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Lexical and child-related factors in word variability and accuracy in infants

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Abstract
The present study investigated the effects of lexical age of acquisition (AoA), phonological complexity, age and expressive vocabulary on spoken word variability and accuracy in typically developing infants, aged 1;9–3;1. It was hypothesized that later-acquired words and those with more complex speech sounds would be produced more variably and less accurately than earlier-acquired words and those with less complex speech sounds. It was also hypothesized that word variability would decrease and word accuracy would increase with increasing age and vocabulary knowledge. Participants' productions of 20 target words, experimentally controlled for AoA and phonological complexity, were audio-recorded during a play session. Results revealed a nonsignificant effect of AoA on variability and accuracy, a significant effect of phonological complexity on variability and accuracy, a significant effect of age on variability and accuracy and a significant effect of vocabulary on variability. Theoretical and clinical implications are discussed.

Keywords: *typical speech and language development*, *age of acquisition*, *phonological complexity*, *vocabulary*, *intra-word variability*, *inconsistency*

Word variability, which refers to variability in repeated productions of the same target word (e.g. *cat* produced as [tæt], [tæ] and [dæt]), is characteristic of both typical and disordered speech-language development. In typical development, word variability tends to decrease while word accuracy tends to increase with increasing age (Burt, Holm, & Dodd, 1999; Holm, Crosbie, & Dodd, 2007; McLeod & Hewett, 2008). In an early study, children aged 1;7–1;9 produced an average of three different forms for every two target words (Schwartz, Leonard, Folger, & Wilcox, 1980). In a more recent study, children aged 3;0–3;5 produced 13% of all target words variably, whereas 86% had at least one accurate production (Holm et al.). In the same study, children aged 6;0–6;11 produced 2.6% of all targets words variably, whereas 98.2% had at least one accurate production. Between 1;0 and 2;0, peaks in word variability have been shown to coincide with the emergence of two-word utterances (Sosa & Stoel-Gammon, 2006). Sosa and Stoel-Gammon suggested that this peak reflects a reorganization of the linguistic system. This view is consistent with dynamic systems theory, which proposes that variability is associated with transitions between developmental stages and is a potential driving force of developmental change (Thelen & Bates, 2003; van Geert & van Dijk, 2002).

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In children with speech sound disorders (SSD), however, abnormally high word variability or variability that persists for an unusually long time may be indicative of a unique underlying deficit. Among children with SSD, word variability has received the most attention as it relates to those with childhood apraxia of speech (CAS). CAS is associated with "inconsistent errors on consonants and vowels in repeated productions of syllables or words, lengthened and disrupted coarticulatory transitions between sounds and syllables, and inappropriate prosody, especially in the realization of lexical or phrasal stress" (American Speech-Language-Hearing Association, 2007). CAS is thought to reflect an impairment in "planning and/or programming spatiotemporal parameters of movement sequences" (American Speech-Language-Hearing Association, 2007). Dodd (2005) proposed a subtype of SSD characterized by high word variability, referred to as "inconsistent disorder." Whereas CAS is based on three key features, inconsistent disorder is characterized solely by high word variability. In contrast to the proposed deficit underlying CAS, Bradford and Dodd (1994) proposed that children with inconsistent disorder have a linguistic-based deficit in selecting and assembling phonemes to form words.

Variability has been measured in the production of the same word across different linguistic contexts (Burt et al., 1999: imitation, spontaneous picture naming, spontaneous production in conversation), using different elicitation techniques (Sosa & Stoel-Gammon, 2012: during play, book reading, object naming, picture naming), across multiple administrations of a picture naming task within a session (Dodd, 1995; Holm et al., 2007) and across multiple sessions spanning several months (Ferguson & Farwell, 1975; McLeod & Hewett, 2008; Sosa & Stoel-Gammon, 2006). Word variability has also been referred to in the literature as "variation" (Ferguson & Farwell, 1975) and "inconsistency" (Burt et al., 1999). The terms "inconsistency" and "variability" are often used interchangeably, whereas some authors differentiate between the two (Holm et al., 2007). Holm et al. (2007, p. 468) defined variability as being attributable to "factors described in normal acquisition and use of speech (e.g. phonetic context …)," while inconsistency "cannot be attributed to factors responsible for normal variability." Several studies have attempted to identify what factors might have an effect on word variability in typically developing children.

