



Published in final edited form as:

*Lang Acquis.* 2011 September 1; 18(4): 294–313. doi:10.1080/10489223.2011.605044.

## The Role of Phonology in Children's Acquisition of the Plural

Marc Ettliger<sup>1</sup> and Jennifer Zapf<sup>2</sup>

<sup>1</sup>Department of Communication Sciences and Disorders, Northwestern University 2240 Campus Drive, Evanston, IL, 60208, USA

<sup>2</sup>Department of Psychology and Human Development, University of Wisconsin-Green Bay, 2420 Nicolet Drive, MAC C310, Green Bay, WI, 54311, USA zapfj@uwgb.edu

### Abstract

The correct use of an affix, such as the English plural suffix, may reflect mastery of a morphological process but it may also depend on children's syntactic, semantic and phonological abilities. The present paper reports a set of experiments in support of this latter view, specifically focusing on the importance of the phonological make-up of plural forms for both production and comprehension. In Experiments 1 and 2 plural productions were elicited from eighty two-year-old children for nouns with codas with varying phonological properties. The results provide evidence that production of the plural morpheme is partly governed by the complexity of the coda and its sonority. Experiments 3 and 4 show that these constraints on codas also hold for comprehension as well, suggesting this effect is not simply articulatory, but also impacts the morphophonology of the plural.

### 1. Introduction

Between infancy and early childhood, children develop a remarkable array of cognitive skills – understandings of causality, number, objects, time, and language. To understand human cognitive development is to understand how these individual achievements inter-relate. Do they develop separately, each according to their own developmental timetable? Or are there dependencies, with acquisition in some domains dependent on acquisition in others? Within the realm of language acquisition, young children demonstrate variable production of grammatical morphemes in between the onset of morphological knowledge and complete mastery. This variability has been attributed to maturing morphological competence (Marcus et al. 1992) or general processing limitations (Bloom 1990). This variability may also result from a confluence of other factors including semantic knowledge (Zapf & Smith 2008), syntactic ability (Wexler 1994) and phonological constraints (Bernhardt & Stemberger 1998; Demuth 1992; Gerken 1991; Song et al. 2009). This paper presents evidence in support of this latter account, specifically focusing on the idea that limitations in phonological ability contribute significantly to the variability in the production and comprehension of one early acquired grammatical morpheme – the English plural.

The plural has long been documented to be one of the earliest learned grammatical morphemes in the English language yet it is not fully mastered by children until quite late in development. Initial plural productions in children's speech appear in children as young as 18 months (de Villiers & de Villiers 1973) and, as Zapf and Smith (2007) have shown, many of these children are beginning to generalize the plural form to novel nouns. Yet, Berko

(1958) demonstrated that children still make significant plural production errors up until seven years of age.

One potential reason why the plural form may take on this developmental trajectory is due to its phonological makeup. The English plural is marked by the *-s* morpheme for most nouns, pronounced [s], [z] or [əz] following voiceless consonants (e.g., *cats*), voiced segments (e.g., *dogs*), and stridents (e.g., *watches*), respectively. The ability to produce a plural is therefore no trivial task given that the suffix is a fricative and most English nouns are consonant final (Kucera & Francis 1967). This combination of sounds yields words with two adjacent consonants at the end of a syllable, a complex coda.

Complex codas are dispreferred cross-linguistically and are illegal in some languages (e.g., Italian; Spanish word finally). This dispreference, or *markedness*, is reflected in acquisition data (Jakobson 1940) where myriad studies have shown that children go through an intermediate stage of phonological development where simple codas are produced correctly and complex codas are not (Fikkert 1994; Levelt & Van de Vijver 2004). For example, G (2;3–2;9), a child acquiring English, went from producing no codas ([dʌ] *duck*) to correctly producing singleton codas ([gɛp] *grape*) but not complex codas ([fɪn] *friend*), before finally being able to correctly produce complex codas (Gnanadesikan 1995).

In addition to a constraint on coda complexity, languages also exhibit constraints on what types of consonants may appear together in a coda. The sonority sequencing principle (SSP; Clements 1990) expresses the generalization that syllables rise in sonority through the onset to a peak at the nucleus then fall in sonority through the coda and that a sharp increase is preferred in the onset, and a minimal decrease is preferred in the coda. The sonority hierarchy for different classes of speech sounds is shown in Table 1 (Bell & Hooper 1978; more detailed hierarchies exist, see Parker 2008 for a review) as well as whether the manner of articulation is sonorant or non-sonorant (obstruent), which is an important subordinate category of sonority (Clements 1990). The well-formedness of certain syllables according to the SSP is shown in Figure 1. Thus, a syllable like [kalb] can be said to adhere to the SSP and a syllable like [kabl] violates it.

There is a large literature on the role of sonority in phonological acquisition. Ohala (1999) found that children tend to reduce complex coda clusters to simple ones and that the choice of which segment to eliminate reflects the sonority generalization. For example, *fricative + stop* (e.g., *dust*) is reduced to a fricative (*dus*) rather than a stop (*dut*) because it yields a less steep drop in sonority. Also, Kirk and Demuth (2003) report higher correct production of monomorphemic nasal (e.g., *n*, *m*)+*s* clusters than stop (e.g., *t*, *d*)+*s* clusters for two-year-old children (84% vs. 74%). Nasal+*s* clusters adhere to the SSP, while stop+*s* clusters do not. These findings suggest that the acquisition of correct plural forms likely depends on a noun's ending: codaless nouns, with a simple coda in the plural (e.g., *keys*) should be acquired first, followed by nouns with high-sonority endings that adhere to the SSP in the plural (e.g., *planes*) followed by nouns with non-sonorant codas that violate the SSP in the plural (e.g., *dogs*).

Previous research has shown a number of instances of phonological factors influencing the production of grammatical morphemes (e.g., Demuth & McCullough 2009; Gerken 1996 on prosodic constraints). In a longitudinal study of four children, Prieto & Bosch-Baliarda (2006) found that complex codas are produced later in development in unstressed syllables in Catalan, which influenced the production of plurals. Furthermore, Song et al. (2009) found longitudinal and elicitation evidence that the production of the English 3<sup>rd</sup> person agreement morpheme *-s* is, in part, dictated by a number of phonological and prosodic

factors. One factor was coda complexity and, as predicted, the agreement morpheme was produced correctly more often when resulting in a simple coda than a complex coda.

Like Song et al. (2009), a goal of the current study was to determine the influence of coda complexity on children's production of a morpheme. However, a number of factors distinguish the present study from theirs. First, they did not analyze sonority as a potential factor in children's morphological productions – only complexity. To our knowledge, no research to date has examined the role of sonority – a phonological factor – on the acquisition of a grammatical morpheme. Second, while the phonological shape of the 3<sup>rd</sup> person agreement morpheme and the plural morpheme are the same, the plural –s bears meaning that is not recoverable if deleted in context (e.g., *Get the dog* means something different than *Get the dogs*) whereas the meaning of agreement –s is salvageable if deleted (e.g., *John eat\_ the cake* is understandable). Hsieh et al. (1999) suggest that the agreement morpheme is also less likely to appear in environments amenable to deletion (e.g., sentence-medially) and is more likely to be shorter in duration than the plural –s. These factors suggest that it is less likely that the plural reflects this same effect (i.e., production influenced by coda complexity) because of its increased acoustic salience and semantic importance.

