CHILDREN'S GRADUAL ACQUISITION OF SINGULAR AND PLURAL

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DOCTOR OF PHILOSOPHY IN LINGUISTICS

BY

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DECLARATION

The research presented in this thesis is my original work and has not been submitted for a higher degree in any other institution. In addition, I certify that all information sources and literature used are indicated in the thesis. The research presented in this thesis has gained ethics approval from Macquarie University (5201401065).

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THESIS SUMMARY

By two years of age children are using singular and plural words appropriately in their speech (Brown 1973), yet it is unclear whether their early representations are adult-like. It is not known how and when children develop the understanding that a word such as *cats* is composed of the lexical root *cat* and the plural morpheme *–s* (i.e., *cat+s*). The aim of this thesis was to therefore to explore some of the factors that potentially affect young children's understanding of the marking of nominal number in English.

The studies presented in **chapters two** and **three** examined children's early comprehension of singular and plural using a novel-word Intermodal Preferential Looking task (Kouider, Halberda, Wood & Carey, 2006). In **chapter two**, the results found that 24-month-olds had an understanding of plural morphology that was limited to the voiceless plural allomorph /-s/ (e.g., cat + /s/), which is longer in duration and more perceptually salient than the voiced allomorph /-z/ (e.g., dog + /z/). However, the results presented in **chapter three** suggested that perceptual salience was not the only factor to play a role in children's acquisition of plural morphology, as 36-months-olds, but not 30-month-olds, were found to understand the most perceptually salient syllabic allomorph /-əz/ (*e.g.,* bus + /əz/).

The studies presented in **chapters four** and **five** examined pre-schoolers' understanding of singular and plural using a novel-word forced choice task. In **chapter four**, the study found 3- to 5-year-olds' comprehension of novel plurals, yet not novel singulars, improved with age. The study in **chapter five** examined children with hearing loss, which is known to affect children's acquisition of English plural and tense inflections, likely due to difficulty perceiving fricatives (Koehlinger, Owen Van Horne, & Moeller, 2013). Overall, the children with hearing loss were no better than chance at identifying novel plurals and singulars. However, comprehension of novel plurals improved with age. The thesis concludes with a discussion of the acquisition of morphological representations more generally.

CHAPTER 1: THESIS INTRODUCTION

CHILDREN'S EARLY WORDS

Young children excel at learning words, yet the nature of their early representations is unclear. Children are sensitive to sound patterns in their language input and can readily extract discrete words from an otherwise continuous stream of speech (e.g., Saffran, Aslin & Newport, 1996; Saffran, 2001, 2002). Their talent for word-learning is perhaps best demonstrated during the so-called word-spurt, in which some one- to two-year-olds produce new words at an astonishing rate of nine per day (e.g., Nelson, 1973; Goldfield & Reznick, 1990). However, while children may appear to be prodigious word-learners, much remains unknown about how and when they develop adult-like representations. For example, a young child might initially understand a phrase such as "*all gone*" to be a single word, or mis-segment other words, such as a little boy telling his babysitter to put something in "*your crowave*" (as in *microwave*, 'my crowave'), or a little girl telling her father *"I am being have!"* in response to being told to "*behave!"* (from Paszek, 1987).

This thesis explores children's developing understanding of singular and plural words in English. While children may use plural words appropriately in their speech from around two years of age (Brown 1973; de Villiers & de Villiers, 1973; Mervis & Johnson, 1991), it is unclear to what degree their early representations are adult-like. A child may understand that a word such as *cats* means *more than one cat*, yet may treat it as a lexical whole, rather than as a combination of lexical item plus plural morpheme (*cat+s*). That is, they may not understand plural morphology. An adult speaker of English knows (intuitively) that the word *cats* is a complex word composed of two meaningful units, or *morphemes*: the root morpheme *cat* (meaning *small fluffy feline*) and the inflectional plural morpheme /-s/ (meaning *more than one*). Just as children eventually come to realise that "*all gone"* is a complex linguistic structure and not a single word, at some point they also learn that *cats* and *dogs* are morphologically complex. The purpose of this thesis was to shed some light onto how and when children acquire

English plural morphology, and to explore some of the factors that could potentially affect this process.

ALLOMORPHIC VARIATION OF THE ENGLISH PLURAL

One of the factors explored in this thesis is the role that allomorphic variation plays in children's acquisition of plural morphology. One potential hurdle to children's acquisition is the fact that the plural morpheme has three different surface forms, or *allomorphs*. The words *buses*, *cats* and *dogs* are all inflected with the plural morpheme, yet each with a different plural allomorph, respectively /-əz/, /-s/ and /-z/. The syllabic plural allomorph /-əz/ attaches to sibilants /s, z, ʃ, ʒ/, such as in *buses* /ˈbɐsəz/ and *roses* /ˈɹəʉzəz/, the voiceless segmental plural allomorph /-s/ attaches to voiceless consonants /p, t, k, f/ such as in *cats* /$\mathrm{k^h}$æts/ and *socks* /sɔks/, and the voiced segmental allomorph /-z/ attaches to vowels or any other voiced segment, such as in *dogs* /dɔgz/ and *zoos* /zu:z/. Thus, in order to acquire the plural morpheme, children need to understand the underlying phonological processes behind allomorphic variation, which requires particular sensitivity to the phonological context at the end of the nouns.

