004, Munson et al. 2005, Zamuner 2009a), though the factor has been less predictive in analyses of children's vocabulary growth (Maekawa and Storkel 2006, Carlson et al. 2014). Lastly, word frequency was included in the analyses. While lexical frequency has been shown to be a significant factor in phonological acquisition (Ota and Green 2013), the expectation was that this would not be a significant predictor of children's imitative speech. This is because all of the direct new offers were new to the children, within the context of the recording sessions.

Correlations between the Age and the Target Word measures are provided in Table 4. Age was not significantly correlated to any of the Target Word measures;

Variable	1	2	3	4	5
1. Age	–	.12	.10	−.15	−.18*
2. Word Length		–	.58***	−.84***	−.28***
3. PP			–	−.33***	−.05
4. ND				–	.19*
5. Word Frequency					–

*$p < .05$ (two-tailed), **$p < .01$ (two-tailed), ***$p < .001$ (two-tailed), using Bonferroni adjusted alpha levels for multiple comparisons

Table 4: Correlations among Age and Target Word measures (N = 264)

however, the high correlation between Word Length and ND is problematic due to high multicollinearity. In fact, a binary hierarchical logistical regression analyses that included both Word Length and ND variables gave a standard error above 3 for Word Length, indicating multicollinearity. Therefore, only the ND measure was used, while keeping in mind that this variable is highly correlated with, and cannot be isolated from, Word Length.

A binary hierarchical logistical regression was used to assess whether characteristics of the Target Word predicted whether children would imitate a direct new offer, after controlling for participants' age (Table 5). There was no evidence of multicollinearity. The full model was statistically significant, accounting for 15% of the variance (Nagelkerke R^2). After controlling for age, the variable ND was a significant predictor for the direct new offers that children imitated ($\chi^2(1, N = 164) = 7.36$, $p < .01$). The value of Exp(B) for the variable ND Log implies that direct new words were three times more likely to be imitated when the word had more phonological neighbours. However, recall that ND was highly correlated with Word Length, and the effect

						95% CI	
Variable	B	S.E.	Wald	p	Exp(B)	Lower	Upper
Block 1							
Age	.003	.001	12.92	.000	1.10	1.00	1.01
Block 2							
Age	.004	.001	17.01	.000	1.04	1.00	1.01
PP	.24	.61	.16	.69	1.28	.39	4.20
ND	1.05	.39	7.36	.007	2.85	1.34	6.09
Word Frequency	1.92	1.47	1.70	.19	6.84	.38	122.80

Block 1: Nagelkerke $R^2 = .08$, $\chi^2 = 13.10$, $df = 1$, $p < .001$; Block 2: Nagelkerke $R^2 = .15$, $\chi^2 = 10.53$, $df = 3$, $p < .05$.

Table 5: Binary hierarchical logistic regression models predicting probability of child imitating direct new offer, Age, and Target Word measures

can therefore not be uniquely attributed to ND. When the same model was run with Word Length in place of ND, the results were the same.

As expected, Word Frequency was not a significant predictor of children's imitations of direct new offers. The same results were found when running correlations and regression analyses using the full set of direct new offers, as when using only those words found in the Child Mental Lexicon.

The relationship between children's age in months, the target word's ND, and whether or not children imitated the direct new offer is provided in Figure 2. Children were more likely to imitate a direct new offer when it had a higher ND.

3.4 Target word production experience

The third analysis focused on children's production experience with the consonants in the direct new offers, to determine whether children were more likely to imitate direct new offers that contained sounds the children had previously produced. Each child's experience producing the consonants in the direct new offers was measured, using the phoneme accuracy tool in *Phon*. The child's production experience was evaluated independently of the child's accuracy (Independent Target, Independent Target 10), and relative to how accurately the child had produced those sounds (Relational Accurate, Relational Accurate 10). For Independent Target and Relational Accurate, a consonant had to occur only once to be counted, and the more conservative estimates of Independent Target 10 and Relational Accurate 10 (which was a measure of children's overall language, i.e., the size of the child's accurate phoneme inventory), required that a consonant occur at least