Finally, and most importantly, while previous research has explored the role of coda complexity in production, it is unclear whether this constraint reflects articulatory, phonological or morphological ability. Confounding these factors further, Song et al.'s (2009) study used a repetition task. The current set of studies includes two comprehension experiments designed to address the question of whether these are articulatory effects or whether these effects operate at the level of phonology or morphology. Furthermore, we use an elicitation task, instead of repetition. If the same effect of coda complexity on production (Experiment 1) is found in comprehension (Experiment 3), this would suggest the constraint impacts morphophonology and is not simply articulatory. Likewise, should sonority impact both children's production (Experiment 2) and comprehension of the plural (Experiment 4), this would provide further evidence that these constraints operate at a morphophonological level.

Given that plural acquisition generally begins around the same time children are beginning to produce complex codas (as mentioned, both occur around age two), it may be more than a coincidence these two abilities appear at the same time. The failure to understand or use the plural morpheme may reflect phonological difficulty with consonant+s coda clusters in addition to possessing an imperfect mastery of morphology. The goal of the current studies, then, is to experimentally assess how different constraints on codas might impact both the production and comprehension of the English plural. In addition, the findings from these four experiments may also provide evidence for a relationship between production and perception, an idea we explore further in the discussion.

## 2. Experiment 1: Coda Complexity and Plural Production

To test the hypothesis that phonology – specifically, coda complexity – partially constrains the correct use of the plural morpheme, we elicited productions by asking children to describe items to a blind-folded teddy bear (Zapf & Smith 2008). On the critical test trials the target set included two instances of the same kind, potentially generating a plural noun (e.g., *dogs*). The nouns used for the plural set varied such that some did not have codas (e.g., *key* [ki\_]) and others did (e.g., *dog* [dɔg]) with the resulting plural forms having either simple (e.g. *keys* [kiz] or complex (e.g., *dogs* [dɔgz]) codas.

## 2.1. Method

**2.1.1. Participants**—Participants were 40 children (19 males, 21 females) between 22 and 32 months of age (mean = 29.6 months). Productive vocabulary was measured by the MacArthur Communicative Developmental Inventory, a parental checklist widely used to measure productive vocabulary (Fenson et al. 1994). By this measure, the children's productive vocabularies ranged in size from 203 to 607 words (mean = 382). An additional three children were excluded from analysis because they failed to complete the task. All children in this, and subsequent experiments, were from monolingual families drawn from a town in the Midwestern United States with no reported hearing, vision or learning disorders of any kind and none reported any illness, such as a cold, that might affect their performance on the day of testing.

**2.1.2. Stimuli and Design**—Fifteen common nouns known by 50% of 21-month-old children (Fenson et al. 1994) were selected. Five words have simple codas in their plural form (*cows, shoes, keys, babies, bunnies*) and ten words have complex codas in their plural form (*hats, cats, boats, cups, ducks, books, heads, beds, pigs, dogs*). For each word selected, a matching three-dimensional object was chosen to represent the word; for plural sets, two identical objects were used.

**2.1.3. Procedure**—Two different sets of objects were used on each trial: a set of one and a set of more than one. To begin each trial the child was given the two sets of toys to play with for 30 seconds to allow the child to familiarize him or herself with the objects and to ensure responses at test were not based on a preference for certain objects. Next, the experimenter took back the two sets of toys and told the child, “In this game I am going to cover teddy bear's eyes and then show you some toys! I will point to some of the toys on the table and then I want you to tell teddy bear in words which toys to get.” Then the experimenter covered the teddy bear's eyes with a blindfold and arranged the objects into two separate sets on the table (Figure 2). The experimenter asked the child “Can you tell teddy to get—?” as the experimenter pointed either to the singleton or to the set of multiple instances. If the child responded verbally with the name of the object(s) on the table, the experimenter took the blindfold off of the teddy bear and had him pick up what the child specified. If the child said nothing or something unrelated to the task, the question was repeated but if that behavior continued, the experimenter moved on to the next trial without the teddy bear picking up any items. Regardless of the response, the experimenter ended the trial by saying “thank you” to the child to signal the next trial would begin.

Each child received ten trials. The first two trials were practice trials where the parent demonstrated the task for the child using non-stimulus words. Immediately following each of those two trials, the child repeated the parent's actions. The child was the only respondent for the remaining eight trials, which were presented in random order. Two of the trials included a query of the singular set and six of the trials included a query of the multiple instance set. One of the fifteen nouns was randomly selected for each trial, with no replacement, such that two of the six plural nouns had simple codas and four had complex codas, two voiced-stop + [z] and two voiceless-stop + [s]. The relative proportion of words from each condition for each participant mirrored the proportion of the words in the larger stimulus set for this and all subsequent experiments. This was done in order to avoid discrepancies in the number of times each word was presented. While using different words between subjects is not ideal, it reflects a balance between maximizing the number of distinct words with the limitation that performance after about ten trials suffers dramatically as some children lose interest.

All responses were recorded and then coded by two separate coders with >95% agreement. For the multiple set queries, a correct response required articulation of the plural *-s* plus the noun's final consonant in the case of complex codas; responses of the singular form of the noun without the plural *-s* were marked as 'singular' and responses marked as 'neither' indicate the child either said nothing, a deictic expression (e.g., "these"), something irrelevant (e.g., "drink Mommy"), a malformed version of the plural (e.g., "dus" for *ducks*), or the plural of another word. The reason these are scored differently is that a response of "neither" could indicate an inability to form the plural or it could indicate not knowing the noun; the "singular" response shows knowledge of the noun and an inability to form the plural.

## 2.2. Results and Discussion

Overall, when the multiple instance set was queried children used the correct plural form 57% (N=137) of the time, the singular 33% (N=86) of the time, and neither form 7% (N=17) of the time. A generalized linear mixed effects model with a logistic regression link function (also known as a mixed logit model) (Jaeger 2008; Johnson 2008) was used to model the results here and in subsequent experiments on a trial-by-trial basis. Several aspects of the current design motivate using a mixed logit model over an ANOVA. First, the response data are categorical (correct/incorrect). Even when averaged within participants to yield percent correct, because of the low number of trials, it is questionable whether it can be considered continuous (e.g., participants scored either 0%, 25%, 50% or 100% on complex plurals) necessitating a logistic model. Furthermore, all the factors are not fully crossed in the experiments (e.g., two-syllable words only had simple coda plurals) and all participants did not receive all possible permutations of factors. Linear mixed models are particularly well suited to unbalanced data of this sort (Jaeger 2008). Finally, linear mixed effect models allow for the simultaneous modeling of multiple random effects (here, participant and word) within a single model.

In the model, fixed effects are coda complexity (main factor of interest), coda voicing (e.g., *dog* vs. *duck*), number of syllables (e.g., *key* vs. *baby*) and coda place of articulation (e.g., *cup* vs. *cat*).<sup>1</sup> Participant and word are modeled as random effects. Of these, only coda complexity is statistically significant (N=240 [and in all other analyses except where noted],  $\beta=.88$ ,  $SE=.38$ ,  $p=.02$ ), where children correctly produced the plural when it consisted of a simple coda (68%) more often than when the plural consisted of a complex coda (51%). Voicing ( $\beta=-.09$ ,  $SE=.35$ ,  $p=.80$ ), place of articulation ( $\beta=.03$ ,  $SE=.33$ ,  $p=.91$ ) and number of syllables ( $\beta=.01$ ,  $SE=.51$ ,  $p=.99$ ) are not significant factors. There is no statistically significant difference between the proportions of different types of incorrect answers (e.g., produced as singular or had no response) for simple codas (80% of incorrect answers were singular) versus complex codas (87% of incorrect answers were singular) ( $\chi^2(1, N=240) = .61$ ,  $p=.43$ ).