Among potential sources of variability, researchers have identified immature speech motor control (Kent, 1992), phonological and structural features of the word that show instability in the child's linguistic system (Leonard, Rowan, Morris, & Fey, 1982), sound changes that are in progress (Ferguson & Farwell, 1975), a transition from whole-word to phonemic underlying representations (Sosa & Stoel-Gammon, 2006), phonological complexity (McLeod & Hewett, 2008; Sosa & Stoel-Gammon, 2012) and limited vocabulary knowledge (Sosa & Stoel-Gammon, 2012). With regard to phonological complexity, Ferguson and Farwell (1975, p. 430) suggested that "variable words are often those which have … harder sounds …," although the authors did not provide evidence of this. More recently, McLeod and Hewett (2008) examined variability and accuracy in the production of words containing consonant clusters in typically developing children, aged 2;0–3;4. They found that 53.7% of all target words produced by all participants were variable. This compares to 13% of the target words, only some of which contained clusters, produced variably by the children aged 3;0–3;5 in Holm et al.'s (2007) study. Although some of McLeod and Hewett's participants were younger than Holm et al.'s participants, the considerable difference in the proportion of words produced variably across the two studies would seem to indicate that words containing clusters are produced with more variability than words containing mainly singletons. This supports Ferguson and Farwell's earlier contention that phonological complexity has an effect on word variability. Although McLeod and Hewett examined both accuracy and variability in their study, they did not provide percent accuracy data that would allow a comparison with Burt et al.'s (1999) and Holm et al.'s (2007) studies, both of which included percent accuracy data. This would have provided a clearer picture of the effect of phonological complexity on word accuracy.

Sosa and Stoel-Gammon (2012) directly tested the effect of phonological complexity on both word variability and accuracy. These authors found that average consonant age of acquisition (CAoA), which reflects the age at which 75% mastery is attained for each target consonant or cluster in the target word (from Smit, Hand, Freilinger, Bernthal, & Bird, 1990), averaged across all consonants and clusters, significantly predicted production variability and accuracy. Words with later-acquired consonants and clusters, hereby referred to as LS words, were produced more variably and less accurately than those with earlier-acquired consonants, hereby referred to as ES words. To the author's knowledge, this is the first study to have found a significant predictive relationship between phonological complexity and word variability and accuracy in children younger than 3;0. Additional research is required to confirm the phonological complexity effect on word variability and accuracy.

With regard to the effect of vocabulary knowledge on word variability and accuracy in typically developing children, findings have been mixed. Sosa and Stoel-Gammon (2006) found a low correlation between expressive vocabulary and word variability in their 1- to 2-year-old participants. Holm, Farrier, and Dodd (2008) found that children with "inconsistent disorder," i.e. those with highly variable word productions, had receptive vocabulary knowledge that was no different to children with other types of SSD. More recently, however, Sosa and Stoel-Gammon (2012) found a high, negative correlation ($r = -0.81$) between expressive vocabulary and word variability in their participants, aged 2;0–2;5. The authors found only a low correlation between expressive vocabulary and word accuracy ($r = 0.22$). The effect of vocabulary knowledge on word variability and accuracy requires further investigation.

Another potential source of word variability that has received very little attention in the literature is AoA of the target words. Sosa and Stoel-Gammon (2012) suggested that AoA reflects familiarity of a word. It is assumed that children have produced words with earlier AoA (i.e. EW words) more often than words with later AoA (i.e. LW words). Presumably, EW words have more stable underlying representations than LW words. One would expect, then, that EW words will be produced with less variability. Sosa and Stoel-Gammon (2012), however, found that AoA was not a significant predictor of word variability. Furthermore, these authors found that AoA was positively related to word accuracy such that LW words were produced more accurately than EW words. These findings are somewhat surprising. With regard to the positive relation between AoA and word accuracy, Sosa and Stoel-Gammon suggested that words that enter the lexicon more recently may benefit from a more advanced phonological system than those that enter earlier. LW words, therefore, may be more accurate than EW words that may not have been modified yet by recent changes in the phonological system. Additional research is required to examine the effect of AoA on word variability and accuracy.

