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Two-Year-Olds’ Sensitivity to Inflectional Plural Morphology: Allomorphic Effects

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ACQUISITION OF PLURAL MORPHOLOGY

Abstract
Many English-speaking children use plural nominal forms in spontaneous speech before the age of two, and display some understanding of plural inflection in production tasks. However, results from an intermodal preferential study suggested a lack of comprehension of nominal plural morphology at 24 months of age (Kouider, Halberda, Wood & Carey, 2006). The goal of the present study was to reexamine this issue using a phonologically and morphologically controlled set of stimuli. The results show that 24-month-olds do demonstrate understanding of nominal plural morphology, but only for the voiceless plural allomorph /s/, not /z/. Further study suggests that this result is not driven by input frequency, but rather by the longer duration of the /s/ allomorph, which may enhance its perceptual salience. The implications for learning grammar more generally are discussed.

Key Words: Language Acquisition, Inflectional Morphology, Allomorphy, Plural
ACQUISITION OF PLURAL MORPHOLOGY

Introduction
By the age of 24 months, children acquiring English are producing many plural words in their everyday speech (Brown, 1973; de Villiers & de Villiers, 1973; Mervis & Johnson, 1991). They understand the semantics of one vs. more-than-one (Barner, Thalwitz, Wood, Yang & Carey, 2007; Li, Ogura, Barner, Yang & Carey, 2009), and have long been sensitive to syntactic violations of subject/verb agreement (e.g., Soderstrom, White, Conwell & Morgan, 2007). However, it is not entirely clear what children understand about nominal plural morphology at this age. That is, it is unclear if 24-month-olds actually understand that a noun such as cats is composed of both the root morpheme cat and the inflected plural morpheme -s. Acquiring an understanding of nominal plural morphology is important as it allows speakers to appropriately inflect newly heard words. Understanding plural inflection is furthermore important for comprehension as it allows listeners to correctly identify the number (singular vs. plural) of a newly learnt word. Here we provide evidence from an intermodal preferential looking experiment (IPL; see Golinkoff, Hirsh-Pasek, Cauley & Gordon, 1987) that 24-month-olds do possess an understanding of the nominal plural morpheme, but that this early understanding is limited to only some allomorphs.

Previous research by Kouider, Halberda, Wood and Carey (2006) has suggested that, while 24-month-olds may understand is vs. are, they lack an understanding of nominal plural morphology. In that study, plural comprehension by 24- and 36-month-olds was tested using an IPL task. Participants were presented with two pictures of unfamiliar objects: a singular picture depicting a solitary object and a plural picture depicting eight identical objects. Auditory stimuli invited children to look at the [nonce word]. The design cleverly used nonce words to eliminate problems that arise through the use of known words. If a child is presented with two pictures, one showing a single cat and another showing eight cats, and told to “look at the cats”, she might simply look back and forward between both pictures, rather than looking
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at the picture of the multiple cats. Similarly, if told to “look at the cat”, a child might single out a cat in the multiple cat picture. Using nonce words and unfamiliar pictures therefore ensured that only children’s understanding of inflectional plural morphology could direct their looking behavior towards the target picture. The nonce words were then presented in either singular or plural form (e.g., “Look at the blicket!” vs. “Look at the blicket-s”). If children shifted their gaze towards a plural picture after hearing a plural nonce word, it was seen as indicative of their understanding of nominal plural morphology. The results showed 36-month-olds could comprehend both singular and plural inflected nouns, but 24-month-olds were unable to do so for either.

However, the findings of Kouider et al. (2006) are at odds with studies of children’s plural production. In addition to using plurals in their spontaneous speech (e.g., Brown, 1973), 2-year-olds show an emerging ability to inflect newly learnt words with plural forms. Using a modified wug task (see Berko (1958)), Zapf and Smith (2007) demonstrated that (at least some) children aged between 18 and 29 months are able to produce previously unheard plural and singular forms of newly-learnt words. While a few children struggled to perform the task, many were able to inflect a word such as wug to form the plural wugs, and vice versa. That is, many children successfully demonstrated a productive understanding of English nominal plural morphology. In another study examining the spontaneous speech of children aged 18 – 30 months, morphemic word-final fricatives (such as the /z/ in toes) were found to be significantly longer than tautomorphemic word-final fricatives (such as the /z/ in nose), again suggesting that English-acquiring children at this age have some representation of nominal plural morphology (Song, Demuth, Evans & Shattuck-Hufnagel, 2013). Children’s ability to perform wug tasks and to differentiate morphemic and non-morphemic fricatives at this age is particularly remarkable, given that between 2 and 3 years old, children acquiring American English correctly produce coda /s/ only 59% of the time, and coda /z/ only 43% of the time.
Taken together, these studies suggest that, despite the articulatory challenges of fricatives, at least some English-acquiring 2-year-olds do have a productive understanding of nominal plural morphology.