## 3. Experiment 2: Coda Sonority and Plural Production

Given the results of Experiment 1 suggest a constraint on the production of complex codas is a limiting factor in correctly using the plural, we consider whether the difficulty associated with different types of complex codas also has an effect. In particular, we explored whether nouns with sonorant codas were correctly pluralized more often than nouns with obstruent codas.

<sup>1</sup>Irrelevant variables are coded as -1 (e.g., one-syllable simple coda words are coded as 1, two-syllable simple coda words are coded as 0 and complex coda words are coded as -1), in line with treatment coding (Johnson, 2008).



### 3.1. Method

**3.1.1. Participants**—The participants were 40 children (16 females, 24 males) between 22 and 35 months of age (mean = 25.8 months). Productive MCDI vocabulary ranged in size from 139 to 686 words (mean = 398). An additional two children were excluded from analysis because they failed to complete the task.

**3.1.2. Stimuli, Design, and Procedure**—Twelve common nouns known by 50% of 21-month-old children (Fenson et al. 1994) were selected. Six words have sonorant codas in their plural form (*ball, bear, car, chair, plane, spoon*) and six words have non-sonorant codas in their plural form, three voiced (*bed, bird, head*) and three voiceless (*hat, cat, boat*). Glides (*y, w*), which are often indistinguishable from vowels/diphthongs in coda position (Levi 2008), were excluded. All nouns ended in a coronal to control for possible effects of place of articulation and because there are only coronal liquids in English. The selection of objects and experimental task were identical to Experiment 1. Out of the ten trials, two were used for practice, two queried the singular form, and six tested plural formation; these six trials included a random selection of three sonorant words and three non-sonorant words.

### 3.2. Results and Discussion

Children correctly produced the plural form on the plural trials 52% ( $n = 125$  tokens) of the time, the singular 33% ( $n = 80$ ) of the time and neither 15% ( $n = 35$ ) of the time. In a mixed logit model with coda sonority (sonorous or not sonorous) and coda voicing as fixed effects, only sonority is statistically significant ( $\beta = .60$ ,  $SE = .26$ ,  $p = .02$ ) wherein plurals that had sonorant codas (liquids and nasals) were produced significantly more often (59%) than plurals with non-sonorant codas (stops; 44%). Coda voicing is not significant ( $\beta = .20$ ,  $SE = .36$ ,  $p = .58$ ) with voiced stops and voiceless stops pluralized at approximately the same rate (47% versus 42% respectively). This difference suggests that a sonority drop within a complex coda facilitated production of the plural.

There is a decrement in sonority from liquids to nasals (Table 1), so there may be a more fine-grained distinction among type of sonorants. That is, *bears* may be easier than *planes*. While the trend is in this direction, with the plural of liquids produced correctly more often than nasals (62% vs. 55%), the difference is not adequate to justify positing a distinction, ( $N = 120$ ,  $\beta = .28$ ,  $SE = .46$ ,  $p = .54$ ).

## 4. Experiment 3: Coda Complexity and Plural Comprehension

Whereas the previous results show evidence that coda complexity impacts children's ability to produce the correct plural form, it remains unclear whether this reflects articulatory ability or whether this reflects knowledge at a morphophonological level. Indeed, previous findings with respect to phonological constraints on morpheme production (e.g., Demuth 1992; Gerken 1991; Song et al. 2009) are unable to distinguish between these possibilities. To explore this further, we investigate children's comprehension of plural forms.

Examining young children's first understanding of the plural – as measured by their comprehension of plural forms – has proved to be difficult. For example, one procedure used to assess this involves a forced-choice task in which a child is presented with two pictures: one of one dog and another of two dogs (Fraser, Bellugi & Brown 1963). The experimenter's expected outcome (if the child comprehends the plural) when asking a child “Can you get the dogs?” is that the child indicates the card with two dogs and not the card with one dog. However, a pragmatically correct answer could also be to indicate both pictures, as three dogs constitute the label “dogs”. Thus, a problem arises if a child selects both cards on the first plural query but then just the card with the two items on it for the

second plural query: does the child really understand what is being asked for? Are both of these answers correct? Performance in this task can be quite difficult to interpret.

To address these concerns, Zapf and Smith (2010) presented a new task that allows children's understanding of the plural to be assessed by forcing a choice of two pictures. Experiments 3 and 4 use this new task, designed to test children's comprehension, with the same words in Experiments 1 and 2. Experiment 3 uses words with simple versus complex coda plural forms. If the constraint on coda complexity in production (Experiment 1) also impacts comprehension this would suggest that the constraint is not simply articulatory, but one that impacts the morphophonology of the plural.

## 4.1 Method

**4.1.1 Participants**—Participants were 40 children (21 males, 19 females) between 21 and 36 months of age (mean = 26 months). Productive MCDI vocabulary ranged in size from 119 to 650 (mean = 374). An additional child was excluded from analysis because he failed to complete the task.

**4.1.2 Stimuli and Design**—The fifteen nouns used in Experiment 1 were selected for the current task. Pictures of these nouns were put into puzzles, which were designed to measure children's comprehension of the plural form.

Three puzzles were created which consisted of twelve pieces each: six pieces on each puzzle were of objects in the singular form and the remaining six pieces were pictures of two of the objects which had appeared in the singular pictures (e.g., one with “shoe”, another with “shoes”, one with “duck”, another with “ducks”, etc.). For each child, one puzzle was chosen to be the training puzzle and the remaining two were given as test puzzles in random order (Figure 3).

As shown in Figure 3, there were two important design ideas that went into the creation of these puzzles: (1) there was just one piece that would fit into each hole in the puzzle and (2) the hole for each piece shows the exact same picture that is on the puzzle piece. Thus, during training, the child need not even understand the experimenter's words but can look to the picture in the frame of the puzzle – the one to which the experimenter is pointing – and find the one matching piece that will fit in the hole. This task is one that is likely to be familiar to children as it is the developmental precursor to the jigsaw puzzle and is a common toy for very young children.

**4.1.3 Procedure**—Children were randomly given one of the three puzzles as a training puzzle and the other two as test puzzles. During the training phase, the experimenter removed all twelve puzzle pieces from the puzzle and laid the pieces and the puzzle on the table for the child to see. The experimenter asked the child for the puzzle piece using a general phrase, such as “Can you find the shoe? Where is the shoe? Can you put the shoe where it goes in my puzzle?” In the training phase, the experimenter would also point to the place on the puzzle where the piece was to fit. If the child handed the experimenter a piece other than what was asked for, feedback was given such as “That piece doesn't go there. See, it's too big.”, and then the initial query was repeated. All twelve pieces were queried during this phase. The purpose of this training puzzle was not to train children on the plural but instead to provide children with a rationale for the task such that they understand there was only one piece that should be handed to the experimenter on each query.