Although studies have revealed a general trend of decreasing word variability and increasing word accuracy with increasing age in typically developing children, this has not been directly tested in children younger than 3;0. Sosa and Stoel-Gammon (2012) were not able to include age in their regression analyses because of the homogeneity of values. Participants were aged either 2;0 or 2;5. The effects of AoA and vocabulary knowledge on word variability and accuracy also require further examination in infants, whereas the effect of phonological complexity on variability and accuracy requires confirmation. The present study investigated whether words experimentally controlled for their AoA and phonological complexity would be produced with differing degrees of variability and accuracy in typically developing infants and whether variability and accuracy vary as a function of participant age and vocabulary knowledge. Spoken word accuracy was also examined because, although much is known about consonant accuracy, for example, as it relates to age, relatively little is known about whole-word accuracy. Schmitt, Howard, and Schmitt (1983) found significant increases in word accuracy with increasing age in their 3- to 7-year-old participants. The present study sought to determine if this is also the case in younger children.

Method

Participants

Fifteen children (4 males; 11 females), aged 1;9–3;1 (M = 2;4), participated in the study. All participants presented with age-appropriate expressive vocabulary, as confirmed by a score at or above the 16th percentile on the Words Produced subtest of the MacArthur-Bates Communicative Development Inventories (CDI), Second Edition (Fenson et al., 2007). All parents reported that either their child had passed a hearing test/screening or they had no concerns about their child's hearing. No participant had a speech-language diagnosis, a medical diagnosis or a neurological condition. All participants had English as their first language. Socioeconomic status (SES) was calculated for each participant using the Hollingshead Four Factor Index of Social Status (Hollingshead, 1975) and information obtained using a caregiver questionnaire. The scores are based on the occupation, education, gender and marital status of the participant's caregiver(s) and can range from 8 to 66. The majority of the participants (14/15) were from high- and middle-SES families. One participant was from a low-SES family. Descriptive statistics are presented in Table 1. Potential participants were recruited from early childhood programs in the local school district and from private preschools in the area. The study was conducted under a protocol approved by the university's Institutional Review Board. All parents signed an informed consent for their children to participate in the study.

Procedures

Each participant took part in a play session for approximately 1 h at either the university's speech and hearing clinic, the participant's preschool or the participant's home. All sessions involved the participant, the author and either the participant's parent(s), a staff member from the participant's preschool or a research assistant. The author attempted to elicit each of 20 target words (see Table 2) a minimum of three times from each participant using toys and other objects. Participants'

Table 1. Descriptive statistics and experimental measures.

Participant	Age	Vocabulary	SES	TV	TA	Targets	Words
1	23	50	61	0.733	0.074	15	68
2	37	81	66	0.500	0.603	20	131
3	28	30	14	0.938	0.034	16	88
4	27	51	49.5	0.800	0.655	20	148
5	25	30	59.5	1.000	0.199	20	136
6	21	75	59.5	0.769	0.250	13	52
7	30	57	57	0.850	0.365	19	115
8	32	65	53.5	0.850	0.238	20	122
9	30	90	41.5	0.500	0.496	20	115
10	33	30	66	0.650	0.542	20	131
11	26	20	46.5	0.750	0.245	20	102
12	28	55	48	0.833	0.396	18	101
13	30	70	51	0.789	0.531	19	111
14	24	85	50.5	0.800	0.345	20	113
15	23	74	57	0.889	0.247	18	97
Mean	27.8	57.5	52.0	0.777	0.348	18.5	108.7
SD	4.3	22.3	12.7	0.140	0.188	2.2	25.5

Note. Age was measured in months. Vocabulary reflects the percentile rank from the CDI. SES reflects Hollingshead's (1975) Four Factor Index of Social Status. TV, target variability; TA, target accuracy. Targets reflect the number of target words (out of 20) that had three or more productions. Words reflect the total number of word productions, across all targets.

Table 2. Lexical and phonological characteristics of target words.