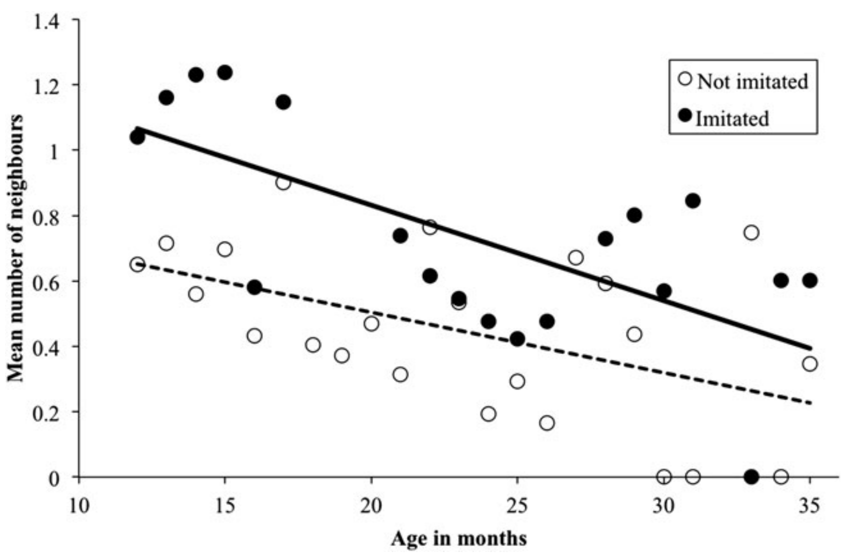

Figure 2: Relationship between direct new offers imitated, children's age, and ND of target word

10 times. To illustrate, take the direct new offer *peacock* (Naima, 1;0;14), with three consonants: /p, k, k/. The /p/ had not yet occurred in Naima's productive vocabulary up to this point in the database, and /k/ occurred in 15 of her words, of which /k/ was produced accurately seven times. Therefore, both the Independent Target and Independent Target 10 cells equaled .66 (two of the three consonants appeared in her target words). For Relational Accurate, the cell also equaled .66 (two of the three consonants appeared accurately at least once in her productive vocabulary); however, Relational Accurate 10 equaled zero, because none of the consonants had been produced accurately by Naima 10 times or more. It is possible to conduct a more nuanced analysis of segmental accuracy, taking into account whether a child produces segments accurately, or makes substitutions or deletions. It is also possible to take positional effects and complexity into account when coding for accuracy. For example, for the word *peacock*, one could code for whether Naima had any words in her lexicon in which /p/ was produced correctly in word-initial position, in singleton onsets. Our initial goal was to analyze the data taking into account prosodic position and complexity; however, the coding became too fine-grained for the dataset, so we decided to code the data on a broader level. Table 6 provides the correlations between age in days and the target word production variables. All variables were significantly correlated with each other, though no correlations were over .85.

A binary hierarchical logistical regression was used to assess whether the child's production experience with the consonants in the target word predicted whether the child would imitate a direct new offer, after controlling for children's age (Table 7). No outliers were detected, and there was no evidence of multicollinearity. The full model was statistically significant and explained 17% of the variance (Nagelkerke R^2). After controlling for Age, the variable Relational Accurate 10 was a significant predictor for distinguishing between the direct new offers that children did and did not imitate ($\chi^2(1, N = 164) = 8.87$, $p < .01$). The value of Exp(B) for Relational Accurate 10 indicates that direct new words were 14 times more likely to be repeated when they consisted of consonants that the child had produced accurately at least 10

Variable	1	2	3	4	5
1. Age	–	.33***	.51***	.35***	.58***
2. Independent Target		–	.70***	.62***	.48***
3. Independent Target 10			–	.60***	.73***
4. Relational Accurate				–	.72***
5. Relational Accurate 10					–

*$p < .05$ (two-tailed), **$p < .01$ (two-tailed), ***$p < .001$ (two-tailed), using Bonferroni adjusted alpha levels for multiple comparisons

Table 6: Correlations among Age and Target Word Production Experience measures (N = 264)

Variable	B	S.E.	Wald	p	Exp(B)	95% CI Lower	95% CI Upper
Block 1							
Age	.003	.001	12.92	.000	1.10	1.00	1.01
Block 2							
Age	.001	.001	1.53	.22	1.00	.99	1.00
Independent Target 10	−.92	1.07	.73	.39	.40	.05	3.25
Relational Accurate 10	2.62	.88	8.87	.003	13.72	2.49	76.85

Block 1: Nagelkerke $R^2 = .08$, $\chi^2 = 13.10$, $df = 1$, $p < .001$; Block 2: Nagelkerke $R^2 = .17$, $\chi^2 = 13.71$, $df = 2$, $p < .001$.

Table 7: Binary hierarchical logistic regression models predicting probability of child imitating direct new offer, age, and child production experience

times previously. The same analyses were conducted using the full set of direct new offers, with the same results.

The relationship between children's age in months, Relational Accurate 10 (average accuracy of children's production for the consonants in the direct new offer), and whether or not children imitated the direct new offer is shown in Figure 3. Children were more likely to imitate a direct new offer when it contained more consonants that the child had accurately produced at least 10 times before.