Once the training phase was complete, the experimenter presented a second puzzle, which was the first of the two test puzzles. During each test puzzle, the experimenter put all puzzle pieces on the table in front of the child and then hid the puzzle by placing it on her lap

underneath the table so the child could not see it. In this phase, there was no feedback given. Instead, the experimenter would ask for a puzzle piece (e.g., “Can you find the duck? Where is the duck?”). The child responded by handing a puzzle piece to the experimenter. The experimenter accepted whichever piece was given and moved on to the next trial. Occasionally, the child would hand the experimenter the incorrect puzzle piece that had yet to be asked for. For example, if the child handed the experimenter the “hats” puzzle piece when “cups” was asked for and then “hats” was to be the next trial, the “hats” trial was skipped because there would only have been one puzzle piece of the hat pair of pieces to choose from.

Of the twelve puzzle pieces on each test puzzle, then, only six were asked for in order to ensure the child would have both pieces of each pair (e.g., shoe and shoes) to choose from when queried. Of the six queries on each test puzzle, three were in the plural form (e.g., “Where are the shoes?”) and three were in the singular form (e.g., “Where is the bunny?”). Thus, of the fifteen stimulus words used in this experiment, each child was exposed to queries in the plural form for six words, two with simple codas, two with voiced complex codas and two with voiceless complex codas. As an example, if a child received puzzle A as the training puzzle (which included six stimulus words), he or she would have received puzzles B and C as test puzzles (and thus would be queried on six plural stimulus words on those two puzzles). Another child, then, would have received puzzle B as the training puzzle (which included six stimulus words), and he or she would have received puzzles A and C as test puzzles (and thus would be queried on six plural stimulus words on those two puzzles). There were six orders possible for the three puzzles; children were randomly assigned to one of those orders.

## 4.2 Results and Discussion

On the critical plural trials, children selected the correct plural puzzle piece 61% of the time. A mixed logit model was used to analyze plural trials with coda complexity, voicing, place of articulation and number of syllables as fixed effects and participant and word as random effects. Coda complexity is a statistically significant factor ( $\beta = 1.45$ ,  $SE = .56$ ,  $p = .01$ ), with simple codas pluralized correctly more often than complex (78% vs. 53%, respectively). Place of articulation ( $\beta = .31$ ,  $SE = .34$ ,  $p = .36$ ), number of syllables ( $\beta = .26$ ,  $SE = .58$ ,  $p = .65$ ) and coda voicing ( $\beta = .22$ ,  $SE = .36$ ,  $p = .54$ ) are not significant.

## 5. Experiment 4: Sonority and Plural Comprehension

In this last experiment we explore whether the SSP, shown in Experiment 2 to impact plural production, also has an effect on comprehension. If the two constraints on production in Experiments 1 and 2 operate in similar fashion, then we expect them to have the same effect on comprehension, with the SSP also impeding comprehension.

### 5.1. Method

**5.1.1. Participants**—The participants were 40 children (18 males; 22 females) between 23 and 34 months of age (mean=28.3 months). Productive MCDI vocabulary ranged in size from 209 to 616 words (mean=381). An additional two children were excluded from analysis; one because he failed to complete the task and due to experimenter error.

**5.1.2. Stimuli, Design, and Procedure**—The same twelve nouns used in Experiment 2 were used in the present experiment and the experimental task was identical to Experiment 3.



## 5.2. Results and Discussion

Children selected the correct plural puzzle piece 63% of the time and the correct singular puzzle piece 75% of the time. A mixed logit model of the plural trials was conducted with sonority and voicing as fixed effects and participant and word as random effects. Sonority is a statistically significant factor ( $\beta = .63$ ,  $SE = .27$ ,  $p = .02$ ) with sonorous codas correct more often than nonsonorous (70% vs. 57%, respectively). Coda voicing for stops is not significant ( $\beta = .46$ ,  $SE = .39$ ,  $p = .23$ ) and there is no significant difference between nasal and liquid codas (77% vs. 68% respectively;  $N = 120$ ,  $\beta = .43$ ,  $SE = .50$ ,  $p = .38$ )

In sum, as in Experiment 2 on plural production, Experiment 4 shows that two-year-old children's comprehension of plural forms is influenced by the phonological nature of the coda. Children not only are more likely to produce the plural form of words with sonorous codas, but they are also more likely to understand them.

## 6. General Discussion

The results of the current set of experiments, summarized in Table 2, suggest three potential conclusions: 1) coda complexity impacts children's comprehension and production of the plural; 2) the SSP impacts children's comprehension and production of the plural; 3) production and comprehension are related. Here, we consider a number of alternate accounts of the results.

One factor to consider in explaining these results is word and plural frequency, which has been shown to affect adult performance (Lau, Rozanova & Phillips 2007, New et al. 2004). Children's performance in these four experiments may have resulted from the relative frequency of the words in their singular and plural forms in children's primary linguistic data as opposed to the phonological properties of the coda, as we hypothesize. Therefore, we examine the degree to which accuracy is accounted for by the rates of raw plural frequency and proportion of plural to singular frequency for all four experiments. Frequency data for the singular and plural realization of each word is extracted from the 100,000-word Brent corpus (Brent & Siskind 2001), part of the CHILDES corpus of child-directed speech (MacWhinney 2000), shown in Table 3. A regression analysis shows that none of the three measures – singular frequency, plural frequency, singular-plural ratio – are significant for any of the four experiments (Experiment 1: singular:  $F[1,13] = 2.4$ ,  $p = .16$ , plural:  $F[1,13] = 1.0$ ,  $p = .34$ , ratio:  $F[1,13] = .24$ ,  $p = .63$ ; Experiment 2: singular:  $F[1,10] = .64$ ,  $p = .44$ , plural:  $F[1,10] = .87$ ,  $p = .37$ , ratio:  $F[1,10] = .01$ ,  $p = .92$ ; Experiment 3: singular:  $F[1,13] = .08$ ,  $p = .78$ , plural:  $F[1,13] = .56$ ,  $p = .47$ , ratio:  $F[1,13] = .03$ ,  $p = .86$ ; Experiment 4: singular:  $F[1,14] = 0.0$ ,  $p = .99$ , plural:  $F[1,14] = 0.1$ ,  $p = .83$ , ratio:  $F[1,14] = 1.8$ ,  $p = .19$ ).

It should also be noted that the only words that are more frequent in the plural form than the singular (*key*, *shoe*) are in the simple condition in Experiments 1 and 3, where participants pluralized most successfully. However, no significant differences in correct pluralization are observed between these two words and the others in the simple condition for production (69% vs. 70% respectively,  $N = 80$ ;  $\beta = .00$ ,  $SE = .50$ ,  $p = .99$ ) or comprehension (78% vs. 76%,  $N = 80$ ;  $\beta = .06$ ,  $SE = .55$ ,  $p = .91$ ). More importantly, when these two words are excluded, there are still significant differences between simple and complex conditions in production (69% vs. 51%,  $N = 208$ ;  $\beta = .84$ ,  $SE = .36$ ,  $p = .02$ ) and comprehension (77% vs. 53%,  $N = 208$ ;  $\beta = 1.09$ ,  $SE = .38$ ,  $p = .004$ ).

The sonority data similarly cannot be explained by the frequency of complex codas in English as frequency predicts the opposite results based on sonority. Corpus data (same as above) showing the type and token frequency of sonorant+s and stop+s words are shown in

Table 4. Stop+s is more frequent than sonorant+s, yet sonorant+s is produced and comprehended better.