	AoA	CAoA	WCM
Early word			
Early sounds			
Dog	78.7	3.00	2
Kitty	61.2	3.00	1
Meow	67.5	3.25	1
Banana	65.0	3.00	2
Cookie	58.7	3.00	2
Late sounds			
Shoes	82.5	4.25	4
Cheese	61.2	4.50	4
Juice	61.2	3.50	4
Fish	50.0	3.50	3
Thank you	50.0	4.38	4
Late word			
Early sounds			
Cup	45.0	3.00	2
Bunny	40.0	3.00	0
Button	37.5	3.00	1
Open	25.0	3.00	1
Tummy	22.5	3.00	0
Late sounds			
Flowers	48.7	4.13	8
Cracker	46.2	3.83	6
Brush	31.3	5.00	4
Chair	40.0	4.00	3
Grapes	21.3	3.83	6

Note. AoA, percentage of 18-month-old children who use target word (from Dale & Fenson, 1996); CAoA, average consonant age of acquisition (from Sosa & Stoel-Gammon, 2012); WCM, Word Complexity Measure (from Stoel-Gammon, 2010).

spoken productions were recorded using a wireless microphone system. The system consisted of a wireless lavalier microphone (Countryman Associates, Inc., Menlo Park, CA) housed in a vest worn by the participant. The microphone was connected to a body pack transmitter (Shure Incorporated, Niles, IL), also housed in the vest. The signal was transmitted to a wireless receiver (Shure Incorporated, Niles, IL), which was connected to a high-quality portable audio recorder (Marantz, Middlesex, UK).

Target words

The 20 target words were selected according to their age of acquisition (AoA) and phonological complexity. Ten words were used by 50% or more of 18-month-old children, as per Dale and Fenson's (1996) lexical development norms for English vocabulary, and were categorized as early words (EW). Ten words were used by less than 50% of 18-month-old children and were categorized as late words (LW). Five of the EWs and five of the LWs were selected to contain only early-developing speech sounds (stops, nasals, glides) and were categorized as early sounds (ES). The remaining words were selected to contain predominantly (but not only) late-developing speech sounds (fricatives, affricates, liquids) and consonant clusters and were categorized as late sounds (LS). There were, therefore, four sets of target words: five words that were categorized as EWES; five as EWLS; five as LWES and five as LWLS.

The four sets of target words were compared on the percentage of 18-month-old children who use the words (Dale & Fenson, 1996), hereby referred to as AoA, and two measures of phonological complexity to confirm these categorizations. The first measure, the Word Complexity Measure (WCM; Stoel-Gammon, 2010), assigns a score to a word based on three levels of complexity: word patterns (number of syllables and stress patterns), syllable structures and sound classes. Words that have more than two syllables and those with stress on any syllable but the first receive 1 point. Words with a word-final consonant receive 1 point and those with a consonant cluster receive 1 point for each cluster. Words with a velar consonant, liquid, rhotic vowel, voiceless fricative and/or voiceless affricate receive 1 point for each of these speech sounds, whereas words with a voiced fricative and/or voiced affricate receive 2 points for each of these speech sounds. The second measure of phonological complexity was CAoA (Sosa & Stoel-Gammon, 2012). For example, the average CAoA for *shoes* is 4.25 (CAoA for initial /ʃ/ is 3.5 and CAoA for final /z/ is 5). Table 2 presents AoA, WCM and average CAoA for each target word.

Univariate analyses of variance were calculated to compare the sets of target words in AoA, WCM and average CAoA. The 10 EW words had significantly higher percentages of use by 18-month-old children than the 10 LW words ($p < 0.001$), but there were no group differences in WCM and average CAoA. The 10 LS words had significantly higher WCM and average CAoA values than the 10 ES words ($p < 0.001$), but there was no group difference in AoA. These findings confirm the target word categorizations.

Predictor variables

Three variables were examined for their ability to predict variance in word variability and accuracy. These included categorization according to lexical AoA and phonological complexity (four sets of target words), age of the participants (in months) and receptive vocabulary (percentile rank from the CDI, Second Edition).

Outcome measures

Participants' target word productions were transcribed by a Master's student in communication science and disorders, who was trained in phonetic transcription, using IPA broad transcription. Both spontaneous and imitated productions were included in the analysis, in line with Ferguson and Farwell (1975). These authors argued that a high percentage of what young children say is imitated and children can imitate words spoken by adults with a considerable separation in time, making it difficult to operationalize imitation. Target word productions were analyzed for variability and accuracy. For target variability (TV), each target word was assigned a score of 1 if all productions were identical and 0 if there was any variability in production, regardless of accuracy. Target accuracy (TA) was calculated as the proportion of productions of each target word that were accurate. Both outcome measures were based only on participants' consonant productions. The decision not to include vowels in the calculations was based on the assumption that transcription reliability for vowels is poor (Ingram, 2002). This decision is consistent with similar research in this area (Ferguson & Farwell, 1975; Ingram, 2002; Leonard et al., 1982; Sosa & Stoel-Gammon, 2006, 2012).