Using an IPL task similar to that used by Kouider et al. (2006), Arias-Trejo, Cantrell, Smith and Canto (2014) found that Mexican-Spanish speaking 24-month-olds demonstrated an understanding of nominal plural morphology. This finding may be due to language specific factors, but it may also be due to experimental differences. While Arias-Trejo et al. (2014) implemented the same experimental design and visual stimuli as that used in Kouider et al. (2006), they also controlled the auditory stimuli phonologically. Nonce stimuli were only of the form CVCV or CVCVs. Thus, although the Mexican-Spanish nominal plural has different allomorphic variants (/s/ as in mesa+s ‘tables’, and /es/ as in pan+es ‘breads’), Arias-Trejo et al. (2014) tested comprehension of only the more frequently occurring plural allomorph /s/. In contrast, participants in the Kouider et al. (2006) study were presented with a mix of phonologically simple and complex nonce words, including both monosyllables and disyllables, long and short vowels, different coda complexities, and all three English plural allomorphs /s, z, əz/ (e.g., blickets/nools/ratches). This is important, as phonological context has been shown to affect not only children’s production of grammatical morphology (Song, Sundara & Demuth, 2009; Theodore, Demuth & Shattuck-Hufnagel, 2011; Mealings, Cox & Demuth, 2013), but also children’s comprehension of known plural words (Ettlinger & Zapf, 2008). Thus, it is possible that nonce stems of differing complexity made the Kouider et al. (2006) task too difficult, washing out any effect that might have been apparent in phonologically simple words.

The English nominal plural is composed of three allomorphic variants, /s/, /z/ and /əz/, each of which arises from the phonological properties of the noun stem. Stems ending in a voiceless consonant take the voiceless plural allomorph /s/ (e.g., cats /kæts/), those ending in a
voiced consonant take the voiced plural allomorph /z/ (e.g., dogs /dɔɡz/), and those ending in a strident consonant are inflected with the syllabic plural allomorph /əz/ (e.g., bushes /buʃəz/).

Kouider et al. (2006) showed that, while no understanding of plural allomorphs /z/ and /əz/ was found, 24-month-olds did appear to demonstrate some understanding of the voiceless plural allomorph /s/. However, while the authors suggested that 24-month-olds may understand the voiceless plural allomorph /s/, this finding only approached significance. Interestingly, the 36-month-olds also performed the best on the /s/-inflected nouns. We therefore hypothesized that, if we used phonologically and morphologically controlled stimulus words to probe these allomorphic effects, 24-month-olds would demonstrate sensitivity to the voiceless plural allomorph /s/. It was unclear, however, if they would also be sensitive to the voiced plural allomorph /z/. The goal of the present study was therefore to examine whether 24-month-olds demonstrate comprehension of nominal plural morphology for the two allomorphs /s/ and /z/ in phonologically simple contexts.

Method

Participants

Thirty-one children were tested to achieve a planned target of 20 participants. Eleven were initially excluded for returning insufficient trials (defined below) due to fussiness, inattention, and/or poor eye tracking. Late in the analysis, however, it was discovered that one of the participants had a bilingual background; this participant was then also excluded from the analysis. The remaining 19 participants (7 girls, 12 boys) were aged 1;11.2–2;1.2, with a mean age of 2;0.3 years. Parents completed the short form of the MacArthur Communicative Development Inventory (CDI), a 100-word checklist used to assess the child’s vocabulary size (Fenson et al., 2000). CDI scores ranged from 40 to 80 (25th–80th percentile) with a mean of
57.5 (55th percentile). None of these children had any reported ear infections, hearing impairment or developmental delay.

**Auditory Stimuli**

The auditory stimuli included 12 CVC nonce words, recorded in both singular and plural-inflected conditions (CVCs/CVCz) (see Table 1). The stimuli were recorded by a female native speaker of Australian English using a child-directed speech register in a sound attenuated room. All onset consonants were selected to be early acquired stops /n/, /m/, /d/, /t/, /b/, /p/, /g/ and /k/ (Smit et al., 1990). Only short vowels /ɐ/, /e/, /ɪ/ and /o/ were used to minimize the effect of syllable weight. Coda stops were /p/, /b/ and /g/. The selection of these coda consonants ensured that the place of articulation of the stop was different from the plural /s, z/ morphemes (hence no /ts/ clusters), and that /ks/, which can be interpreted as tautomorphic (e.g., box and fox), were avoided. Two carrier phrases were used: “Look at the X” and “Find the X”. Each stimulus was recorded with its carrier phrase as a complete utterance, e.g., “Look at the mips”. The audio was digitally recorded at 48kHz using Cool Edit Pro 2.0. In each version of the experiment, participants heard three nonce words with the voiceless plural allomorph /s/, three with the voiced plural allomorph /z/, and six singular (uninflected) words.