With respect to the conclusion that performance on plural forms is driven by the SSP, there are a number of factors to consider. First, this finding contrasts with that of Kirk (2008) where nasal+stop clusters (e.g., *tent*, *pump*), which adhere to the SSP, were shown to be acquired later than stop+fricative (e.g., *box*) clusters, which violate the SSP. However, stops are more susceptible to deletion after nasals (Guy 1980, 1991) suggesting that Kirk's finding may be specific to nasal+stop coda clusters as opposed to being evidence against the SSP. The delayed production of nasal+stop coda clusters that Kirk finds in children may be because of the same articulatory constraints affecting adults, or may be because they do not hear nasal+stop clusters in adults' speech. Thus, phonological development may proceed from nasal+fricative, followed by stop+fricative, followed by nasal+stop and still be consistent with ours and Kirk's data and would not rule out the SSP as an explanatory principle for some of the findings. Furthermore, Kirk (2008) used mono-morphemic words and morpheme structure may also play a role, as discussed below and as suggested in Guy (1980, 1991). While there is evidence that nasal+fricative coda clusters are also marked (Ali *et al.* 1979), our data suggest that nasal+stop is more so. Exploration of the production of different complex coda types, and whether the clusters are mono-morphemic versus bi-morphemic will help address these questions.

Second, while sonority is the most likely explanation for this difference in performance, there are other phonetic properties that co-vary with sonority, in particular vowel length. Vowels are longer before sonorants; with liquids, particularly *r*, there may even be reduction or deletion of the consonant and compensatory lengthening of the vowel (e.g., Bowen 1998). However, although vowels are longer before voiced consonants than before voiceless (~240 ms. versus ~140 ms., Labov, Ash & Boberg 2006) voicing does not result in a statistically significant difference in performance in Experiments 2 or 4. On the other hand, the smaller vowel length difference between nasals and voiced stops (~260 ms. vs. ~240 ms., Labov, Ash & Boberg 2006), which differ in sonority, do differ significantly in plural production (55% vs 46%, N=160;  $\beta = .46$ ,  $SE = .22$ ,  $p = .035$ ).

By the same token, while liquids often delete post-vocally, these were scored as correct productions. This was done because deletion occurs in both child and adult speech and determining segmental status for liquids is controversial without the benefit articulatory measures (e.g., MRI, Proctor 2009). This does represent somewhere a confound since the result of postvocalic liquid deletion is a simple-coda plural (e.g., [bawz] for *balls*) and simple codas are produced correctly more often, as in Experiment 1. However, removing liquids from the data reflects the same comparison as above, with sonorants being formed correctly more often than non-sonorants (55% vs. 46%).

Third, the allomorphy of the plural may also play a role in performance. Sonorant codas always take the [-z] allomorph and obstruents take either [-z] or [-s], depending on their voicing. Children may perform worse on the plurals of obstruent-final words because [-s] may be more difficult to produce than [-z]. The current results do not support this hypothesis, however, as sonority is still a factor after excluding voiceless obstruents (66% vs. 51%; N=128;  $\beta = .86$ ,  $SE = .38$ ,  $p = .02$ ). The direction of this possible effect is also difficult to predict as [-z] is the more common allomorph (Berko 1958), but is also more difficult to articulate since it is a voiced fricative and voicing diminishes airstream velocity, making frication more difficult to produce (Ohalá 1983).

The variability in morpheme realization for obstruents itself may also be a factor (e.g., Zamuner, Kerkhoff & Fikkert 2006 on the Dutch plural alternation). That is, while sonorants

are always pluralized with [-z], obstruents require either [-s] or [-z], which may make it more difficult to learn because of a lack of consistency. Previous research suggests that the impact of variability on language learning depends on many factors such that variability can impede learning (e.g., Ryalls & Pisoni 1997) or help it (e.g., Rost & McMurray 2009; Singh 2008), so further research is required to assess this hypothesis.

The two nasal-final words (*spoon, plane*) also have complex onsets. This was unavoidable as these are the only two nasal-final words known by over 50% of 21-month olds (aside from *balloon*, which is even more problematic). While errors in onset production were ignored, onset complexity may have been a factor in plural productions. Subtracting them still yields the same significant effect of coda sonority (N=200,  $\beta=.69$ , SE=.29,  $p=.019$ ), but is a confound for the nasal-liquid distinction with respect to sonority differences.

Thus, while we contend that the SSP represents the most parsimonious explanation of the results in Experiments 2 and 4 showing significant differences in plural comprehension and production between sonorant-final and non-sonorant-final words, other interpretations of the results are possible.

With respect to the final conclusion, on the relationship between production and comprehension, there are number of possible ways to interpret the similar results for the two different tasks.

One explanation to consider is that it may be that these constraints are perceptual in nature. So, children's production of the plural in Experiment 1 may reflect difficulty in perceiving the -s, which would yield the observed results in comprehension (Experiment 3) – children cannot produce what they cannot hear. While Steriade (1999) argues that consonant cooccurrence restrictions are perceptual in nature, this framework primarily applies to onsets and is not relevant to stop+s codas. Indeed, post-consonantal s is quite perceptible in coda position after a stop (Engstrand & Ericsson 1999; Jongman, Wayland & Wong 2000) supporting the presumption that the difficulty associated with complex codas is articulatory (e.g., Bernhardt & Stemberger 1998; Levelt, Schiller & Levelt 2000). This may be explained by the difficulty of reopening the jaw for the fricative after it is closed for the stop (MacNeilage & Davis 2000) or by the difficulty of producing a high-energy airstream mechanism following a stop as needed for a fricative (Ohala 1983) at the end a word.

If the source of the coda complexity constraint is articulatory in nature, the question becomes whether the effects on comprehension reflect a constraint at the phonological level or an imperfect mapping between phonology and morphology. This may ultimately be addressed by assessing the performance of two-year-old children on mono-morphemic words like *box* and *fox*. Kirk and Demuth (2003) found no difference between bi-morphemic and mono-morphemic words (e.g., *ducks* vs. *box*) in a study of C+s production and argued the constraint is phonological. However, mono-morphemic productions were produced correctly more often (81% vs. 72%), just not significantly so. So it is difficult to draw strong conclusions from this null result. Indeed, myriad studies have found differences in deletion rates in adults depending on morphological constituency (e.g., Guy 1980, 1991), so it is certainly a possibility. The lack of minimal pairs such as *\*bock~box* or *\*fock~fox* mean the present paradigm cannot to be used to test this and thus represents an interesting avenue for future investigation.

The nature of the sonority constraint in Experiments 2 and 4 is more equivocal. It may be articulatory as the airstream stoppage for sonorants is not complete compared to stops (Clements 1990) making sonorant+s codas less difficult than stop+s to articulate. However, it may be perceptual since the release of an obstruent coda has similar acoustic properties to

a fricative, while a sonorant coda release does not. We are not aware of any studies comparing the perception of stop+s versus sonorant+s codas.

Finally, we can also consider the effects of individual children's age and expressive vocabulary on their performance on each test. Table 5 shows the correlation between percent correct and age and CDI-measured vocabulary for the children for all four experiments. In each case, we used percent correct for all words and for each condition (i.e., complex coda vs. simple coda for Experiments 1 and 3; sonorant vs. non-sonorant coda for Experiments 2 and 4) and the dependant variable.