Different phonological contexts have been shown to affect children's production of inflectional morphemes (Song, Sundara & Demuth, 2009; Theodore, Demuth & Shattuck-Hufnagel, 2011; Mealings, Cox & Demuth, 2013), and allomorphic variation has specifically been shown to affect children's production of the plural morpheme. For example, the syllabic plural allomorph /-əz/ is acquired long after /-s/ and /-z/ in children's day-to-day speech (Brown, 1973), and even children as old as seven have difficulty inflecting both familiar nouns (e.g., *bush* /bʊʃ/ → *bushes* /ˈbʊʃəz/) and novel nouns (e.g., *tizz* /tɪz/ → *tizzes* /ˈtɪzəz/) with syllabic plural /-əz/ (Berko, 1958; Graves & Kozoil, 1971; Matthews & Theakston, 2006). Allomorphic variation also plays a role in the production of the plural morpheme by children with hearing loss. However, for these children the syllabic plural allomorph /-əz/ is mastered in their speech earlier than the segmental allomorphs /-s/ and /-z/ (Koehlinger et al., 2015).

MORPHOLOGICAL STRUCTURE AND THE ENGLISH SINGULAR

This thesis explores whether there is an asymmetry between children's acquisition of singular and plural nouns. In contrast to the three surface forms of the plural morpheme, the English singular has no surface form and is instead represented by a null morpheme. While some languages, such as Sesotho, use inflectional morphology to mark both singular and plural nouns (e.g., mo-sadi = *woman*, ba-sadi = *women*; Demuth, 1992; Demuth & Weschler, 2012), the English singular is simply marked by the absence of the plural morpheme (e.g., *cats* = *more than one cat*, *cat_* = *exactly one cat*). In some ways this could make the singular more difficult for children to acquire than the plural. In order to notice that the plural morpheme is absent on a newly heard word, a child needs a good understanding of allomorphic variation, as well as morphological structure. Even when a noun ends in an /s/ or /z/, a competent speaker of English will know if that word is singular or not. For example, even though *ice* /ɑes/ ends in an /s/, it cannot be the plural form of *eye* /ɑe/, just as *peace* /pi:s/ cannot be the plural form of *pea* /pi:/, because the plural morpheme following a vowel must be /-z/ (the plural forms are therefore *eyes* /ɑez/ and *peas* /pi:z/). A competent speaker of English knows also that the word *fizz* /fɪz/ cannot be plural, because the resulting singular form */fɪ/ is not a possible word in English (as open stressed syllables with short vowels are phonologically illegal). Of course, there are some phonological forms in English that can be ambiguous, such as *rose* and *rows*, which share a phonological structure /ɹəʉz/, yet have different morphological structures, one being singular (*rose*), and the other plural (*row+s*).

To date, there has not been much research into children's acquisition of the English singular. However, in the classic *wug* study, Berko (1958) suggested that children's inability to inflect novel nouns with the syllabic plural allomorph /-əz/ (e.g., *nizz* /nɪz/ → *nizzes* /nɪzəz/) was due to the fact that the singular novel words in the task were /s/- or /z/-final, and so the children interpreted them as being already plural. Thus, perhaps children were not paying attention to the morphological structure of the novel words, but simply listening to whether they ended in an /s/ or /z/. One study that has discovered differences between children's comprehension of singular and plural was performed in Mexican Spanish (Arias-Trejo, Cantrell, Smith & Canto, 2014). In an intermodal preferential looking experiment (IPL; see Golinkoff, Hirsh-Pasek, Cauley & Gordon, 1987), 24-month-old Mexican Spanish-speakers were tested on their comprehension of singular and plural novel words. Similar to English, the singular in Spanish is morphologically unmarked (e.g., Spanish: gato_ = *cat*, gatos = *cats*). In this study, children showed an understanding of plural novel words, but not singular. While there are obviously many differences between English and Spanish, the asymmetry between children's singular and plural comprehension is nonetheless interesting, and was therefore investigated further in this thesis.

Plural morphology and copula subject-verb agreement

Children's comprehension of singular and plural nouns might be assisted via subject-verb agreement within a sentence. Because English verbs can agree in number with their subject in certain conditions (e.g., *the cat is/was purring*, *the cats are/were purring*), agreement may help children to acquire grammatical morphology. The copula may be especially helpful to children, as it is frequent in children's input, relatively early-acquired (Brown, 1973), and unlike many other English verbs, it also changes its surface form entirely to agree with its subject noun (e.g., *is*, *are*, *was*, *were*). Children as young as 30 months are able to use at least the plural copula (e.g., *are*) to help facilitate their comprehension of plural subject nouns (Lukyanenko & Fisher, 2016), and three-year-olds can identify singular and plural pictures before they are explicitly named with the help of *is* and *are* agreement (Deevy, Leonard & Marchman, 2017; Lukyanenko & Fisher, 2016). There is also evidence that copula agreement in conjunction with determiner agreement (e.g., *a*, *some*) helps 24-month-olds identify singular and plural novel nouns (e.g., *there are some blickets* vs. *look at the blickets*; Kouider at al., 2006; Wood, Kouider & Carey, 2009). However, it is unclear to what extent children use copula agreement alone in their comprehension of singular and plural nouns. This thesis therefore further explored the effect of copula subject-verb agreement on children's comprehension of unfamiliar singular and plural words.