**Table 1:** Nonce word stimuli plus plural allomorph

<table>
<thead>
<tr>
<th>stem+/s/</th>
<th>stem+/z/</th>
</tr>
</thead>
<tbody>
<tr>
<td>mip</td>
<td>kib</td>
</tr>
<tr>
<td>tep</td>
<td>gub</td>
</tr>
<tr>
<td>gop</td>
<td>pog</td>
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<td>nep</td>
<td>Nug</td>
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<tr>
<td>gip</td>
<td>deg</td>
</tr>
<tr>
<td>dup</td>
<td>tig</td>
</tr>
</tbody>
</table>

1 As stimuli are in Australian-English, the International Phonetic Alphabet (IPA) transcriptions here reflect Australian-English vowels (see Harrington, Cox & Evans, 1997).
In addition to the nonce stimuli used in the test trials, known words were recorded for the known test trials and the orientation trials. The known test trials had the following targets in both singular and inflected forms: bug/z/, crab/z/, duck/s/, frog/z/, pig/z/ and snake/s/. Orientation trials used only the singular targets dog, cat and bird with the carrier phrase “Look at the X”.

Visual Stimuli

Visual stimuli included cartoon drawings of 16 unknown animals, designed to not resemble any real or familiar fictional characters, depicted with happy faces and closed eyes (see Figure 1). For each drawing, a one-animal (singular) picture and a five-animal (plural) picture were constructed. Two versions of each picture were then created, one in which the animals were colored in solid red, the other in which the animals were colored in solid blue. This color variation was to make trials more interesting for the children. During the experiment, only pictures of the same color were displayed side-by-side, and the singular and plural pictures were always of different animals. Each picture measured 23.3cm by 27.7cm. All animals were depicted against an off-white background. To ensure all pictures were comparable in visual salience, the foreground area of each picture (for both singular and plural animal depictions) was controlled using ImageMagick (v6.8.6-3). The greatest area difference between any two pictures (including both singular and plural conditions) was 0.80cm² or 0.35%. The mean area difference was 0.05cm² or 0.02%.
Figure 1: Unknown animals used in test trials

For known test trials and the orientation trials, cartoon drawings of 10 known animals were used. These included six animals used in the known test trials (pig, duck, bug, frog, crab and snake) and four used in the orientation trials (dog, cat, bird and cow). Both singular and plural pictures were constructed for the animals used in the known test trials, whereas only singular pictures were made for those used in the orientation trials. Known animals were displayed in colors best suiting their depiction.

Apparatus

Children’s looking behavior was recorded using a Tobii Eye Tracker model x120 (Tobii Technology, Danderyd, Sweden), tilted at 30°, and positioned 60 cm in front of the child. A widescreen 27” LG Flatron W2753VC monitor displayed visual pictures and was 15 cm above the eye-tracker. Auditory stimuli were played through 2 Edifer USB M1250 computer speakers
on either side of the screen. The experimental media consisted of video (.AVI) files and picture (.PNG) files presented through Tobii Studio software (2.2). Video was encoded in JPEG codec 3.2.4 at 24 frames-per-second, and displayed at 1080x1920 pixels at 81.6 pixels-per-inch. Audio was uncompressed 16-bit 48kHz played at normal speech level (≈65dBA). The eye-tracker took samples at 120Hz, with a 100 ms recovery time for lost tracking, and collecting gaze data from both eyes.

Procedure

The parent and child were invited into a small test room to listen to some new words while looking at a computer. Parents wore opaque glasses so as not to bias their children’s behavior, and to prevent their retinal reflections being detected by the eye tracker. Each child was seated facing forward, on his or her parent’s lap, approximately 80 cm in front of the monitor and 60 cm from the eye-tracker.

Orientation Trials

In order to acquaint children with the experimental task, each experiment commenced with three orientation trials. Orientation trials were presented in five phases (see Figure 2).

![Figure 2: Orientation trial and test trial procedures](image)
In the pre-auditory stimulus (familiarization) phase, children were shown two pictures side-by-side on the screen, each picture depicting of a familiar animal (e.g., cat vs. bird). After 1.25 seconds, one picture flashed for 250 ms followed by the other picture for 250 ms, after which both pictures remained on the screen for 2 seconds. The sequential flashing of the two pictures ensured children looked at each picture and became familiar with both. The pre-auditory stimulus phase lasted 4 seconds, after which the pictures were replaced with a looming red ball in the middle of a black screen. The gaze-centering phase lasted 1 second, after which the looming ball faded out completely. Next the auditory stimulus presentation began over a black screen. The audio stimulus instructed the child to look at one of the animals previously displayed. The pictures then reappeared onscreen 330 ms after the coda burst of the target word. This post-auditory stimulus phase lasted for 3 seconds. This was followed by the animation phase where the non-target distractor picture faded out, and the target picture became animated, dancing to music for 1 second. This served as reinforcement for the association between the auditory instruction and the target picture, cueing children to perform the task.