The results generally show a correlation between performance and age, driven primarily by performances on complex codas in Experiments 1 and 3. This suggests that the ability to produce simple coda forms is already developed, while the ability to produce complex codas forms is still developing. This is supported by the fact that in Experiment 1, performance on simple and complex forms at the high end of the age range is similar. For children 28 months old and older ( $N = 10$ ), performance on simple (63%) and complex (60%) are not significantly different ( $\beta=.22$ ,  $SE=.80$ ,  $p = .78$ ), whereas below 28 months ( $N=30$ ), they are (simple: 77%, complex: 56%,  $\beta=1.02$ ,  $SE=.33$ ,  $p = .002$ ). Similar results are observed for comprehension ( $\geq 28$  months,  $N=22$ , simple: 96%, complex: 78%;  $\beta=.80$ ,  $SE=.47$ ,  $p = .09$ ;  $< 28$  months,  $N=18$ , simple: 81%, complex: 50%,  $\beta=1.5$ ,  $SE=.45$ ,  $p < .001$ ), though the lack of significant difference in older children in comprehension may be due to sample size or ceiling effects. Generally, this accords with previous research showing that simple coda production develops around 12–24 months, while complex codas are acquired later (e.g., Fikkert 1994; Levelt & Van de Vijver 2004). The sonority distinction, in Experiments 2 and 4, does not show the same pattern and there is no age by coda sonority interaction in production or comprehension ( $\beta=.01$ ,  $SE=.07$ ,  $p=.93$ ;  $\beta=.13$ ,  $SE=.08$ ,  $p=.13$ , respectively).

## 7. Conclusion

The present results show that children's early use of the plural is limited in part by the phonological properties of the nouns being used. Two-year-old children were more likely to use the plural when the form had a simple, rather than complex, coda. Furthermore, when the resulting coda was complex, the plural form was correctly used more often when the noun ended in a sonorant coda compared to a non-sonorant coda. The results of Experiments 2 are the first to demonstrate that production of the plural is also governed by sonority, where plurals with codas comprised of sonorant+s are produced correctly more often than those comprised of non-sonorant+s coda. The SSP, which expresses the cross-linguistic generalization that syllables tend to fall in sonority in codas, may account for this, though other explanations are possible. Finally, children's comprehension of the plural was impacted in the same way by these same phonological constraints. Two-year-old children were more likely to comprehend the plural when the form had a simple, rather than complex, coda and when the resulting coda was complex, children were more likely to comprehend the plural form when the noun ended in a sonorant coda compared to a non-sonorant coda. This suggests that these are not simply articulatory constraints, but also affect the morphophonology of the plural.

The current results corroborate and extend the results of Song et al. (2009) where the use of the agreement marker *-s* (e.g., *She hits*) is also constrained by phonology. The current study extends these results by also looking at coda sonority as a potential factor in plural morphology.

Importantly, the present comparison between production and comprehension also contributes to a more in-depth understanding of how these phonological constraints impact

children's morphological ability. Song et al. (2009) (and other similar studies on the impact of phonology on morphological competence, e.g., Bernhardt & Stemberger 1998; Demuth 1992; Demuth & McCullough 2009; Gerken 1991; Prieto & Bosch-Baliarda 2006) are unable to draw specific conclusions about whether they are demonstrating variability in knowledge of morphology or whether they are showing purely articulatory constraints limiting a morpheme's surface realization. By investigating the comprehension of plural words with different phonological forms, we have shown that variability in children's use of the plural form is not purely articulatory. Because the constraints are reflected in comprehension, we conclude that they are present at a phonological and/or morphological level as well. Differentiating between these two levels from each other remains an interesting question to explore further.

These findings suggest a number of other interesting areas for future investigation, as well. For example, the present paradigm controls for the effect of syntax (none in production, "Where is/are the X?" in comprehension), meaning (two identical objects) and task (instruction elicitation in production, forced choice selection in comprehension). Future studies can explore how these different linguistic factors interact with each other. This could provide evidence as to the level at which these constraints operate and the degree to which articulatory constraints impact deeper levels of language acquisition.

Furthermore, because production and comprehension of the plural is dependent on phonology, phonology should be considered when juxtaposing the time-course of plural acquisition in different languages. Previous research (Leonard 1989) has shown that Italian-speaking children with SLI show less delay in acquiring the plural morpheme than English-speaking SLI children, for example. An explanation may lie in the fact that the plural in Italian (vowel change *libro* – *libri* `book/s') does not change phonological markedness in the same way as English pluralization does (change from simple to complex coda, *book* ~ *books*). Further research can show whether morphemes are acquired at different rates cross-linguistically with reference to comparative phonological markedness across languages.

Finally, the symmetry between the production and comprehension results relate to research on the interface between production and comprehension more generally. Our results suggest that an articulatory constraint (against complex codas) can impact comprehension in children, corroborating existing literature on adults suggesting that the motor system plays an important role in speech perception (Galantucci, Fowler & Goldstein 2009; Liberman & Mattingly 1985; but see Hickok & Poeppel 2007). An understudied aspect of this hypothesis is the developmental trajectory of this possible relationship.

Broadly, phonotactic constraints provide a model for exploring the phonology-morphology interface and suggest a principled explanation for some of the variable production of grammatical morphemes. This lends support to the idea that linguistic components must be analyzed in concert (e.g., Bates 1994; Jackendoff 2002) and is particularly relevant here where, at two years of age, the phonological development necessary for the production of a morpheme runs parallel to morphological development. If myriad non-morphological factors constrain the acquisition of morphology, as we have shown, then this interaction should be reflected in models of language acquisition.

## Acknowledgments

The research presented in this article was conducted with the generous support of a National Institute of Health grant (T32 NS047987) to M.E. and National Institute of Mental Health grant (R01 MH60200) to J.A.Z. We are grateful to the participants in this study and their parents, to research assistants Jennifer Benson, Elizabeth Dahlberg, Leah Dudderar, Alex Lavallo, and McKenzie Skipper and to Linda Smith, Katherine Demuth, David Barner and Jesse Snedeker for helpful discussion and comments.