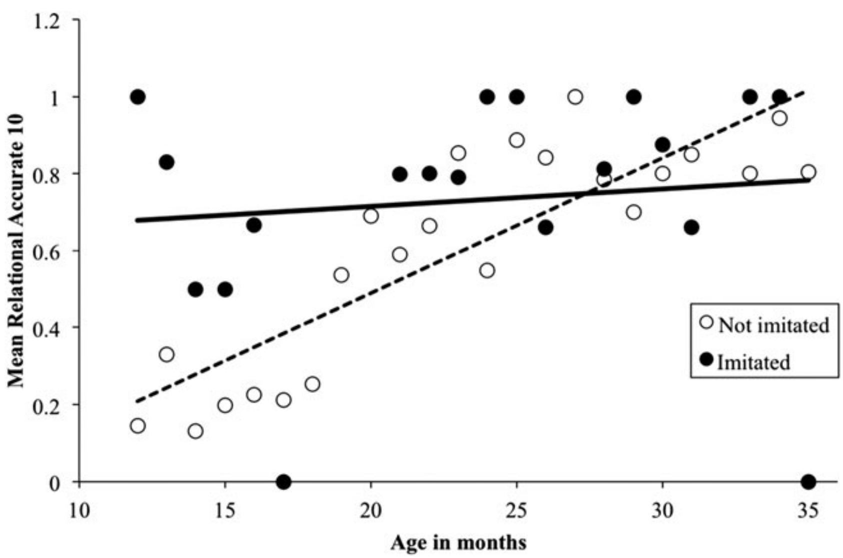

Figure 3: Relationship between direct new offers imitated, children's age, and Relational Accurate 10

Variable	1	2	3	4
1. Age	–	.81***	−.15	.58***
2. Accurate Inventory 10		–	−.18*	.78***
3. ND			–	−.06
4. Relational Accurate 10				–

*$p < .05$ (two-tailed), **$p < .01$ (two-tailed), ***$p < .001$ (two-tailed), using Bonferroni adjusted alpha levels for multiple comparisons

Table 8: Correlations among age and all measures, subset of words (N = 264)

3.5 Combined measures

The last analysis combined the significant predictor variables from the previous analyses: Accurate Inventory 10, which was a measure of children's overall language (size of the child's accurate phoneme inventory), ND, and Relational Accurate 10. Correlations among the variables are given in Table 8. There were significant correlations between many of the variables, though none were over .85.

Finally, we assessed a combination of the predictor variables, after controlling for participants' age (Table 9). The model was run with outliers removed that had standard residuals of ±2.58; however, this did not improve classification by more than 2%, so the original model with all data was used. There was no evidence of multicollinearity. The full model was statistically significant ($\chi^2(3, N = 164) = 22.13$, $p < .001$), explaining 22% of the variance (Nagelkerke R^2). After controlling for age, the variables ND ($\chi^2(1, N = 164) = 8.47$, $p < .01$) and Relational Accurate 10 ($\chi^2(1, N = 164) = 3.91$, $p < .05$) were significant predictors for distinguishing between the direct new offers that children did and did not imitate. Direct new offers were three times more likely to be imitated when the word resided in a

						95% CI	
Variable	B	S.E.	Wald	p	Exp(B)	Lower	Upper
Block 1							
Age	.003	.001	12.92	.000	1.10	1.00	1.01
Block 2							
Age	.001	.002	.18	.67	1.00	.998	1.00
Accurate Inventory 10	.07	.06	1.48	.22	1.07	.96	1.20
ND	1.10	.38	8.47	.004	3.01	1.43	6.31
Relational Accurate 10	1.46	.74	3.91	.048	4.32	1.01	18.37

Block 1: Nagelkerke $R^2 = .08$, $\chi^2 = 13.10$, $df = 1$, $p < .001$; Block 2: Nagelkerke $R^2 = .22$, $\chi^2 = 22.13$, $df = 3$, $p < .001$.

Table 9: Binary hierarchical logistic regression models predicting probability of child imitating direct new offer, age, and all measures

denser phonological neighbourhood, and direct new offers were four times more likely to be imitated when the target word contained phonemes that the child had previously produced accurately. The variable Accurate Inventory 10 was not a significant predictor when the other variables were included in the model.

The combined models were run with Inventory 10 replaced by Expressive Vocabulary Type and with ND replaced by Word Length, with the same results. The same analyses were also conducted using the full set of direct new offers with partially different results. The full model was significant, $\chi^2(3, N = 514) = 29.34, p < .001$, explaining 24% of the variance (Nagelkerke R^2). After controlling for age, the variable ND was a significant predictor ($\chi^2(1, N = 164) = 11.35, p < .001$), but Relational Accurate 10 only approached significance ($\chi^2(1, N = 164) = 3.26, p = .071$). Lastly, the variable Accurate Inventory 10 was significant ($\chi^2(1, N = 164) = 4.92, p < .05$).

3.6 General perceptual or articulatory ease

One important remaining question is whether it is the child's own production accuracy that is predictive of which words they imitate, or whether children's imitation patterns reflect more general perceptual or articulatory ease. To test for this possibility, we coded the initial and final consonants of the direct new offers with the percentage of children who accurately produced the consonants at age 3, using normative data from Smit et al. (1990). We then performed two additional logistic regressions to determine whether, after controlling for age, normative data for initial and final consonant accuracy was a significant predictor of whether children would imitate a direct new offer. There were no significant effects for either the initial or the final consonant.