HEARING LOSS AND THE ACQUISITION OF PLURAL MORPHOLOGY

Because hearing loss disproportionately affects access to high frequency fricative sounds such as /s/ and /z/ (Stelmachowicz, Pittman, Hoover & Lewis, 2002; Pittman & Stelmachowicz, 2003), many children with hearing loss are delayed in both their production and comprehension of plural morphology (Young & Killen, 2002; McGuckian & Henry, 2007; Moeller et al., 2010; Koehlinger et al., 2013). As mentioned above, allomorphic variation also appears to play a role in the acquisition of plural morphology by children with hearing loss, where they master the syllabic plural allomorph /-əz/ in their speech before the segmental allomorphs /-s/ and /-z/ (Koehlinger et al., 2015). However, to date there have been no studies that have explored what effect hearing loss has on children's representations of morphological structure. While children with hearing loss may be able to use plural words such as *cats* and *dogs* in their day-to-day speech, it is unclear if words such as these are understood as being morphologically complex, or just treated as simple lexical items meaning *more than one cat* and *more than one dog*. This thesis therefore explores the understanding of plural morphology by children with hearing loss.

INVESTIGATING MORPHOLOGICAL STRUCTURE THROUGH NOVEL WORDS

In order to assess children's productive understanding of singular and plural morphology, the experiments presented in this thesis employ a novel word paradigm inspired by an IPL task designed by Kouider, Halberda, Wood and Carey (2006). In that experiment, the plural comprehension of 24- and 36-month-olds was tested in a cleverly designed novel-word task. In this task, children were presented with two pictures depicting unknown objects. One picture displayed one unknown object (singular picture), while the other displayed eight identical instances of another unknown object (plural picture). An auditory prompt encouraged children to *look at the [novel word]*. The novel word was either singular, and encouraged the child to look at the singular picture (e.g., *Look at the blicket!*) or it was inflected for plural, and encouraged the child to look at the plural picture (e.g., *Look at the blicket<u>s</u>*). By using novel words and pictures of unknown objects, children's understanding of plural morphology and morphological structure was tested directly. The only way to understand that *blicket* is singular and *blickets* is plural is through an understanding of morphological structure (e.g., *blicket* = singular, *blicket+s* = plural). The experiment furthermore avoided potential problems that would arise through the use of known words. For example, if a child was presented with one picture showing a single cat and another showing eight cats, when told to *look at the cats*, the child's response might be to simply look back and forward between both pictures, rather than focusing upon the plural cat picture. Using this novel word paradigm, the study found that 36-month-olds were successfully able to comprehend plural novel nouns, but 24-month-olds were not. However, unlike the designs employed in this thesis, the Kouider et al. (2006) task was not specifically designed to test the effect of allomorphic variation on children's comprehension.

The four studies presented in this thesis all employ a novel-word paradigm similar to that used by Kouider et al., (2006), with unknown pictures and novel words. The studies presented in chapters two and three explored children's understanding of plural morphology in the lab using an IPL eye-tracking task. In these studies, children's understanding of plural morphology was assessed via indirect behavioural measures (i.e., children's looking behaviour). The studies in chapters four and five were conducted on an iPad and carried out at children's preschools and speech clinics. In these studies, children's understanding was assessed directly through an explicit forced choice paradigm.

The study presented in chapter two investigated 24-month-olds' comprehension of the segmental plural allomorphs. Children were tested on their comprehension of novel words inflected with the voiceless plural allomorph /-s/ (e.g., *teps*) and the voiced plural allomorph /-z/ (e.g., *degs*), as well as on novel CVC singular words (e.g., *tep*, *deg*). Based on previous findings from Kouider et al. (2006), it was hypothesised that children would at least be able to demonstrate understanding of voiceless plural /-s/, if not for both of the allomorphs tested. The results showed that children were able to comprehend the number of novel words inflected with the voiceless plural allomorph /-s/, but not those inflected with voiced plural /-z/, or for novel singular words. A corpus analysis suggests that children's better comprehension of /-s/ was not driven by input frequency. However an acoustic analysis suggests that the longer duration, and thus the greater perceptual salience of the /-s/ allomorph, aids children's comprehension.

The study presented in chapter three investigated children's comprehension of the syllabic plural allomorph /-əz/, and of /s/- and /z/-final singular words. Using the same IPL paradigm as in Study One, participants aged 30 and 36 months were tested on novel plural /əz/-inflected words, such as *kosses* /kɔsəz/ and *nizzes* /nɪzəz/ and on words such as *koss* /kɔs/ and *nizz* /nɪz/, that are necessarily singular in English. Results found that 36-month-olds were able to understand both plural and singular forms, but 30-month-olds could not. A time course analysis of children's looking behaviour also revealed that children took longer to process plural novel words than singular novel words, potentially due to their more complex morphological structure. This study suggests that children have good knowledge of singular and plural morphology by the age of three.

The study presented in chapter four examined 3- and 4-year-olds' comprehension of novel singular and plural words using a forced choice task, presented to them on an iPad. Children were tested on novel words infected with all three plural allomorphs (/-s/, /-z/ and /-əz/), as well as on stop- and fricative-final novel singular words (e.g., *deg*, *nizz*). Children were also tested on their understanding of copula subject-verb agreement using *is* and *are*. It was hypothesised that by this age allomorphic variation should not affect comprehension (as previous results suggest that they are all acquired by this age), yet they may be more accurate in the trials with copula agreement. The results indeed found children comprehend all plural allomorphs equally, and that there was no performance difference between stop final and fricative final singular words. However, children's accuracy with plural nouns increased with age, yet singulars did not. Furthermore, children of both ages seemed to ignore copula agreement entirely. The results of this study therefore suggest that children's comprehension of singular and plural are on different developmental trajectories. The study also suggests that copula agreement plays a limited role in pre-schoolers' processing of language.