Test Trials

Following the orientation trials, 15 test trials were presented, including 12 critical trials and 3 known trials. Critical trials presented children with novel pictures. Known trials displayed pictures of familiar animals (e.g., five bats vs. one snake), and were included to help maintain children’s attention, and to give an indication of participants’ ability to perform the task. Test trials differed from orientation trials in three important ways: pictures were always presented as singular vs. plural; pre-auditory stimulus (familiarization) and post-auditory stimulus phases were longer in duration (5 and 4 seconds, respectively, as nonce words and unknown pictures are more difficult for children to process), and there was no animation phase, thereby avoiding possible training effects. Each test trial (both critical and familiar) consisted of four phases (Figure 2). The pre-auditory stimulus (familiarization) phase followed the same
basic process as in the orientation trials. After presenting both pictures for 1.25 seconds, one picture flashed for 250 ms, followed by the other picture, which flashed for 250 ms. Both pictures then remained onscreen for a further 3.25 seconds. This was then followed by the gaze centering phase, the auditory stimulus phase and post-auditory stimulus phase. The onset of the visual stimulus was time locked to 330 ms after the onset of coda burst in the target word (i.e., the /p/ in ‘Look at the gups’). The visual stimuli were displayed for 4 seconds.

**Design**

To ensure that there were no stimulus presentation order or fatigue effects, four pseudo-randomized versions of the experiment were constructed. Depictions of each nonce animal were counterbalanced across two variables: (1) whether it was presented in a plural or singular picture, and (2) whether it was presented as either a target or distractor. While each version contained a different order of both auditory and visual stimuli presentations, the basic order in which the trial types were presented was the same: 3 orientation → 1 known → 4 critical → 1 known → 4 critical → 1 known → 4 critical. The final four critical test trials in each version consisted of the distractor pictures from the previous eight critical test trials. Of the participants included in the final analysis, five each were tested in versions 1, 2 and 3, and four were tested in version 4.

**Data Analysis**

Children’s raw looking data were converted into fixations using the IVT fixation filter in Tobii Studio (3.2.3). Fixation points were averaged across both eyes over a three-sample window, missing data points were interpolated for up to 60 ms, and fixations less than 75 ms were discarded. Areas of interest (AOIs) were defined as the target picture and distractor picture in each trial.

Individual trials were excluded if the child failed to record fixations on both the target and the distractor during the pre-auditory stimulus (familiarization) phase, or if they failed to
return any samples during the post-auditory stimulus phase. Trials were also excluded if the child did not return any samples anywhere on the screen during the auditory stimulus phase, as this was taken as indication of not paying attention to the stimulus. Children included in the final analysis returned a minimum two each of /s/, /z/ and singular trials.

Results

Proportional difference scores were used as the dependent measure in this analysis. A proportional difference score is a calculation of a child’s looking preference shift towards the target picture after hearing the audio stimulus. In IPL studies with children, a difference score is typically used as a within-subject control of item preference. Looking data were analyzed in both the pre-auditory stimulus (familiarization) phase, and the post-auditory stimulus phase. For each phase, the proportion of looking to target was obtained by dividing the total fixation durations recorded for the target picture by the sum total fixation durations recorded for both the target and distractor picture. Any time spent not looking at either picture was thus excluded from this calculation. Looking preference shift to target was then calculated by subtracting the proportion looking to target during the pre-auditory stimulus phase from that of the post-auditory stimulus phase, and multiplying by one hundred to gain a percentage. A positive difference score indicated the child’s looking behavior had shifted towards the target picture after hearing the audio stimulus, and vice versa for a negative shift.

To assess participants’ ability to perform the task itself, the first analyses were carried out on the proportional difference scores of the orientation trials and the known test trials. It was expected that there would be significant positive proportional difference scores, indicating children’s looking preference shift towards the target picture. With alpha set at 0.05, planned t-tests compared children’s mean target preference shift to that of zero. As hypothesized, children returned positive proportional difference scores that were significantly different from
chance for both the orientation trials and the known test trials, showing a 14.8% ($t(18) = 3.90$, $p < 0.01$) shift towards the target for the orientation trials ($M = 14.75$, $SD = 16.47$), and an 11.0% ($t(18) = 3.74$, $p < 0.01$) shift towards the target for the known test trials ($M = 12.82$, $SD = 12.82$).

With this as an indication that the children were able to perform the task, proportional difference scores were then calculated for the singular and plural (collapsed /s/ and /z/) novel test trials. Figure 3 compares children’s proportion of looks to the target for pre- and post-auditory stimulus phases, and illustrates the preference shift.