4. Discussion

This study analyzed children's imitation of direct new offers from longitudinal production data. First, we found an increase in the number of direct new offers that children imitated between 1 and 2 years of age. We then examined a variety of predictor variables: the child's productive language maturation (Expressive Language Measures), phonological and lexical characteristics of the direct new offers (Target Word Measures), and lastly phonetic (output) factors which were measures of the child's production experience with the sounds in the direct new offers (Target Word Production Experience). When analyzing the measures separately, all had significant predictors for children's imitations. For the Expressive Language Measures, the size of the child's consonant inventory was a significant predictor of imitation rates (though this could not be attributed solely to consonant inventories, because it was highly correlated with vocabulary size). When examining the phonological and lexical properties of the target words (Target Word Measures), the target word's ND was a significant predictor of children's imitations (though again, ND was highly correlated with Word Length). In addition, the child's own production experience with the sounds in the direct new offers (Target Word Production Experience), was a significant predictor of children's imitations. When all variables were combined, Target Word and Target Word Production Experience were significant predictors of, but not the measure of, Expressive Language.

What emerges is that both the properties of a word and the child's own accuracy in producing the words' sounds predicts whether or not the word is imitated. These results are in line with previous findings, which found that the child's age, word length, and ND are all significant predictors of children's productive vocabulary development (Stoel-Gammon 1998, Maekawa and Storkel 2006, Carlson et al. 2014). Our findings are different from those of Maekawa and Storkel (2006), who found that for one of the three children examined, a significant predictor for the child's productive vocabulary development was the words' final (but not initial) consonant accuracy at age 3, based on normative data from Smit et al. (1990). Our primary analyses differed from Maekawa and Storkel's in that we examined the child's own production accuracy with all of the consonants in the direct new offers, rather than based on normative data of the initial and final consonants. When we analyzed imitation patterns using normative data for initial and final consonant accuracy, these were not significant predictors for whether children would imitate a direct new offer. Thus, our data suggest that it is the child's own production experience with the sounds of a word that predicts the child's imitation patterns. However, the effects of perceptual salience and ease of articulation on children's imitative speech are worth examining in more detail in the future.

Our findings are also in line with studies of lexical selection and avoidance at the earliest stages of speech production (Ferguson and Farwell 1975, Leonard et al. 1979, Schwartz and Leonard 1982, Vihman et al. 2016, Vihman 2017). It has been suggested that these effects are strongest when children have a small productive vocabulary, that is, under 50 words. It is possible that the effects found in our study were driven by the earliest stages, when children had fewer than 50 words in their vocabulary. To test for this possibility, we restricted the data to when children's productive vocabulary was over 50 words and redid the analyses. After controlling for age, we found that there were no longer any significant Expressive Language predictors on children's imitation rates. However, we did find the same significant effects with the Target Word and Target Word Production Experience measures (also see Storkel 2006 for analyses of data beyond 50 words). Thus, the findings held that the properties of a word and the child's own accuracy in producing the words' sounds were significant predictors of children's imitations beyond the 50-word stage.

These findings can be captured by models in which representations have multiple dimensions, and in which phonetic details are stored bundled together with semantic and other lexical information. In Exemplar and Usage-Based Theories of speech perception and speech production (e.g., Goldinger 1998, Pierrehumbert 2003, Sosa and Bybee 2008), the speaker keeps track of instances of a particular input to create an exemplar cloud. Each token leaves a unique memory trace, which includes detailed perceptual and conceptual information. In perception, traces are activated according to their similarity to the input stimulus. The average features of the traces with the highest activation provide the meaning to the incoming token (Goldinger 1998). In speech production, a trace is selected randomly from the exemplar cloud and the target for production is a weight of the surrounding exemplars (Pierrehumbert 2003). The assumption is that the production and perception system are closely tied together. Imitation has been conceptualized as pattern matching, which describes the learner's ability to match and to detect differences between their vocal productions and the target (Olmsted 1971, Locke 1983, Vihman 1993). The recently developed A-Map Model (McAllister Byun et al. 2016) captures this notion of pattern matching. We see this model as making the logical prediction that children would be more likely to learn words that they are able to produce accurately, because these words would have the least amount of pressure for both matching the adult target and for the child to produce the words reliably (also see McAllister and Tessier 2016).