The study presented in chapter five investigated the understanding of plural morphology by children with hearing loss. Using the same iPad paradigm as the previous study, pre-schoolers with varying degrees of hearing loss were tested on their understanding of novel singular and plural words. It was hypothesised that they might show comprehension of the more perceptually salient syllabic plural allomorph /-əz/. However, while a handful of individuals with less hearing loss were able to demonstrate some degree of comprehension, results show that, as a group, children were unable to demonstrate comprehension of plural and singular novel words, regardless of allomorph or copula agreement. This suggests that representations of plural morphology is delayed for children with hearing loss.

Taken together, these studies paint a picture of children's gradually developing understanding of the singular and the plural in English, and gives us insight as to how children acquire representations of morphological structure. This thesis highlights the early importance of allomorphic variation in children's acquisition of the plural, and starts to build an account of children's acquisition of the singular, something which has been largely overlooked in the literature so far. By gaining a better understanding of what children's acquisition looks like for typically developing populations, we can better design interventions for those who are at risk of language delay, such as children with hearing loss. This thesis aims to contribute to the growing body of research uncovering the processes behind children's incredible word-learning abilities.

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CHAPTER 2: TWO-YEAR-OLDS' SENSITIVITY TO INFLECTIONAL PLURAL MORPHOLOGY: ALLOMORPHIC EFFECTS

This chapter comprises the following published paper:

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All components of this paper, both experimental and written, have been completed by me, with advice from the co-authors (my supervisors) when needed.

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 re-examine 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

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 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), two-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

(Smit, 1993). Taken together, these studies suggest that, despite the articulatory challenges of fricatives, at least some English-acquiring two-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/ and /-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., *ca<u>ts</u>* /kæ<u>ts</u>/), those ending in a voiced consonant take the voiced plural allomorph /-z/ (e.g., *dogs* /dɔgz/), and those ending in a strident consonant are inflected with the syllabic plural allomorph /-əz/ (e.g., *bushes* /bʊʃəz/). 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/[1] 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 tautomorphemic (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 recoded 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.

[1] As stimuli are in Australian-English, the International Phonetic Alphabet (IPA) transcriptions here reflect Australian-English vowels (see Harrington, Cox & Evans, 1997).

Table 1: Nonce word stimuli plus plural allomorph

stem+/s/	stem+/z/
mip	kib
tep	gub
gop	pog
nep	nug
gip	deg
dup	tig

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 23.3 cm by 27.7 cm. 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 0.80 cm^2 or 0.35%. The mean area difference was 0.05 cm^2 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 1080 x 1920 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.

<u>Orientation Trials</u>

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).

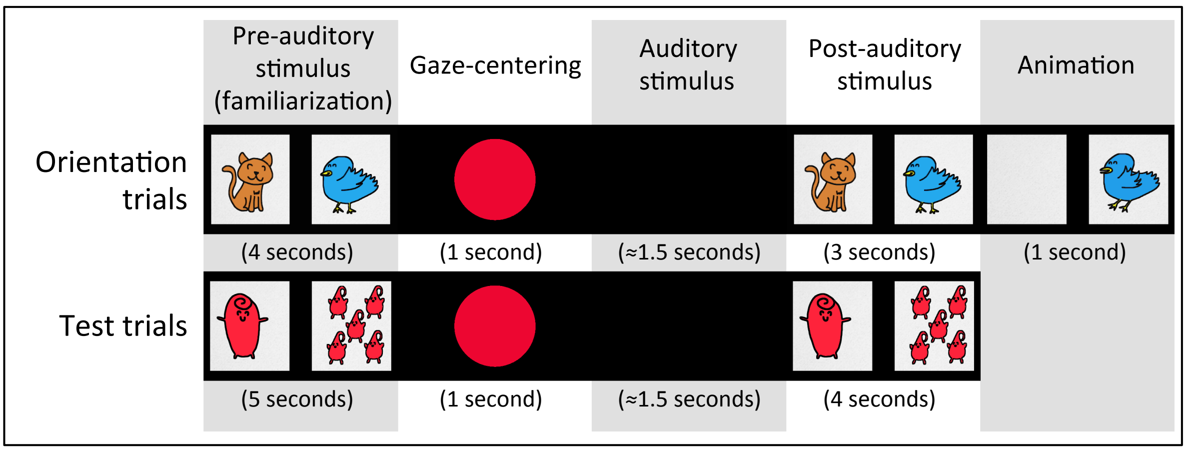

Figure 2: Orientation trial and test trial procedures

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% ($t(18) = 3.90$, $p < .01$) shift towards the target for the orientation trials ($M = 14.75$, $SD = 16.47$), and an 11.0% ($t(18) = 3.74$, $p < .01$) 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.