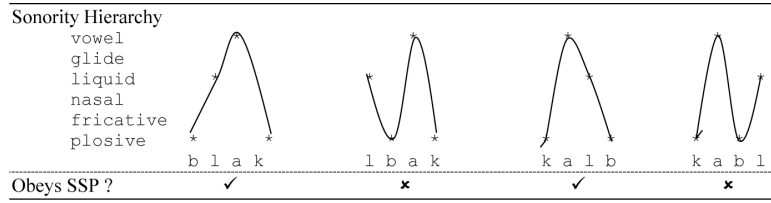
## References

- Ali, Latif; Daniloff, Ray G.; Hammarberg, Robert. Intrusive Stops in Nasal-Fricative Clusters: An Aerodynamic and Acoustic Investigation. *Phonetica*. 1979; 36:85–97. [PubMed: 482373]
- Bates, Elizabeth. Modularity, domain specificity and the development of language. *Discussions in Neuroscience*. 1994; 10:136–149.
- Bell, Alan; Hooper, Joan B. Issues and evidence in syllabic phonology. In: Bell, A.; Hooper, J., editors. *Syllables and Segments*. North-Holland Publishing Company; Amsterdam: 1978. p. 3-22.
- Berko, Jean. The child's learning of English morphology. *Word*. 1958; 14:150–177.
- Bernhardt, Barbara H.; Stemberger, Joseph P. *Handbook of Phonological Development: From the Perspective of Constraint-based Nonlinear Phonology*. Academic Press; San Diego, CA: 1998.
- Bloom, Paul. Subjectless sentences in child language. *Linguistic Inquiry*. 1990; 21:491–504.
- Bowen, Caroline. *Developmental phonological disorders. A practical guide for families and teachers*. ACER Press; Melbourne: 1998.
- Brent, Mark R.; Siskind, Jeffrey M. The role of exposure to isolated words in early vocabulary development. *Cognition*. 2001; 81:31–44.
- Clements, George N. The role of the sonority cycle in core syllabification. In: Kingston, J.; Beckman, M., editors. *Papers in Laboratory Phonology I*. CUP; Cambridge: 1990. p. 283-333.
- Demuth, Katherine. Accessing functional categories in Sesotho: Interactions at the morpho-syntax interface. In: Meisel, Jürgen, editor. *The acquisition of verb placement: Functional categories and V2 phenomena in language development*. Kluwer; Dordrecht: 1992. p. 83-107.
- Demuth, Katherine; McCullough, Erica. The prosodic (re)organization of children's early English articles. *Journal of Child Language*. 2009; 36:173–200. [PubMed: 18778531]
- Engstrand, Olle; Ericsson, Christine. Explaining a violation of the sonority hierarchy: stop place perception in adjacent [s]. In: Botinis, A.; Torstein, N., editors. *Proceedings of the XIIth Swedish Phonetics Conference*. Göteborg University; Göteborg, Sweden: 1999. p. 49-52.
- Fenson, Larry; Dale, Philip S.; Reznick, JS.; Bates, Elizabeth; Thal, Donna J.; Pethick, Stephen J. Variability in Early Communicative Development. *Monographs of the Society for Research in Child Development*. 1994; 59(5, Serial No. 242)
- Fikkert, Paula. On the acquisition of rhyme structure in Dutch. In: Bok-Bennema, R.; Cremers, C., editors. *Linguistics in the Netherlands 1994*. John Benjamins; Amsterdam: 1994. p. 37-48.
- Fraser, Colin; Bellugi, Ursula; Brown, Roger. Control of grammar in imitation, comprehension, and production. *Journal of Verbal Learning and Verbal Behavior*. 1963; 2:121–135.
- Galantucci, Bruno; Fowler, Carol A.; Turvey, Michael T. The motor theory of speech perception reviewed. *Psychonomic Bulletin & Review*. 2006; 13:361–377. [PubMed: 17048719]
- Gerken, Louanne. A. The metrical basis for children's subjectless sentences. *Journal of Memory and Language*. 1991; 30:431–451.
- Gerken, Louanne. A. Prosodic structure in young children's language production. *Language*. 1996; 72:683–712.
- Gnanadesikan, Amelia. Markedness and Faithfulness Constraints in Child Phonology. In: Kager, R.; Pater, J.; Zonneveld, W., editors. *Fixing Priorities: Constraints in Phonological Acquisition*. Cambridge University Press; Cambridge, U.K.: 1995. p. 73-108.
- Guy, Gregory R. Variation in the group and the individual: The case of final stop deletion. In: Labov, W., editor. *Locating language in time and space*. Academic Press; New York: 1980. p. 1-36.
- Guy, Gregory R. Explanation in variable phonology: An exponential model of morphological constraints. *Language Variation & Change*. 1991; 3(1):1–22.
- Hickok, Greg; Poeppel, David. The cortical organization of speech processing. *Nature Reviews Neuroscience*. 2007; 8:393–402.
- Hsieh, Li; Leonard, Laurence B.; Swanson, Lori A. Some differences between English plural noun inflections and third singular verb inflections in the input: The contribution of frequency, sentence position, and duration. *Journal of Child Language*. 1999; 26:531–543. [PubMed: 10603695]
- Jackendoff, Ray. *Foundations of Language*. Oxford University Press; 2002.

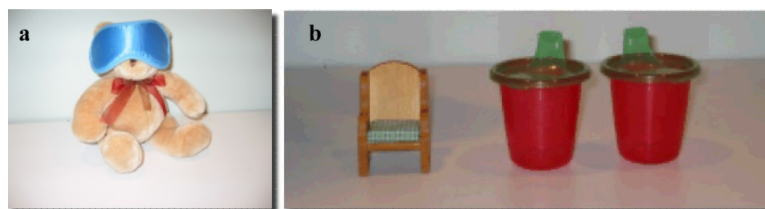


- Jaeger, T. Florian. Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language*. 2008; 59:434–446. [PubMed: 19884961]
- Jakobson, Roman. *Kindersprache, Aphasie, und allgemeine Lautgesetze*. Almqvist & Wiksell; Uppsala: 1940. tr. *Child Language, Aphasia and Phonological Universals*, Mouton
- Johnson, Keith. *Quantitative Methods In Linguistics*. Wiley-Blackwell; 2008.
- Jongman, Allard; Wayland, Ratree; Serena, Wong. Acoustic Characteristic of English Fricatives. *Journal of the Acoustical Society of America*. 2000; 108:1252–63. [PubMed: 11008825]
- Kirk, Cecilia. Substitution errors in the production of word-initial and word-final consonant clusters. *Journal of Speech, Language, and Hearing Research*. 2008; 51:1–14.
- Kirk, Cecilia; Demuth, Katherine. Onset/coda asymmetries in the acquisition of clusters. In: Beachley, B.; Brown, A.; Conlin, F., editors. *Proceedings of the 27th Annual Boston University Conference on Language Development*. Cascadilla Press; Somerville, MA: 2003. p. 437-448.
- Kucera, Henry; Francis, W. Nelson *Computational analysis of present-day American English*. Brown University Press; Providence, RI: 1967.
- Labov, William; Ash, Sharon; Boberg, Charles. *Atlas of North American English: Phonetics, Phonology and Sound Change*. Mouton de Gruyter. 2006
- Lau, Ellen F.; Rozanova, Katya; Phillips, Colin. Syntactic prediction and lexical frequency effects in sentence processing. *University of Maryland Working Papers in Linguistics*. 2007; 16:163–200.
- Leonard, Laurence B. Language learnability and specific language impairment in children. *Applied Psycholinguistics*. 1989; 10:179–202.
- Levelt, Claartje C.; Schiller, Neils O.; Levelt, Willem J. The acquisition of syllable types. *Language Acquisition*. 2000; 8:237–264.
- Levelt, Claartje C.; van de Vijver, Ruben. Syllable types in cross-linguistic and developmental grammars. In: Kager, R.; Pater, J.; Zonneveld, W., editors. *Constraints in phonological acquisition*. Cambridge University Press; New York, NY: 2004. p. 204-218.
- Levi, Susannah V. Phonemic vs. derived glides. *Lingua*. 2008; 118:1956–1978.
- Lieberman, Alvin M.; Mattingly, Ignatius G. The motor theory of speech perception revised. *Cognition*. 1985; 21:1–36. [PubMed: 4075760]
- MacNeilage, Peter F.; Davis, Barbara L. On the origin of internal structure of word forms. *Science*. 2000; 288:527–531. [PubMed: 10775113]
- MacWhinney, Brian. *The CHILDES Project: Tools for Analyzing Talk*. Lawrence Erlbaum; Mahwah, NJ: 2000.
- Marcus, Gary. F.; Pinker, Steven; Ullman, Michael; Hollander, Michelle; Rosen, T.J.; Xu, Fei. Overregularization in Language Acquisition. *Monographs of the Society for Research in Child Development*. 1992; 57(4):1–182. [PubMed: 1518508]
- New, Boris; Brysbaert, Marc; Segui, Juan; Ferrand, Ludovic; Rastle, Kathleen. The processing of singular and plural nouns in French and English. *Journal of Memory and Language*. 2004; 51:568–585.
- Ohala, Dianne K. The influence of sonority on children's cluster reductions. *Journal of Communication Disorders*. 1999; 32(6):397–422. [PubMed: 10560714]
- Ohala, John J. The origin of sound patterns in vocal tract constraints. In: MacNeilage, Peter, editor. *The Production of Speech*. Springer; New York: 1983. p. 189-216.
- Parker, Stephen. Sound level protrusions as physical correlates of sonority. *Journal of Phonetics*. 2008; 36(1):55–90.
- Prieto, Pilar; Bosch-Baliarda, Marta. The development of codas in catalan. *Catalan Journal of Linguistics*. 2006; 5:237–272.
- Proctor, Michael. Ph.D. dissertation. Yale University Department of Linguistics; 2009. *Gestural Characterization of a Phonological Class: the Liquids*.
- Rost, Gwyneth; McMurray, Bob. Speaker variability augments phonological processing in early word learning. *Developmental Science*. 2009; 12(2):339–34. [PubMed: 19143806]
- Ryalls, Brigitte Oliver; Pisoni, David B. The effect of talker variability on word recognition in preschool children. *Developmental Psychology*. 1997; 33(3):441–452. [PubMed: 9149923]