![Figure 3: Looking proportion shifts to target (black arrows) by participant for singular and plural novel test trials.](image)

Proportional difference scores were then calculated for voiceless plural /s/ and voiced plural /z/ novel test trials. Figure 4 shows children’s proportion of looks to the target for pre- and post-auditory stimulus phases, and shows the preference shift. During the voiceless plural /s/ trials, 15 children shifted their looking preference towards the target picture after hearing the audio stimulus, whereas for the voiced plural /z/ trials, only 6 children did so. Note that
five out of the six children who returned positive proportional difference scores in the voiced plural /z/ trials also returned positive proportional difference scores in the voiceless plural /s/ trials, suggesting more robust knowledge of nominal plural morphology.

![Figure 4: Looking proportion shifts to target (black arrows) by participant for plural /s/ and /z/ novel test trials.](image)

Planned contrasts were then carried out on the mean proportional difference scores of the novel test trials. Two orthogonal planned comparisons were made in the analysis program PSY (Bird, Hadzi-Pavlovic & Isaac, 2000). The first compared the proportional difference scores of singular ($M = -4.86, SD = 11.47$) to plural (collapsed /s/ and /z/; $M = 0.80, SD = 12.04$) conditions, with no significant difference found between the conditions ($F(1, 18) = 2.16, p = 0.16, \eta_p^2 = 0.11$). Second, we compared the two plural conditions and found a significant difference between /s/ and /z/ proportional difference scores, ($F(1, 18) = 4.79, p = 0.04, \eta_p^2 = 0.21$), showing that children’s looks to plural targets were higher for /s/ ($M = 6.70, SD = 12.54$) than for /z/ ($M = -3.91, SD = 18.94$).

To test whether children’s proportional difference score for each condition was greater
than chance, $t$-tests were carried out. Neither singular ($t(18) = -1.85, p = 0.08$), nor plural ($t(18) = 0.29, p = 0.78$) was significantly different to chance (see Figure 5). The plural allomorphs /s/ and /z/ were then separately compared to chance. While voiceless plural /s/ was significantly above chance ($t(18) = 2.33, p = 0.03$), voiced plural /z/ ($t(18) = -0.90, p = 0.38$) was not (see figure 6).

![Figure 5: Mean difference scores for critical test trials by number. Error bars ± 1 SE](image)

![Figure 6: Mean difference scores for plural critical trials by allomorph. Error bars ± 1 SE. *$p = .03$](image)
To test whether children’s proportional difference scores were driven by a preference for certain items during the pre-auditory phase, paired *t*-tests comparing pre-auditory stimulus familiarization looking proportions was performed. While the overall mean looking proportion was slightly higher for /z/ \((M = 0.55, SD = 0.10)\) than /s/ \((M = 0.51, SD = 0.08)\) this difference was not significant \((t(18) = 1.14, p = 0.27)\). Similarly there was no difference between the singular \((M = 0.50, SD = 0.10)\) and collapsed plural \((M = 0.53, SD = 0.06)\) conditions \((t(18) = 0.62, p = 0.54)\).

Taken together, these results indicate that children’s looking preference shift was random for the voiced plural /z/, but systematically towards the target picture and significantly above chance for the voiceless /s/ condition, suggesting that children had some comprehension for the /s/ plural allomorph.

Pearson product-moment correlation coefficients were then calculated to assess the relationship between children’s proportional difference scores for each condition and their reported productive vocabulary score (raw CDI score). No significant correlation was found for the singular \((r = 0.21, n = 19, p = 0.39)\) or the collapsed plural condition \((r = 0.17, n = 19, p = 0.48)\). Nor was there a significant correlation found for voiced plural /z/ \((r = -0.05, n = 19, p = 0.82)\). However a significant positive moderate correlation was found between children’s raw CDI vocabulary scores and their proportional difference score for voiceless plural /s/ \((r = 0.47, n = 19, p = 0.04)\). These results suggest that children with larger vocabularies showed greater sensitivity to the voiceless plural /s/. Figure 7 shows individual participant proportional difference scores for /s/, /z/ and singular conditions, and their correlation with their raw CDI scores.
The results of this first study therefore show that children aged 24 months do demonstrate an understanding of plural morphology, but that this is limited to the voiceless plural allomorph /s/. Thus, looking preference shift measures (proportional difference scores) reveal that children are sensitive to the meaning of voiceless plural /s/ in a way they are not for voiced plural /z/, and that productive vocabulary (CDI score) is correlated with this sensitivity. However, the reason for why children should demonstrate understanding of voiceless plural /s/ but not voiced plural /z/ is unclear. The following study therefore explored possible reasons behind this difference, namely frequency and perceptual salience.
Exploring Differences Between Plural Allomorphs - Frequency and Perceptual Salience

The 24-month-olds in this study demonstrated sensitivity to the voiceless plural allomorph /s/, but not to voiced allomorph /z/. There are at least two possible explanations for this result. One possibility is that allomorph /s/ is more frequent in the input children hear, leading to its earlier acquisition. Another possibility is that allomorph /s/ is more perceptually salient, making children more sensitive to its presence in the speech signal. We explore both possibilities below.