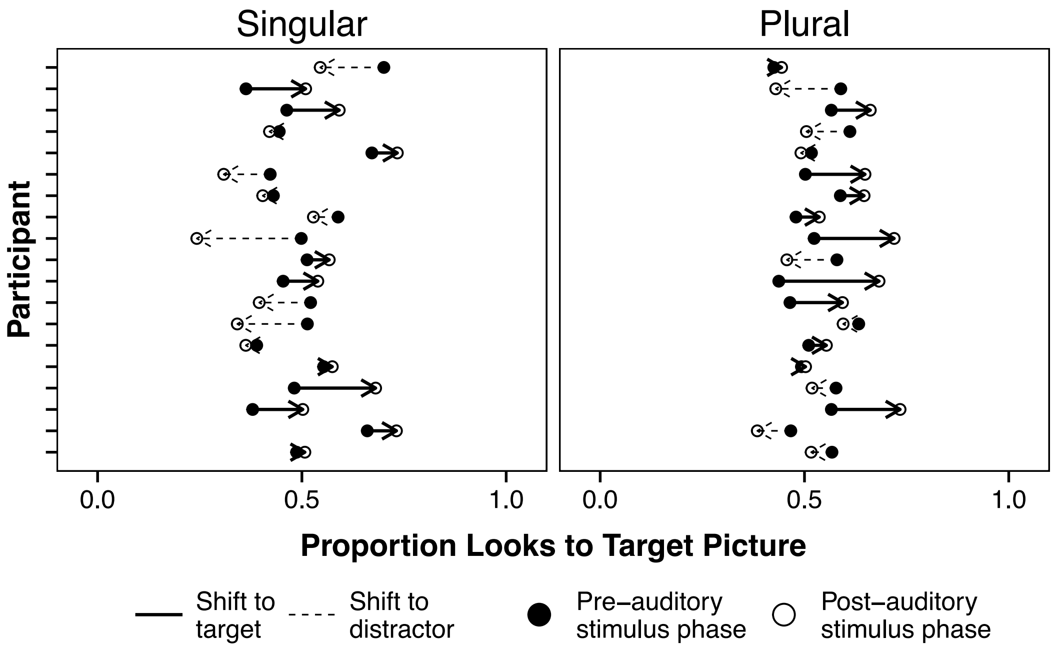

Figure 3: Looking proportion shifts to target (black arrows) by participant for singular and plural novel test trials.

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.

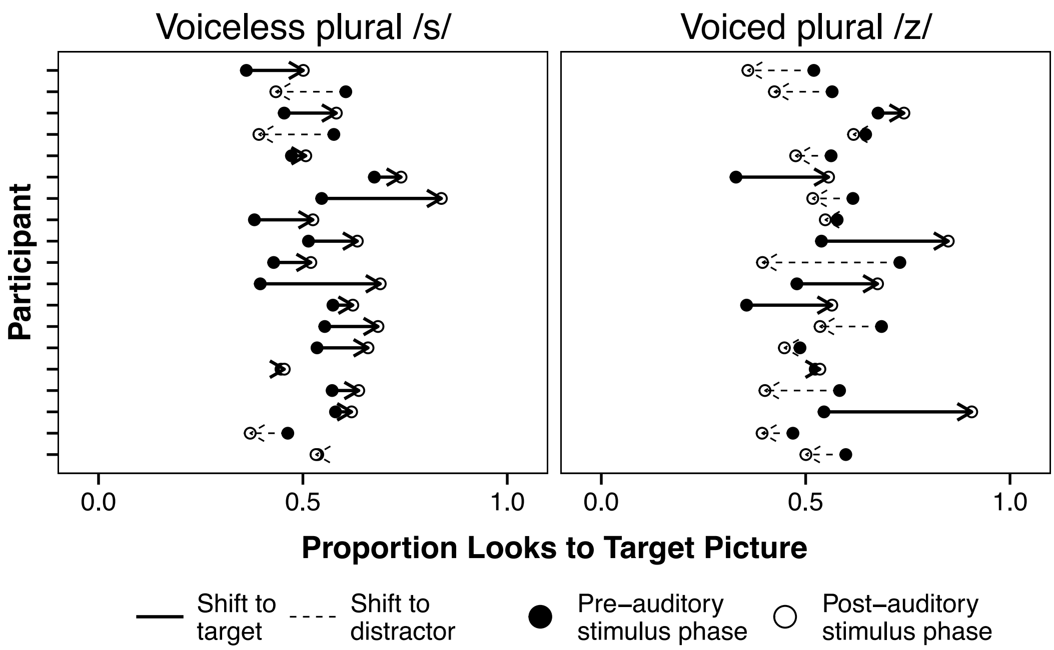

Figure 4: Looking proportion shifts to target (black arrows) by participant for plural /-s/ and /-z/ novel test trials.

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, $p = .16$, $\eta_p^2 = 0.11$). Second, we compared the two plural conditions and found a significant difference between /-s/ and /-z/ proportional difference scores, (F(1, 18) = 4.79, $p = .04$, $\eta_p^2 = 0.21$), 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 ($t(18) = -1.85$, $p = .08$), nor plural ($t(18) = 0.29$, $p = .78$) 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 ($t(18) = 2.33$, $p = .03$), voiced plural /-z/ ($t(18) = -0.90$, $p = .38$) was not (see figure 6).