Reliability

Inter- and intra-rater reliability were assessed for the identification of the participants' consonant productions in the target words using IPA broad transcription. Approximately 10% of all productions across all participants (231/2302) were selected at random for reliability calculations. Inter-rater reliability was calculated as the percentage agreement between the original transcriber and the

author in their transcription of these productions. Inter-rater reliability was 80%. Intra-rater reliability was calculated as the percentage agreement between the original transcriber's initial and repeated transcriptions of these productions. Intra-rater reliability was 82%.

Results

Table 1 presents the proportion of word productions that were accurate, the proportion of target words produced variably, the number of target words (out of 20) that had three or more productions and the total number of target word productions, across all targets, for each participant. Across all participants, an average of 34.8% of all word productions was accurate, whereas an average of 77.7% of target words was produced variably. Across all participants, an average of 108.7 productions of 18.5 target words was attempted during the play sessions. This reflects an average of approximately six productions of each target word. Multi-level mixed-effects linear regression models were used to examine the effects of target word categorization, i.e. lexical AoA and phonological complexity, participant age and expressive vocabulary on the variability and accuracy of target word production. Target word categorization served as the fixed effect while participants served as the random effect. Separate models were constructed for variability and accuracy.

Variability

When phonological complexity was held constant, lexical AoA did not have an effect on word variability. When EWES words were excluded from the regression model, LWES words had no effect on TV. When EWLS words were excluded from the model, LWLS words had no effect on TV. When lexical AoA was held constant, phonological complexity had a significant effect on word variability such that words with more complex speech sounds were produced with more variability than those with less complex speech sounds. When EWES words were excluded from the regression model, EWLS words had a significant positive effect on TV ($\beta = 0.247$, SE $= 0.081$, $p < 0.01$). When LWES words were excluded from the model, LWLS words had a significant positive effect on TV ($\beta = 0.314$, SE $= 0.065$, $p < 0.001$). These results are presented in Figure 1. Participant age had a significant negative effect on TV in all models ($\beta = -0.015$, SE $= 0.006$, $p < 0.01$). As participant age increased, word variability decreased. Expressive vocabulary also had a significant negative effect on TV in all models ($\beta = -0.002$, SE $= 0.001$, $p < 0.05$). As CDI percentile rank increased, word variability decreased.

Accuracy

When phonological complexity was held constant, lexical AoA did not have an effect on word accuracy. When EWES words were excluded from the regression model, LWES words had no effect on TA. When EWLS words were excluded from the model, LWLS words had no effect on TA. When lexical AoA was held constant, phonological complexity had a significant effect on word accuracy such that words with more complex speech sounds were produced less accurately than those with less complex speech sounds. When EWES words were excluded from the regression model, EWLS words had a significant negative effect on TA ($\beta = -0.368$, SE $= 0.069$, $p < 0.001$). When LWES words were excluded from the model, LWLS words had a significant negative effect on TV ($\beta = -0.473$, SE $= 0.061$, $p < 0.001$). These results are presented in Figure 2. Participant age had a significant positive effect on TA in all models ($\beta = 0.022$, SE $= 0.005$, $p < 0.001$). As participant age increased, word accuracy increased. Expressive vocabulary had a marginally significant positive effect on TA in all models ($\beta = 0.002$, SE $= 0.001$, $p = 0.066$). As CDI percentile rank increased, word accuracy increased.