While naturalistic studies provide a large-scale overview of development, they may miss crucial data and may not contain certain words or structures. Future studies could be conducted to control the structures of the new words presented to children, while measuring which words are imitated; furthermore, to measure whether the words that are imitated are subsequently learned better. This type of controlled approach is seen in the literature on the production effect, where a subset of words are produced by participants during training (akin to imitation) and another subset of words are not produced. In most cases, adults' and children's production leads to better recall and recognition of items (e.g., MacLeod et al. 2010, Icht and Mama 2015, Zamuner et al. 2016). However, the effect of production is not always systematic. A reverse production effect has also been documented, where there is an advantage in recall and recognition for items that are not produced during training. The reverse production effect has been found both with adults (Kaushanskaya and Yoo 2011) and with children (Zamuner et al. 2015, Zamuner et al., in press). In sum, the effects of production appear to be subject to task-, attentional-, linguistic-, and experience-related factors (Zamuner et al. 2017). Controlled studies would also allow us to address issues of individual variability. A shortcoming of our corpus analyses is that the data were not dense enough to analyze each child separately. To know how generalizable the results are, we want to know whether the effects described in this research are similar across children or whether their relative weighting varies by child. The same questions can also be asked about whether the results are generalizable across different languages. Lastly, it is important to point out that the selection of variables used in hierarchical logistic regression analyses can impact the results, given that one has to decide which variables to include in the analyses (Reed and Yu 2013). As this is one of the first studies to apply these analyses to examine phonological, lexical, and phonetic factors in children's imitative speech, it can serve as a comparison for future research on language development.

Corpora and Databases

Providence Corpus: drawn from CHILDES (Child Language Exchange System) database <https://childes.talkbank.org/>.

Child Mental Lexicon online <http://wordlearning.ku.edu/child-calculator>.

Phon software <https://www.phon.ca>.

References

de Bree, Elise, Tania S. Zamuner, and Frank Wijnen. 2014. Neighbourhood densities in the vocabularies of Dutch children with a familial risk of dyslexia. In *Where the principles fail. A festschrift for Wim Zonneveld on the occasion of his 64th birthday*, ed. René Kager, Janet Grijzenhout, and Koen Sebregts, 17–28. Utrecht: Utrecht Institute of Linguistics OTS.

Bruderer, Alison G., D. Kyle Danielson, Padmapriya Kandhadai, and Janet F. Werker. 2015. Sensorimotor influences on speech perception in infancy. *Proceedings of the National Academy of Sciences*, 112(44): 13531–13536.

Carlson, Matthew T., Morgan Sonderegger, and Max Bane. 2014. How children explore the phonological network in child-directed speech: A survival analysis of children's first word productions. *Journal of Memory and Language* 75: 159–180.

Chomsky, Noam. 1957. *Syntactic structures*. The Hague: Mouton.

Chomsky, Noam. 1959. A review of B.F. Skinner's verbal behavior. *Language* 35(1): 26–58.

Clark, Eve V. 2007. Young children's uptake of new words in conversation. *Language in Society* 36(2): 157–182.

Clark, Eve V., and Andrew D-W. Wong. 2002. Pragmatic directions about language use: Offers of words and relations. *Language in Society* 31(2): 181–212.

Clark, Ruth. 1977. What's the use of imitation? *Journal of Child Language* 4(3): 341–358.

Coady, Jeffry A., and Richard N. Aslin. 2004. Young children's sensitivity to probabilistic phonotactics in the developing lexicon. *Journal of Experimental Child Psychology* 89(3): 183–213.

Curtin, Suzanne, and Tania S. Zamuner. 2014. Understanding the developing sound system: Interactions between sounds and words. *WIREs Cognitive Science* 5(5): 589–602.

Demuth, Katherine, Jennifer Culbertson, and Jennifer Alter. 2006. Word-minimality, epenthesis and coda licensing in the early acquisition of English. *Language and Speech* 49 (2): 137–173.

DePaolis, Rory A., Marilyn M. Vihman, and Tamar Keren-Portnoy. 2011. Do production patterns influence the processing of speech in prelinguistic infants? *Infant Behavior and Development* 34(4): 590–601.

Ferguson, Charles A., and Carol B. Farwell. 1975. Words and sounds in early language acquisition. *Language* 51(2): 419–439.

Fraser, Colin, Ursula Bellugi, and Roger Brown. 1963. Control of grammar in imitation, comprehension, and production. *Journal of Verbal Learning and Verbal Behavior* 2(2): 121–35.

Goldinger, Stephen D. 1998. Echoes of echoes? An episodic theory of lexical access. *Psychological Review* 105(2): 251–279.

Gonzalez-Gomez, Nayeli, Silvana Poltrock, and Thierry Nazzi. 2013. A "bat" is easier to learn than a "tab": Effects of relative phonotactic frequency on infant word learning. *PloS ONE* 8(3): e59601.

Hoff, Erika, Cynthia Core, and Kelly Bridges. 2008. Non-word repetition assesses phonological memory and is related to vocabulary development in 20-to 24-month-olds. *Journal of Child Language* 35(4): 903–916.

Icht, Michal, and Yaniv Mama. 2015. The production effect in memory: A prominent mnemonic in children. *Journal of Child Language* 42(5): 1102–1124.