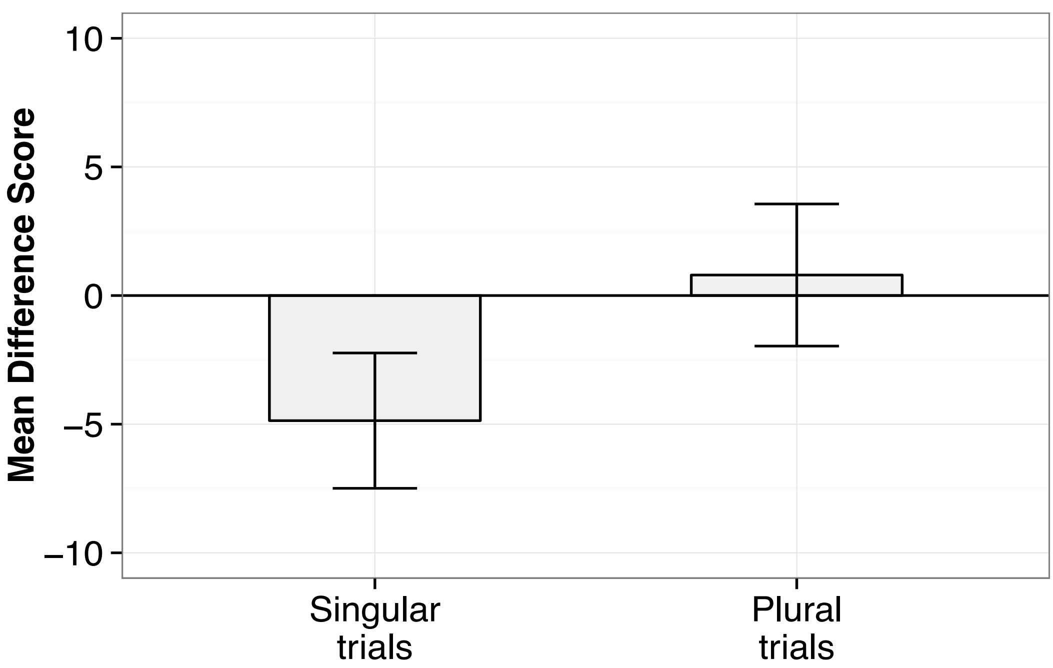

Figure 5: Mean difference scores for critical test trials by number. Error bars ± 1 SE

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 ($t(18) = 1.14$, $p = .27$). Similarly there was no difference between the singular (*M* = 0.50, *SD* = 0.10) and collapsed plural (*M* = 0.53, *SD* = 0.06) conditions ($t(18) = -0.62$, $p = .54$).

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.

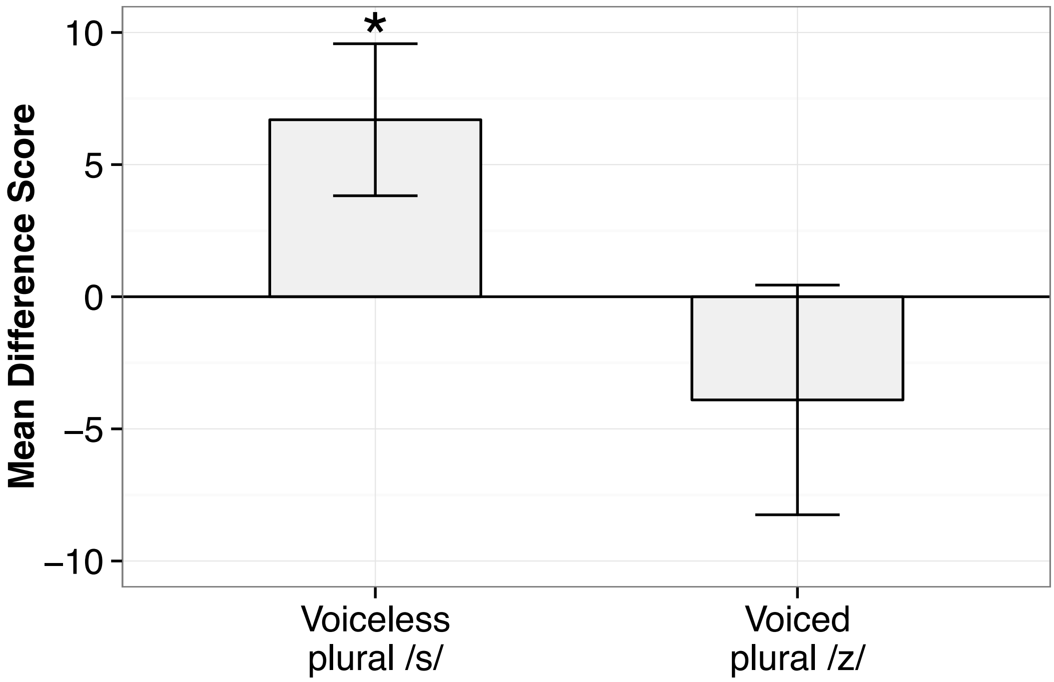

Figure 6: Mean difference scores for plural critical trials by allomorph. Error bars ± 1 SE. *p = .03

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 (N = 19, r = .21, $p = .39$) or the collapsed plural condition (N = 19, r = .17, $p = .48$). Nor was there a significant correlation found for voiced plural /-z/ (N = 19, r = -.05, *p* = .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/ (N = 19, r = .47, *p* = .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.