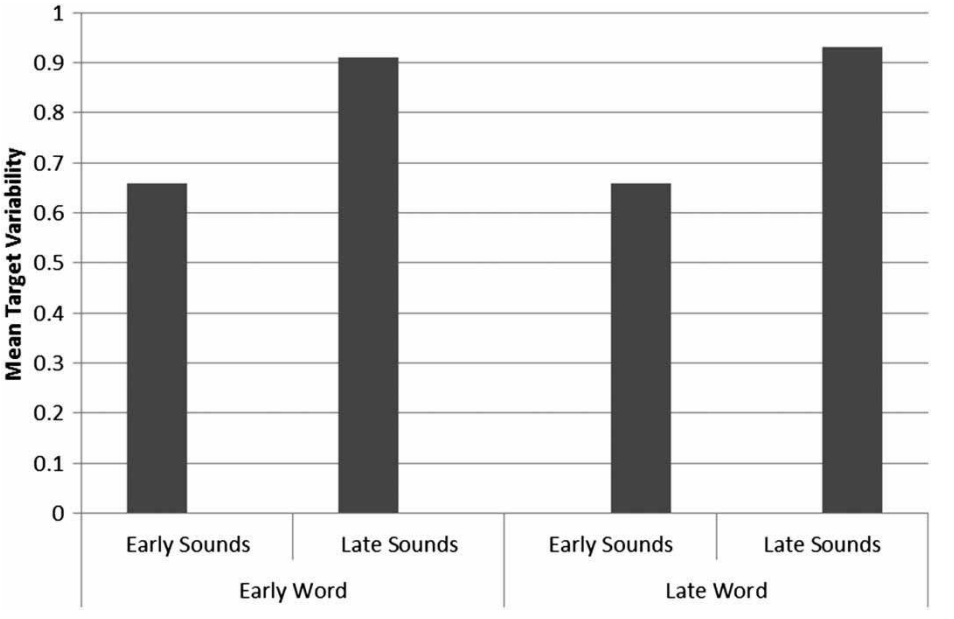

Figure 1. Mean target variability according to word type.

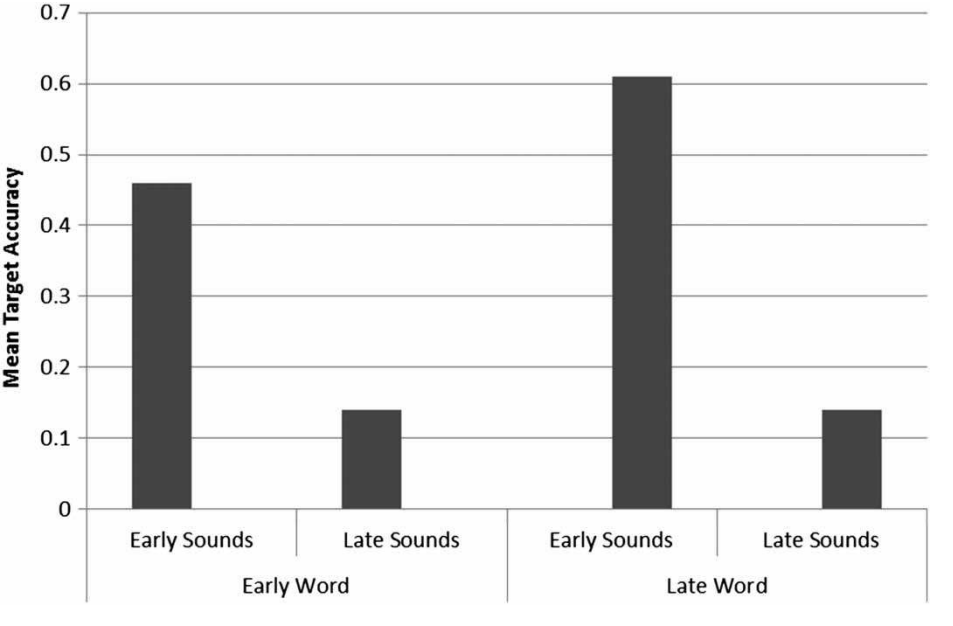

Figure 2. Mean target accuracy according to word type.

Discussion

The present study investigated whether lexical and child-related factors have an effect on spoken word variability and accuracy in typically developing infants aged 1;9–3;1. The lexical factor of AoA did not have a significant effect on word variability. This was not expected but is nevertheless

in line with Sosa and Stoel-Gammon (2012), who found that AoA was not a significant predictor of variability in their study. It was expected that, since EW words are assumed to have been produced more often and be more familiar to the children than LW words, the former would have been produced with less variability. The reason for the lack of significant effect may lie in how AoA was used to select the target words in the present study. Half of the target words were used by 50% or more of 18-month-old children, whereas the other half were used by <50% of 18-month-old children. Eighteen months may have been too early for a reference point for determining AoA. Although this age represented the low end cut-off for potential participants, the youngest participant recruited was aged 21 months. The majority of the target words may have been present and well established in the participants' lexicons. The mean age of the participants would seem to be the best age to use as a reference point for determining AoA; however, this would be difficult to do before participant recruitment begins. Although there were limitations in how AoA was used to select the target words in the present study, the lack of effect is in line with Sosa and Stoel-Gammon, who controlled for AoA differently. Sosa and Stoel-Gammon selected only target words that were in each participant's productive inventory. The AoA of each target word was included in a regression analysis that examined the effect of AoA on word accuracy and variability. This is a more fine-grained method of measuring AoA than the present study, which categorized target words as either early- or late-acquired. Another method would be to select target words based on their AoA in each child. Caregivers could be asked to estimate the age at which the child first started using words and this measure, months since first appearance, could be used in calculations of the effect of AoA on word variability and accuracy in specific words.