Johnson, Elizabeth, and Tania S. Zamuner. 2010. Using infant and toddler testing methods in language acquisition research. In *Experimental Methods in Language Acquisition Research*, ed. Elma Blom and Sharon Unsworth, 73–94. Amsterdam: Benjamins.

Kaushanskaya, Margarita, and Jeewon Yoo. 2011. Rehearsal effects in adult word learning. *Language and Cognitive Processes* 26(1): 121–148.

Keren-Portnoy, Tamar, Marilyn M. Vihman, Rory A. DePaolis, Chris J. Whitaker, and Nicola M. Williams. 2010. The role of vocal practice in constructing phonological memory. *Journal of Speech, Language, and Hearing Research* 53(5): 1280–1293.

Kymissis, Effie, and Claire L. Poulson. 1990. The history of imitation in learning theory: The language acquisition process. *Journal of the Experimental Analysis of Behavior* 54(2): 113–127.

Leonard, Laurence B., Richard G. Schwartz, M. Karen Folger, Marilyn Newhoff, and M. Jeanne Wilcox. 1979. Children's imitation of lexical items. *Child Development* 50(1): 19–27.

Lewis, Morris M. 1999. *Infant speech*. New York: Routledge. [1936].

Locke, John L. 1983. *Phonological acquisition and change*. New York: Academic Press.

MacLeod, Colin M., Nigel Gopie, Kathleen L. Hourihan, Karen R. Neary, and Jason D. Ozubko. 2010. The production effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 36(3): 671–685.

Macken, Marlys A. 1975. The acquisition of intervocalic consonants in Mexican Spanish: A cross-sectional study based on imitation data. *Papers and Reports on Child Language Development* 9: 29–42.

Macrae, Toby. 2013. Lexical and child-related factors in word variability and accuracy in infants. *Clinical Linguistics and Phonetics* 27(6–7): 497–507.

MacWhinney, Brian. 2000. *The CHILDES project: Tools for analyzing talk*. 3rd ed. Mahwah NJ: Lawrence Erlbaum Associates.

McAllister Byun, Tara, and Anne-Michelle Tessier. 2016. Motor influences on grammar in an emergentist model of phonology. *Language and Linguistic Compass* 10(9): 431–452.

McAllister Byun, Tara, Sharon Inkelas, and Yvan Rose. 2016. The A-map model. *Language* 92(1): 141–178.

Maekawa, Junko, and Holly L. Storkel. 2006. Individual differences in the influence of phonological characteristics on expressive vocabulary development by young children. *Journal of Child Language* 33(3): 439–459.

Masur, Elise Frank, and Doreen L. Eichorst. 2002. Infants' spontaneous imitation of novel versus familiar words: Relations to observational and maternal report measures of their lexicons. *Merrill-Palmer Quarterly* 48(4): 405–426.

Meltzoff, Andrew N. 2005. Imitation and other minds: The "Like Me" hypothesis. In *Perspectives on imitation: From cognitive neuroscience to social science*, ed. Susan Hurley and Nick Chater, 55–77. Cambridge: MIT Press.

Munson, Benjamin, Beth A. Kurtz, and Jennifer Windsor. 2005. The influence of vocabulary size, phonotactic probability, and wordlikeness on nonword repetitions of children with and without specific language impairment. *Journal of Speech, Language, and Hearing Research* 48(5): 1033–1047.

Munson, Benjamin, Jan Edwards, and Mary E. Beckman. 2011. Phonological representations in language acquisition: Climbing the ladder of abstraction. In *The Oxford handbook of laboratory phonology*, ed. Abigail C. Cohn, Cécile Fougeron, and Marie K. Huffman, 288–309. Oxford: Oxford University Press.

Olmsted, David L. 1971. *Out of the mouths of babes: Earliest stages in language learning*. The Hague: Mouton.

Ota, Mitsuhiko, and Sam J. Green. 2013. Input frequency and lexical variability in phonological development: A survival analysis of word-initial cluster production. *Journal of Child Language* 40(3): 539–566.

Pierrehumbert, Janet B. 2003. Phonetic diversity, statistical learning, and acquisition of phonology. *Language and Speech* 46(2–3): 115–154.

Reed, Phil, and Yaqionq Wu. 2013. Logistic regression for risk factor modelling in stuttering research. *Journal of Fluency Disorders* 38(2): 88–101.

Rizzolatti, Giacomo, and Michael A. Arbib. 1998. Language within our grasp. *Trends in Neurosciences* 21(5): 188–194.

Rose, Yvan, and Brian MacWhinney. 2014. The PhonBank project: Data and software-assisted methods for the study of phonology and phonological development. In *The Oxford handbook of corpus phonology*, ed. Jacques Durand, Ulrike Gut, and Gjert Kristoffersen, 308–401. Oxford: Oxford University Press.