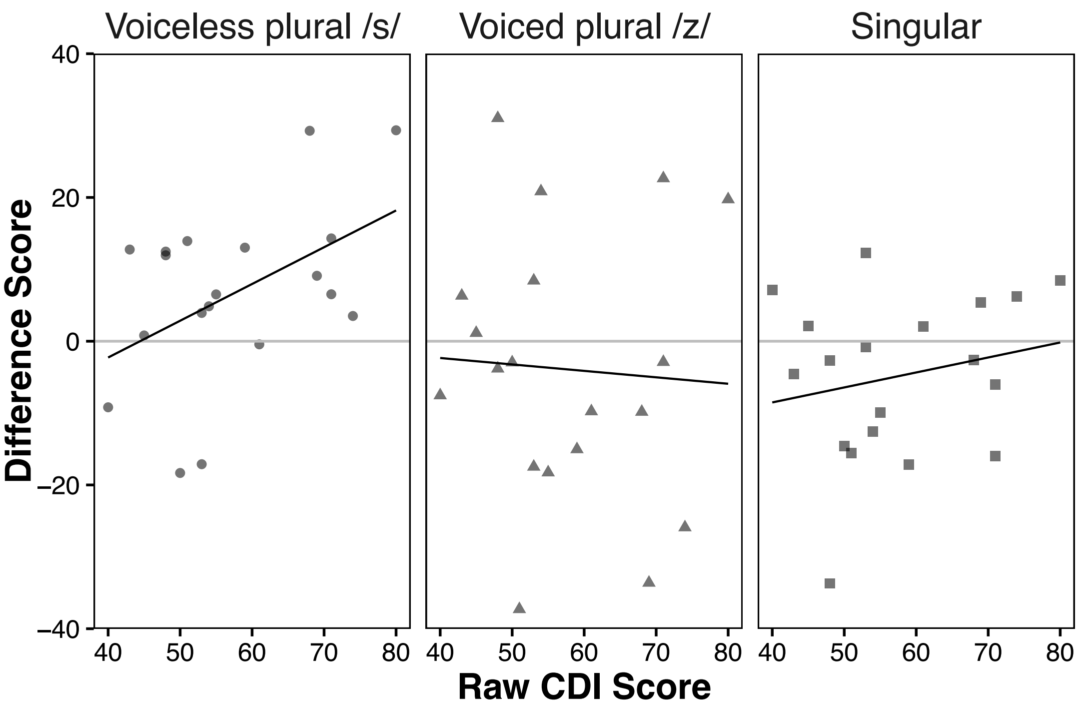

Figure 7: Correlations between individual children's raw CDI score and mean difference scores for voiceless plural /-s/, voiced plural /-z/, and singular.

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 allomorphic 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.

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).

Table 2: Number of mothers' lexical items ending in /s/ or /z/ for each child.

Child	Tokens	Recordings	Age range
Alex	6,393	18	1;10 – 2;1
Ethan	12,287	31	0;11 – 2;1
Lily	18,179	28	1;1 – 2;1
Naima	23,831	44	0;11 – 2;1
Violet	6,721	23	1;10 – 2;1
William	7,134	16	1;10 – 2;1
Total	**74,545**	**160**	**0;11 – 2;1**

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.

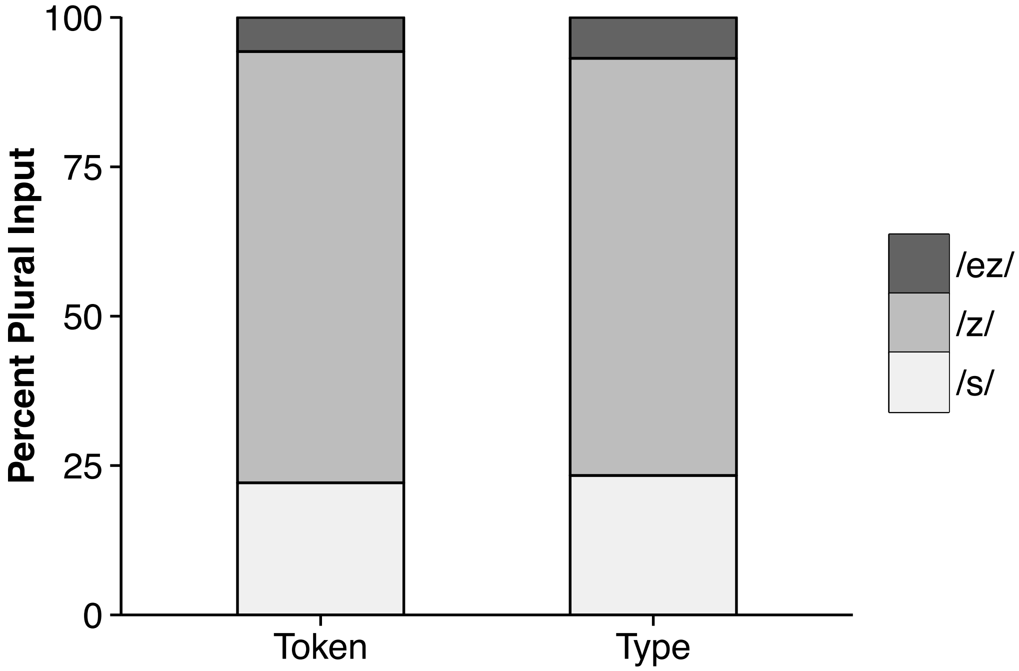

Figure 8: Percent input for plural allomorphs by token and type

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) ($t(21.57) = -2.34$, $p = .03$), significantly longer closure duration for tokens with plural /s/ (M = 171.07, SD = 22.97) than plural /-z/ (M = 142.02, SD = 18.95) ($t(21.24) = 3.38$, $p < .01$), and significantly longer burst+frication duration for /-s/ (M = 267.43, SD = 21.01) than /-z/ (M = 239.79, SD = 15.00) ($t(19.90) = 3.71$, $p < .01$) (Figure 9).

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.