Frequency Analysis

The frequency of different linguistic units has been shown to play an important role in language acquisition. For example, infants are sensitive to the statistical patterns in language, which allows them to discover the phonemes of their native language (Kuhl, 2004), and to segment words from continuous linguistic input (Saffran, Aslin & Newport, 1996). Furthermore, children acquire syllable structures and prosodic word structures that are the most frequent in the ambient language before they acquire less frequent prosodic structures (e.g. Levelt, Schiller & Levelt, 2000; Roark & Demuth, 2000). Perhaps then the plural allomorph /s/ is more frequent than the plural allomorph /z/. If so, this might provide an explanation for children’s earlier sensitivity to this form. However, Brown (1973) showed in a sample of parents’ speech, that the allomorph /z/ accounted for 70% of regularly inflected plurals, while /s/ accounted for only 22%, and /əz/ for 8%. Given children’s lack of sensitivity to the /z/ allomorph, its reported dominance in the input is surprising. However, Brown’s results came from a relatively small dataset of only 147 plural tokens, and there was no analysis of tokens vs. types. We therefore performed a more comprehensive corpus analysis to examine the frequency of plural allomorphs in the input children hear by analyzing the input of six children from the time they...
started speaking to just after their second birthday. It should be noted that the corpus is of American English, as opposed to Australian English. While not ideal, this is not considered problematic as the dialects do not differ with regard to consonant voicing or plural allomorph variation.

**Method**

*The Data*

The Providence Corpus (Demuth, Culbertson & Alter, 2006) contains the spontaneous speech interactions of six mothers and their children collected from the New England region of the United States. Approximately one hour of audio was recorded every two weeks from the onset of the child’s first words up to age of 3. The data analyzed here were extracted from mothers’ speech up until each child was 25 months, using Computerized Language Analysis software (CLAN, V.04-Feb-2013) from the Child Language Data Exchange System database (CHILDES; see MacWhinney, 2000).

The mothers’ speech had been transcribed orthographically using Codes for the Human Analysis of Transcripts conventions (CHAT; see MacWhinney, 2000). The tokens extracted for this study were words ending with alveolar fricatives /s/ and /z/ spoken by a mother to her child. This was orthographically represented in the data by words ending in s, z, se, ze, ce and x. Each token was extracted along with its surrounding utterance. Non-English words were excluded from the dataset. The number of tokens extracted, number of files extracted, and age ranges are presented in Table 2.
Table 2: Number of mothers’ lexical items ending in /s/ or /z/ for each child.

<table>
<thead>
<tr>
<th>Child</th>
<th>Tokens</th>
<th>Recordings</th>
<th>Age range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alex</td>
<td>6,393</td>
<td>18</td>
<td>1;10 – 2;1</td>
</tr>
<tr>
<td>Ethan</td>
<td>12,287</td>
<td>31</td>
<td>0;11 – 2;1</td>
</tr>
<tr>
<td>Lily</td>
<td>18,179</td>
<td>28</td>
<td>1;1 – 2;1</td>
</tr>
<tr>
<td>Naima</td>
<td>23,831</td>
<td>44</td>
<td>0;11 – 2;1</td>
</tr>
<tr>
<td>Violet</td>
<td>6,721</td>
<td>23</td>
<td>1;10 – 2;1</td>
</tr>
<tr>
<td>William</td>
<td>7,134</td>
<td>16</td>
<td>1;10 – 2;1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>74,545</strong></td>
<td><strong>160</strong></td>
<td><strong>0;11 – 2;1</strong></td>
</tr>
</tbody>
</table>

Each token was then manually coded for the grammatical function of the alveolar fricative (3sg, plural, possessive, contraction or none/monomorphemic), and the type of alveolar fricative (/s/, /z/, or /əz/, if morphemic).

Results

Because the voiced plural allomorph /z/ appears in more phonological contexts, it was anticipated that it might actually be more frequent than the voiceless plural allomorph /s/, by both token and type. With alpha set at 0.05, a one-way chi-square analysis revealed statistically different proportions of /s/, /z/, and /əz/ plural allomorphs in children’s input, by both token $\chi^2 (2, N = 13,114) = 9619, p < .001$, and type $\chi^2 (2, N = 2400) = 1476, p < .001$. Similar to the findings of Brown (1973), the most frequent plural allomorph heard on average per child was the voiced plural allomorph /z/, which accounted for 72.2% of plural tokens and 69.8% of plural types. The voiceless plural allomorph /s/, by contrast, only accounted for only 22.1% of plural tokens and 23.3% of plural types. Furthermore, distribution across the six children was consistent, with all type and token proportions of /s/, /z/ and /əz/ plural allomorphs varying...
only by 3 percent. Thus, as shown in Figure 8, plural allomorph /z/ was roughly three times more frequent compared to the voiceless plural allomorph /s/, by both token and type.