Rose, Yvan, Brian MacWhinney, Rodrigue Byrne, Gregory Hedlund, Keith Maddocks, Philip O'Brien, and Todd Wareham. 2006. Introducing *Phon*: A software solution for the study of phonological acquisition. In *Proceedings of the 30th Annual Boston University Conference on Language Development*, ed. David Bamman, Tatiana Magnitskaia, and Colleen Zaller, 489–500. Somerville MA: Cascadilla Press.

Rvachew, Susan. 1994. Speech perception training can facilitate sound production learning. *Journal of Speech and Hearing Research* 37(2): 347–357.

Saffran, Jenny R., and Katharine Graf Estes. 2006. Mapping sound to meaning: Connections between learning about sounds and learning about words. *Advances in Child Development and Behaviour* 34: 1–38.

Saville-Troike, Muriel. 1988. Private speech: Evidence for second language learning strategies during the 'silent period'. *Journal of Child Language* 15(3): 567–590.

Schwartz, Richard G., and Laurence B. Leonard. 1982. Do children pick and choose? An examination of phonological selection and avoidance in early lexical acquisition. *Journal of Child Language* 9(2): 319–336.

Skinner, B. F. 1957. *Verbal behavior*. New York: Appleton-Century-Crofts.

Smit, Ann Bosma, Linda Hand, J. Joseph Freilinger, John E. Bernthal, and Ann Bird. 1990. The Iowa articulation norms project and its Nebraska replication. *Journal of Speech and Hearing Disorders* 55(4): 779–798.

Snow, Catherine E. 1989. Imitativeness: A trait or a skill? In *The many faces of imitation*, ed. Gisela Speidel and Keith Nelson, 73–90. New York: Springer Verlag.

Sosa, Anna V., and Carol Stoel-Gammon. 2012. Lexical and phonological effects in early word production. *Journal of Speech, Language, and Hearing Research* 55(2): 596–608.

Sosa, Anna V., and Joan L. Bybee. 2008. A cognitive approach to clinical phonology. In *The Handbook of Clinical Linguistics*, ed. Martin J. Ball, 480–490. Oxford: Blackwell.

Speidel, Gisela E., and Keith E. Nelson, eds. 1989. *The many faces of imitation in language learning*. Berlin: Springer.

Stoel-Gammon, Carol. 1998. Sounds and words in early language acquisition: The relationship between lexical and phonological development. In *Exploring the speech–language connection*, ed. Rhea Paul, 25–52. Baltimore: Paul H. Brookes.

Stoel-Gammon, Carol. 2011. Relationships between lexical and phonological development in young children. *Journal of Child Language* 38(1): 1–34.

Stokes, Stephanie F. 2010. Neighborhood density and word frequency predict vocabulary size in toddlers. *Journal of Speech, Language, and Hearing Research* 53(3): 670–683.

Storkel, Holly L. 2004. Do children acquire dense neighborhoods? An investigation of similarity neighborhoods in lexical acquisition. *Applied Psycholinguistics* 25(2): 201–221.

Storkel, Holly L. 2006. Do children still pick and choose? The relationship between phonological knowledge and lexical acquisition beyond 50 words. *Clinical Linguistics and Phonetics* 20(7–8): 523–529.

Storkel, Holly L. 2009. Developmental differences in the effects of phonological, lexical, and semantic variables on word learning by infants. *Journal of Child Language* 36(2): 291–321.

Storkel, Holly L., and Jill R. Hoover. 2010. An online calculator to compute phonotactic probability and neighborhood density on the basis of child corpora of spoken American English. *Behavior Research Methods* 42: 497–506.

Vihman, Marilyn M. 1993. Variable paths to early word production. *Journal of Phonetics* 21(1): 61–82.

Vihman, Marilyn M. 2002. The role of mirror neurons in the ontogeny of speech. In *Mirror neurons and the evolution of brain and language*, ed. Maksim Stamenov, and Vittorio Gallese, 305–314. Amsterdam: Benjamins.

Vihman, Marilyn M. 2009. Word learning and the origins of phonological system. In *Language acquisition*, ed. Susan Foster-Cohen, 15–39. Basingstoke: Palgrave Macmillan.

Vihman, Marilyn M. 2017. Learning words and learning sounds: Advances in language development. *British Journal of Psychology* 108(1): 1–27.

Vihman, Marilyn M., Rory A. DePaolis, and Tamar Keren-Portnoy. 2014. The role of production in infant word learning. *Language Learning* 64(1): 121–140.

Vihman, Marilyn M., Rory A. DePaolis, and Tamar Keren-Portnoy. 2016. Babbling and words: A dynamic systems perspective on phonological development. In *The Cambridge Handbook of Child Language*, ed. Edith L. Bavin, and Letitia R. Naigles, 207–228. Cambridge: Cambridge University Press.

Vihman, Marilyn M., Marlys A. Macken, Ruth Miller, Hazel Simmons, and Jim Miller. 1985. From babbling to speech: A re-assessment of the continuity issue. *Language* 61(2): 397–445.