The nonsignificant effect of AoA on accuracy was also not expected. Sosa and Stoel-Gammon (2012) found that AoA was a significant predictor of accuracy in their participants such that LW words were produced more accurately than EW words. Again, the lack of an AoA effect on accuracy in the present study may be due to how AoA was used to select the target words, as discussed above. Alternatively, the lack of effect in this study may be due to the ages of the participants, who were younger than Sosa and Stoel-Gammon's participants. The younger participants may not yet have gone through the significant changes in the phonological system that might result in later-acquired words being produced more accurately than early-acquired words, as discussed by Sosa and Stoel-Gammon.

The lexical factor of phonological complexity was shown to have a significant positive effect on variability and a significant negative effect on accuracy. These findings confirm those of Sosa and Stoel-Gammon (2012). In both studies, LS words were produced less accurately and with more variability than ES words. The present study differs slightly to Sosa and Stoel-Gammon in that it included participants with heterogeneous ages across a wider range (1;9–3;1). Children in Sosa and Stoel-Gammon's study were aged either 2;0 or 2;5 at the time of testing. These findings provide further evidence of the link between lexical and phonological development (see Stoel-Gammon, 2011). As Ferguson and Farwell (1975, p. 430) argued, "one cannot profitably study either the phonetic or the lexical parameter of child language acquisition without taking account of the other." Future studies might include other measures of phonological complexity. For example, Ingram's (2002) Phonological Mean Length of Utterance reflects the average length of a child's words, in phonemes, and the number of correct consonants. A child who produces [tæt] for *cat* would receive a score of 4 (1 point for each phoneme produced and 1 point for each correct consonant). Phonological complexity might be calculated for each child's production of each target word and then compared to the variability and accuracy of that word.

The child-related factor of age had a significant negative effect on variability. This finding builds on that of Holm et al. (2007), whose participants were aged 3 years or older. In the present study, children younger than 3 years old showed the same decreasing variability with increasing age seen in Holm et al. Sosa and Stoel-Gammon (2012) were not able to include age in their regression

analyses because of the homogeneity of values. These authors did, however, compare children aged 2;0 and 2;5 in their word variability and accuracy. They found no significant group differences in variability or accuracy and this was likely due to the homogeneity of age values. Age also had a significant positive effect on accuracy in the present study. This extends Schmitt et al.'s (1983) finding of significant increases in word accuracy with increasing age in 3- to 7-year-old children to children aged younger than 3 years. It also builds on the numerous studies that have found increasing consonant accuracy with increasing age (see Bernthal, Bankson, & Flipsen, 2009).

Expressive vocabulary had a significant negative effect on variability. As expressive vocabulary increased, variability decreased. This finding is in contrast to earlier research that found no evidence of a relationship between the two (Holm et al., 2008; Sosa & Stoel-Gammon, 2006) but supports that of Sosa and Stoel-Gammon (2012), who found a high, significant, negative correlation between expressive vocabulary and variability. While Sosa and Stoel-Gammon used the number of words used from the CDI as a measure of expressive vocabulary, the present study used a less sensitive measure: the percentile rank from the CDI. The number of words used is not reported for children older than 3;0. Even so, the effect was found to be significant. The present study also found a marginally significant positive effect of expressive vocabulary on accuracy. As vocabulary increased, accuracy increased. Sosa and Stoel-Gammon, however, found a nonsignificant low correlation between the two.