![Figure 8: Percent input for plural allomorphs by token and type](image)

These results, however, do not entirely rule out frequency as an explanation for children’s greater sensitivity to plural /s/. While inflected plural nouns in children’s input were shown to be predominately /z/-final, it was hypothesized that /s/-final words might constitute proportionally more plurals than /z/-final words. That is, while plurals were more likely to be /z/-final, perhaps /s/-final words are more likely be plural. Again, however, the results suggest that this is not the case. With alpha set to 0.05, a two-way chi-square analysis revealed a significant relationship between coda fricative (/z/ or /s/) and proportion of plural to non-plural words (i.e., 3SG, possessive, contraction or monomorphemic), for both token $\chi^2 (1, N = 74,545) = 3642.5, p < .001$ and type $\chi^2 (1, N = 5332) = 188.5, p < .001$. The results showed that /z/-final words were 24.9% plural by token and 51.8% plural by type. This is a much higher proportion than the /s/-final words, of which only 7.9% were plural by token, and 30.1% plural by type.
In fact, /s/-final words were most likely to contain no inflectional morphology at all, with 47.6% of all tokens being monomorphemic (e.g. *house*).

The results of the frequency analysis therefore indicate that input frequency cannot account for the results of our IPL experiment. A greater proportion of plural words in children’s input are inflected with the voiced plural allomorph /z/ compared to the voiceless /s/, and a greater proportion of /z/-final words were shown to be plurals compared to /s/-final words. However, it has long been known that /s/ is durationally longer than /z/ (Crystal & House, 1988; Stevens, Blumstein, Glicksman, Burton & Kurowski, 1992). It has also been shown that infants are more sensitive to 3rd person singular fricative inflection (e.g. *eat+s*) when it is longer in duration utterance-finally compared to shorter in duration utterance-medially (Sundara et al., 2011). This raises the possibility that perceptual salience might play a role in explaining children’s selective attention to plural /s/. An acoustic analysis therefore examined the properties of the stimuli used in our IPL study.

**Acoustic Analysis**

As illustrated in studies by Crystal & House (1988) and Stevens et al. (1992), /s/ fricatives are typically longer in duration than /z/ fricatives. Perhaps children are listening more attentively to /s/ allomorphs because these are more perceptually salient, i.e., contain a longer frication period. Note also that vowels are longer before voiced consonants (Peterson & Lehiste, 1960; House, 1961). Thus, the ratio of word duration to frication duration will also be greater for the voiceless allomorph /s/ (shorter vowel and longer frication duration), enhancing its perceptual salience. Therefore, even though the nonce words in the IPL study were heard in utterance-final position, where the /z/ morphemes may be partially devoiced due to phrase final devoicing, robust acoustic cues to voicing would still remain (Smith, 1997).
Evidence that children may be sensitive to this fricative durational contrast comes from a recent acoustic study of the spontaneous speech of six children aged 18-30 months and their mothers (obtained from the Providence Corpus, the same used for the frequency analysis above), where adult-like durational contrasts were found for coda productions of /s/ and /z/ (Song, Demuth, Evans & Shattuck-Hufnagel, 2013). In particular, children’s /s/ durations were significantly longer than for /z/, and morphemic fricatives were significantly longer than non-morphemic fricatives. An acoustic analysis was therefore performed on the plural stimuli used in our IPL study to determine whether children’s differential sensitivity to different plural allomorphs might be attributed to the acoustic salience of the stimuli they were listening to during the task.

### Method

For each plural token in the test stimuli (see Table 1), three durational measurements were taken: *vowel duration* (from beginning to end of F2); *closure duration* (from the end of vowel to burst onset of the lexical coda consonant); and *burst+frication duration* (from the burst onset to the end of plural frication). Acoustic measurements were carried out using PRAAT (v5.3.62; Boersma, & Weenink, 2009)

### Results

As expected, with alpha set at .05, two sample t-tests revealed significantly shorter vowel duration preceding /s/ ($M = 209.50, SD = 28.72$) than /z/ ($M = 239.13, SD = 33.13$) ($t(21.57) = -2.34, p = 0.03$), significantly longer closure duration for tokens with plural /s/ ($M = 171.07, SD = 22.97$) than plural /z/ ($M = 142.02, SD = 18.95$) ($t(21.24) = 3.38, p < 0.01$), and significantly longer burst+frication duration for /s/ ($M = 267.43, SD = 21.01$) than /z/ ($M = 239.79, SD = 15.00$) ($t(19.90) = 3.71, p < 0.01$) (Figure 9).
Figure 9: Durational differences in plural stimuli allomorphs /s/ (e.g., *teps* /teps/) and /z/ (e.g., *degs* /degs/). Error bars ± 1 SE. *p < .04.