Werker, Janet F., and Suzanne Curtin. 2005. PRIMIR: A developmental framework of infant speech processing. *Language Learning and Development* 1(2): 197–234.

Yeung, H. Henny, and Janet F. Werker. 2013. Lip movements affect infants' audiovisual speech perception. *Psychological Science* 24(5): 603–612.

Zamuner, Tania S. 2009a. Phonotactic probabilities at the onset of language development: Speech production and word position. *Journal of Speech, Language, and Hearing Research*, 52(1): 49–60.

Zamuner, Tania S. 2009b. The structure and nature of phonological neighbourhoods in children's early lexicons. *Journal of Child Language* 36(1): 3–21.

Zamuner, Tania S., LouAnn Gerken, and Michael Hammond. 2004. Phonotactic probabilities in young children's speech production. *Journal of Child Language* 31(3): 515–536.

Zamuner, Tania S., and Viktor Kharlamov. 2016. Phonotactics and syllable structure. In *Oxford Handbook of Developmental Linguistics*, ed. Jeffrey Lidz, William Synder, and Joe Pater, 27–42. Oxford: Oxford University Press.

Zamuner, Tania S., Elizabeth Morin-Lessard, Stephanie Strahm, and Michael P.A. Page. 2015. Developmental differences in the effect of production on word-learning. Paper presented at the International Child Phonology Conference, St. John's, Newfoundland.

Zamuner, Tania S., Stephanie Strahm, Elizabeth Morin-Lessard, and Michael P.A. Page. In press. Reverse production effect: children recognize novel words better when they are heard rather than produced. *Developmental Science*.

Zamuner, Tania S., Henny H. Yeung, and Myriam Dumos. 2017. The many facets of speech production and its complex effects on phonological processing. *British Journal of Psychology* 108(1): 37–39.

Zamuner, Tania S., Elizabeth Morin-Lessard, Stephanie Strahm, and Michael P.A. Page. 2016. Spoken word recognition of novel words, either produced or only heard during training. *Journal of Memory and Language* 89: 55–67.

Appendix: Token list of direct new offers between 0;11 and 2;11, found in Child Mental Lexicon. Words appear multiple times if they were direct new offers to more than one child.

alligator
alphabet
angel
antelopes*
ants*
arrow
arrow
bacon
ball
balloon
barn
barn
bass
bat
beak
bell
bell
bells
bill
bird
blanket
bottles
bow
boy
bridge
bubbles*
bug
bulldozer
butterfly
butterfly
cabbage
cake
candle
cardinals*
carrot
caterpillar
ceiling
chair
chair
chef
chef
chick
chimpanzee
chipmunks *
chips*
clock
cloud
clover
clown
clown
coal
coat
coat
comb
concrete
conductor
cord
cork
cottage
cousin
cover
crab
crane
crayon
crayons*
cub
curtain
diamond
diamond
diapers*
dime
dipper
dot
dress
drum
drum
elastic
engine
escalator
feet
fence
fish
flag
flag
flags*
flower
flowers*
food
fork
ghost
glove
gloves*
goat
goose
goose
grapes*
gray
hair
handle
hat
hay
heels*
hen
hen
holly
hook
horns*
hose
hose
hose
hunters*
icecream
icecream
irises*
iron
iron
jam
jar
keys*
kid
king
king
kite
kitten
ladle
lamp
lawnmower
lemon
lettuce
line
lips
lizard
lobster
loop
magazine
man
map
Mars
mice
mixer
monster
monsters*
moose
mop
mountain
mustache
mustache
napkin
needles*
nest
net
nightgown
note
octopus
octopus
oven
pail
pajamas
pants
parrot

peach	roller	spider	tomato
peaches*	rollingpin	spider	**tongue**
peacock	rollingpin	sponge	tricycle
pelican	rooster	spring	truck
penguin	rooster	square	trunk
pepper	rug	squirrel	tunnel
piglets*	ruler	stamps*	turkey
pilot	ruler	star	turtle
pipes*	**saddle**	steak	umbrella
planet	**sand**	**steam**	**vanilla**
plant	scales	stem	**vine**
platform	scarf	stocking	violet
playdoh	screen	stool	wagon
porcupine	screwdriver	strap	walrus
potato	**seal**	**string**	walrus
present	seeds*	swing	walrus
puck	shadow	swing	whale
rabbit	shapes*	table	wing
rabbit	sheep	tail	wire
rake	shirt	tan	**witch**
rat	shovel	taxi	wolf
reindeer	sign	teacher	woman
rhinoceros	skirt	**tickets***	worm
rhinoceros	slippers*	tie	wrench
ring	smoke	**tiger**	zebra
rocket	soldier	tires	zebra

*Indicates words that were found in the singular. Bold indicates words that were imitated.