- Singh, Leher. Influences of high and low variability on infant word recognition. *Cognition*. 2008; 106(2):833–870. [PubMed: 17586482]
- Song, Judy Y.; Sundara, Megha; Demuth, Katherine. Effects of phonology on children's production of English 3rd person singular –s. *Journal of Speech, Language, and Hearing Research*. 2009; 52(3): 623–642.
- Steriade, Donca. Alternatives to syllable-based accounts of consonantal phonotactics. In: Fujimura, O.; Joseph, B.; Palek, B., editors. *Proceedings of the 1998 Linguistics and Phonetics Conference*. Karolinum Press; Prague: 1999. p. 205-242.
- de Villiers, Jill. G.; de Villiers, Paul. A. A cross-sectional study of the acquisition of grammatical morphemes in child speech. *Journal of Psycholinguistic Research*. 1973; 2:267–278.
- Wexler, Kenneth. Optional infinitives, head movement and the economy of derivations in child grammar. In: Lightfoot, D.; Hornstein, N., editors. *Verb movement*. Cambridge University Press; Cambridge, MA: 1994. p. 305-350.
- Zamuner, Tania S.; Kerkhoff, Annemarie; Fikkert, Paula. Acquisition of voicing neutralization and alternations in Dutch. In: Bamman, D.; Magnitskaia, T.; Zaller, C., editors. *Proceedings of the 30th annual Boston University Conference on Language Development*. Cascadilla Press; Somerville, MA: 2006. p. 701-712.
- Zapf, Jennifer. A.; Smith, Linda. B. When do children generalize the plural to novel nouns? *First Language*. 2007; 27(1):53–73.
- Zapf, Jennifer. A.; Smith, Linda. B. Meaning matters in children's plural productions. *Cognition*. 2008; 108:466–476. [PubMed: 18452911]
- Zapf, Jennifer. A.; Smith, Linda. B. The plural: What it means and when it matters. Paper presentation at the 17 th Biennial International Conference on Infant Studies; Baltimore, MD. 2010, March;



**Figure 1.**  
 Demonstration of SSP-adhering and SSP-violating syllables.



**Figure 2.** (a) the blindfolded teddy bear used to elicit responses; (b) a sample set of objects used during one trial.



**Figure 3.** During the training puzzle for the comprehension task, the experimenter shows the complete puzzle to the child and lays out the puzzle pieces on the table in front of the child. The experimenter asks for the puzzle pieces and can correct the child, if necessary, as he or she places the puzzle pieces into the puzzle.

**Table 1**

Sonority of English phones (Bell &amp; Hooper 1978; Clements 1990; Parker 2008)

Manner of articulation	Example	Class
vowel	<i>i, e</i>	sonorant
glide	<i>y, w</i>	sonorant
liquid	<i>r, l</i>	sonorant
nasal	<i>n, m</i>	sonorant
fricative	<i>s, z</i>	obstruent
stop	<i>d, t</i>	obstruent



**Table 2**

Summary of results across all four experiments showing percent correct for each condition for each phonological manipulation for production and comprehension.

	Coda Complexity		SSP-adherence	
	Simple	Complex	Adhere	Violate
Production	68%	51%	59%	44%
Comprehension	78%	53%	70%	57%

Table 3

Data for each stimulus word from all four experiments showing (a) percent correct and (b) CHILDES corpus frequency of occurrence in the singular, the plural and the ratio between the two.

Plural Coda	% Correct		Frequency		Ratio
	Production	Comprehension	Singular	Plural	
<u>Exp. 1 &amp; 3</u>					
Simple	81	75	2037	152	13.4
baby					
bunny	56	81	433	32	13.5
cow	69	75	243	39	6.2
key	75	81	13	73	0.2
shoe	63	75	183	328	0.6
head	38	56	478	4	119.5
boat	50	44	54	7	7.7
book	50	38	996	189	5.3
cat	69	56	138	7	19.7
cup	50	50	234	11	21.3
dog	69	44	260	19	13.7
duck	44	69	172	32	5.4
hat	50	69	202	3	67.3
pig	44	69	97	12	8.1
bed	50	38	205	6	34.2
<u>Exp. 2 &amp; 4</u>					
sonorant coda	45	73	1052	51	20.6
ball					
bear	75	80	518	48	10.8
car	65	60	311	23	13.5
chair	60	67	324	5	64.8
plane	40	87	10	1	10.0
spoon	70	67	240	14	17.1
non-sonorant coda	45	60	341	48	7.1
bird					
bed	35	47	205	6	34.2
head	60	43	478	4	119.5
boat	40	67	54	7	7.7

Plural Coda	% Correct		Frequency		Ratio
	Production	Comprehension	Singular	Plural	
hat	35	40	202	3	67.3
cat	50	67	138	7	19.7

**Table 4**

Type and token frequency of mono-morphemic and bi-morphemic words with complex codas.

<b>Coda</b>	<b>Type</b>	<b>Token</b>
Son+s	390	3500
Stop+s	1633	14642

**Table 5**

Correlation between percent correct for all, simple and complex conditions and age and vocabulary for all four experiments. In the table “simple” refers to sonorant coda, “complex” to non-sonorant coda for experiments 2 and 4.

Experiment	Age			Vocabulary		
	All	Simple	Complex	All	Simple	Complex
1. Coda complexity production	.38*	.03	.40*	.40*	0.27	.43**
2. Coda sonority production	.42**	.01	.60***	.36*	.14	.38*
3. Coda complexity comprehension	.57***	.32*	.56***	.29	.11	.31*
4. Coda sonority comprehension	.30*	.20	.28	.28	.17	.28

\* p<.05

\*\*

p<.01

\*\*\*

p<.001