These results are consistent with findings from Crystal and House (1988) and Smith (1997). Thus, for our CVC+s/z stimuli, voiceless plural /s/ had significantly longer coda consonant closure duration and significantly longer burst+frication duration than voiced plural /z/, and vowel length was significantly shorter for words inflected with voiceless plural /s/ than with voiced plural /z/. This suggests that the children in the IPL experiment may be more sensitive to plural /s/ allomorphs due to the fact that these are longer in duration, rendering nouns inflected with voiceless plural /s/ more perceptually salient than their plural /z/ counterparts.

**General Discussion**
The IPL experiment in this study was carried out to determine if 24-month-old English-learning children have some understanding of nominal plural morphology. The results showed that 24-month-olds do comprehend the voiceless plural allomorph /s/, but do not yet show a similar level of sensitivity for the voiced plural allomorph /z/. An analysis of child language corpora showed that this effect is not driven by input frequency. Acoustic analysis on the IPL stimuli, however, showed that the voiceless plural /s/ stimuli had longer closure and burst+fricitation duration than the voiced plural /z/. This suggests that children’s sensitivity to the plural /s/ allomorph may be due to its longer duration, resulting in greater perceptual salience. Perhaps this is one reason children are reported to acquire /s/ before /z/ in production as well (Smit, 1993). It is therefore possible that children’s initial sensitivity to plural /s/ stems from greater acoustic (and perceptual) salience. In elicited imitation tasks, for example, the greater duration given to segments by phrase-final lengthening allows children more time to perceive final consonants, as well as more time to produce them (Song et al., 2013; Theodore et al., 2011). The same is found in perception/looking time studies, where 2-year-olds show greater sensitivity to 3rd person singular morphemes utterance finally, where they are longer in duration, compared to utterance medially (Sundara et al., 2011). These results confirm that children are sensitive to at least some plural allomorphs, helping to explain why they might also be using them in early speech.

However, questions remain regarding why children seem to be so slow at learning nominal plural inflection when other studies have showed perceptual sensitively to later mastered 3rd person singular –s at the earlier age of 20 months (Sundara et al., 2011). One of the reasons that this study, as well as Kouider et al. (2006), failed to show sensitivity to all nominal plural morphology could be due to the use of nonce words, which may result in increased cognitive demand. Stager and Werker (1997) showed that children aged 14 months are unable to use their knowledge of phonetic contrasts in a novel word-learning task, but older
children, aged 17 months, can. It is therefore possible that when children are developing an initial understanding of plural morphology that a nonce word paradigm is overly demanding.

This could also explain the puzzling results for the singular condition in this study. It might be expected that singulars would be the first grammatical representations a child learns before they are able to acquire plural representations (i.e., to have a representation of ‘more-than-one’ necessitates a representation of ‘one’). However, the present results, consistent with that of Kouider et al. (2006), suggest that this is not the case for the mapping of singular vs. plural morphology. Interestingly, Arias-Trejo et al. (2014) also found Mexican-Spanish speaking children were not sensitive to the singular condition, even when the stimuli included copula and determiner information. As noted in that study, children’s failure to perform on this condition may not be indicative of children misunderstanding singular, but instead may be a result of children’s natural preference towards plural pictures (see also Carey, 1978; Jolly & Plunkett, 2008), or may be due to children choosing to focus on an individual in the plural picture. Thus, it is also possible that this type of IPL task may obscure children’s knowledge of singular.

Another reason for children’s lack of preference for the singular could be that it is, in effect, the absence of the inflected plural morpheme. If children have not yet acquired a complete representation of the plural, they would not be able to notice the absence of the plural morpheme. Or, perhaps children first become sensitive to nominal plural morphology when they begin to reassess the representation of singulars in their lexicon. English has many high frequency irregular plurals, e.g., ‘children’ and ‘sheep’, and monomorphemic words ending in /s/ and /z/, e.g., ‘box’ and ‘nose’. When faced with nonce words it may not be entirely clear whether a CVs/CVts or CVz/CVdz word is a singular or a plural, especially when representations for inflectional morphology are still in the process of being learned. Therefore,
without additional redundant markings from the copula (e.g., Where is the X), children may find this task very challenging.

What is clear from the present study is that English-learning children do have a productive understanding of nominal plural morphology by 24 months, and that this may be correlated with vocabulary size. While they may not understand all the plural allomorph variants, they are aware that adding an /s/ to the end of a word can indicate plurality. While Kouider et al. (2006) argue that children do not acquire English nominal plural morphology until the age of three, our study shows that 2-year-old’s have an emergent understanding of the English plural /s/. This goes some way to bridging the gap between studies of children’s language perception and production, given that many children this age are already producing plural morphemes with high frequency familiar words in appropriate discourse contexts, and have demonstrated an emerging ability to perform plural wug tasks (Zapf & Smith, 2007). The findings presented here therefore contribute to a growing literature showing phonological/acoustic effects on the acquisition of grammatical morphemes. A better understanding of these issues will help inform the nature of children’s emerging linguistic competence, and why it sometimes appears as a gradual and variable process.
ACQUISITION OF PLURAL MORPHOLOGY

References