While the decision to exclude vowels in the calculations of accuracy and variability is in line with a number of other similar studies (Ferguson & Farwell, 1975; Ingram, 2002; Leonard et al., 1982; Sosa & Stoel-Gammon, 2006, 2012), this is nevertheless seen as a limitation. Other studies have included vowels in their calculations (McLeod & Hewett, 2008; Schwartz et al., 1980). Furthermore, the participants in the present study were not likely to have mastered vowels at their young age. In their review of vowel development, Bernthal et al. (2009) concluded that most vowels are mastered in isolation and simple monosyllabic words by age 3 years and in polysyllabic words and unstressed syllables by age 4 or 5 years. This suggests that by excluding vowels in calculations of word variability and accuracy in young children, researchers are ignoring an important area of phonological development. Future studies should include vowels in calculations of word variability and accuracy in young children.

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References

American Speech-Language-Hearing Association. (2007). *Childhood apraxia of speech* [Position statement]. Available from www.asha.org/policy.

Bernthal, J. E., Bankson, N. W., & Flipsen, P., Jr. (2009). *Articulation and phonological disorders: Speech sound disorders in children* (6th edn.). Boston: Pearson.

Bradford, A., & Dodd, B. (1994). The motor planning abilities of phonologically disordered children. *European Journal of Disorders of Communication*, *29*, 349–369.

Burt, L., Holm, A., & Dodd, B. (1999). Phonological awareness skills of 4-year-old British children: An assessment and developmental data. *International Journal of Language and Communication Disorders*, *34*(3), 311–335.

Dale, P. S., & Fenson, L. (1996). Lexical development norms for young children. *Behavior Research Methods, Instruments, & Computers*, *28*, 125–127.

Dodd, B. (1995). *Differential diagnosis and treatment of children with speech disorder.* London: Whurr.

Dodd, B. (2005). *Differential diagnosis and treatment of children with speech disorder.* London: Whurr.

Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., Reznick, J. S., & Bates, E. (2007). *MacArthur-Bates Communicative Development Inventories* (2nd edn.). Baltimore: Brookes.

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

van Geert, P., & van Dijk, M. (2002). Focus on variability: New tools to study intra-individual variability in developmental data. *Infant Behavior & Development*, *25*, 340–374.

Hollingshead, A. B. (1975). *Four-factor index of social status*. Unpublished working paper. New Haven, CT: Department of Sociology, Yale University.

Holm, A., Crosbie, S., & Dodd, B. (2007). Differentiating normal variability from inconsistency in children's speech: Normative data. *International Journal of Language and Communication Disorders*, *42*(4), 467–486.

Holm, A., Farrier, F., & Dodd, B. (2008). Phonological awareness, reading accuracy and spelling ability of children with inconsistent phonological disorder. *International Journal of Language and Communication Disorders*, *43*(3), 300–322.

Ingram, D. (2002). The measurement of whole-word productions. *Journal of Child Language*, *29*, 713–733.

Kent, R. D. (1992). The biology of phonological development. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 65–90). Timonium, MD: York Press.

Leonard, L. B., Rowan, L. E., Morris, B., & Fey, M. E. (1982). Intra-word phonological variability in young children. *Journal of Child Language*, *9*, 55–69.

McLeod, S., & Hewett, S. R. (2008). Variability in the production of words containing consonant clusters by typical 2- and 3-year-old children. *Folia Phoniatrica et Logopaedica*, *60*, 163–172.

Schmitt, L. S., Howard, B. H., & Schmitt, J. F. (1983). Conversational speech sampling in the assessment of articulation proficiency. *Language, Speech, and Hearing Services in Schools*, *14*, 210–214.

Schwartz, R. G., Leonard, L. B., Folger, M. K., & Wilcox, M. J. (1980). Early phonological behavior in normal-speaking and language disordered children: Evidence for a synergistic view of linguistic disorders. *Journal of Speech and Hearing Disorders*, *45*, 357–377.

Smit, A. B., Hand, L., Freilinger, J. J., Bernthal, J. E., & Bird, A. (1990). The Iowa articulation norms project and its Nebraska replication. *Journal of Speech and Hearing Disorders*, *55*, 779–798.

Sosa, A. V., & Stoel-Gammon, C. (2006). Patterns of intra-word phonological variability during the second year of life. *Journal of Child Language*, *33*, 31–50.

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

Stoel-Gammon, C. (2010). The word complexity measure: Description and application to developmental phonology and disorders. *Clinical Linguistics & Phonetics*, *24*(4–5), 271–282.

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

Thelen, E., & Bates, E. (2003). Connectionism and dynamic systems: Are they really different? *Developmental Science*, *6*(4), 378–391.