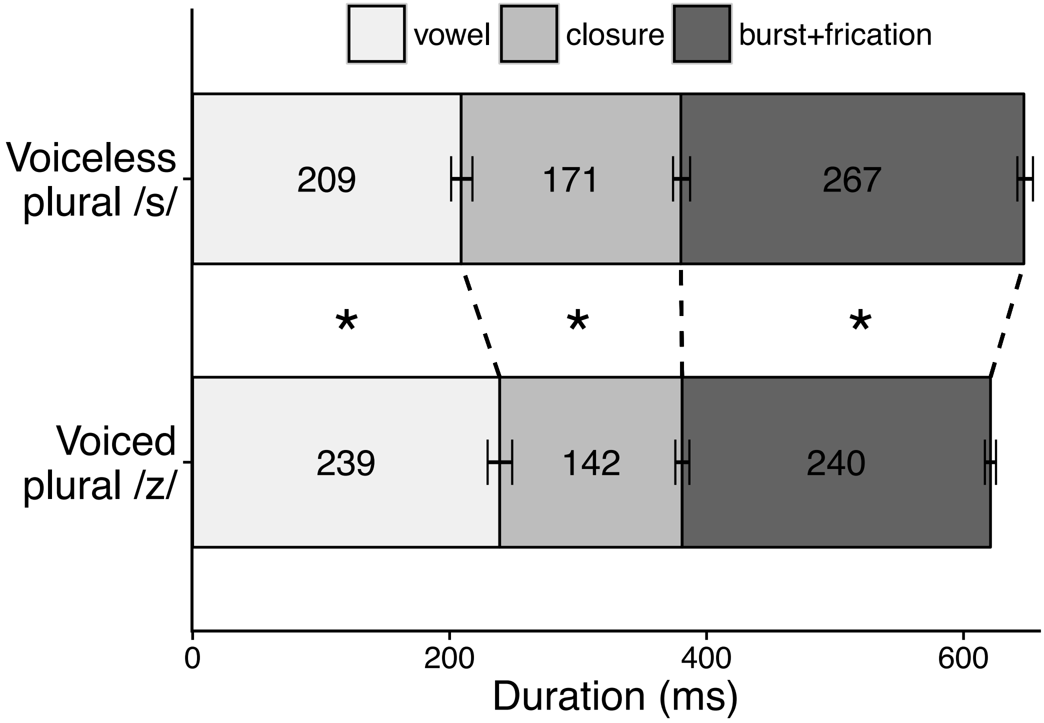

Figure 9: Durational differences in plural stimuli allomorphs /-s/ (e.g. teps /teps/) and /-z/ (e.g., degs /degz/). Error bars ± 1 SE. ****p* **< .04.**

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+frication 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 two-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 allomorphic 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 two-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.

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CHAPTER 3: ONE *KOSS*, TWO *KOSSES*: THREE-YEAR-OLDS KNOW WHEN /S/ MEANS PLURAL AND WHEN IT DOES NOT

This chapter comprises the following paper in preparation:

Davies, B., Xu Rattanasone, N., & Demuth, K. (in prep). One koss, two kosses: Three-year-olds know when /s/ means plural and when it does not.

All components of this paper, both experimental and written, have been completed by me, with advice from the co-authors (my supervisors) when needed.

ABSTRACT

English-speaking children readily produce plural words from the age of two, yet it is unclear when they develop an understanding of morphological structure. For example, it is possible that a word such as *cats* might be interpreted as plural because it ends in a fricative /s/, and this might be overgeneralized to words like *bus*. The present study therefore employed an intermodal preferential looking (IPL) eye-tracking task to determine if and when children begin to understand English singular vs. plural morphological structure. Children aged 30 and 36 months were tested on novel words such as *koss* /kɔs/ and *nizz* /nɪz/, that are necessarily singular in English, and novel plural /əz/-inflected words, such as *kosses* /kɔsəz/ and *nizzes* /nɪzəz/. The results show that, while 30-month-olds struggled to identify the number condition of singular/plural nonce words, 36-month-olds identified both singular and plural forms. Time course analysis also revealed that children took much longer to process plurals than singulars, perhaps due to their more complex morphological structure. These findings suggest that, at least by the age of 3, children have a productive knowledge of English singular vs. plural morphological structure. The implications for learning morphological structure more generally are discussed.

INTRODUCTION

One of the early challenges for language learners is to map sounds to words and meanings. However, unlike words on a page, which are separated by spaces, words in the speech stream are continuous. In many languages, including English, this is further compounded by inflectional morphology. The ultimate challenge for the learner is to be able to identify words and their component morphemes and to map appropriate meanings to both. In order to be able to do this, children must acquire an understanding of *morphological structure*.

While learners have been shown to be sensitive to the distributional patterns of the sound sequences in the input they hear (e.g., Saffran, 2001), it remains unclear how and when they acquire an understanding of morphological structure, and can determine that the /z/ at the end of *bees* /biz/ is morphemic (*bee* + plural), whereas the /z/ at the end of *nose* /noʊz/ is not. Of course, there are famous cases of mis-parsing, where *pease* (Middle English mass noun; see Palmer, 1990) became reanalysed as *pea+s* (plural of *pea*), and we know that children sometimes over-segment words, as in the case of *behave* parsed as *be+have*: (*e.g.,* Parent: *you have to behave*. Child: *I am being have!*; from Paszek, 1987). Learners must attend closely to all kinds of distributional cues to understand what is a lexical word, and what is productive morphology. Yet little is known about how and when this actually takes place.

Some models of language acquisition suggest that children acquire the concept of morphological structure later than other lexical or syntactic representations. Marcus et al. (1992), for example, propose that children acquiring English initially learn inflected words (e.g., *cats*) as whole undivided lexical units, and only reanalyse these words as having morphological structure (e.g., *cat+s*) after sufficient language exposure. This period of lexical reanalysis is argued to give rise to children's *U-shaped development* of overgeneralisation, in which they erroneously apply regular morphological patterns to irregular words they have previously produced correctly (such as saying **comed* instead of *came*). In contrast, computational modelling suggests that word and morphological boundaries are instead acquired jointly (e.g., Johnson, Christophe, Demuth, & Dupoux, 2014). That is, children are aware that words have some sort of internal structure even before necessarily understanding what that structure is.

Acquiring an understanding of English plural morphology requires an understanding of morphological structure. This involves more than simply interpreting words ending with an /s/ or a /z/ as plural, and interpreting those without as being singular. For example, a noun such as *cats* is not a lexical item meaning 'multiple small furry animals', but rather the morphologically complex word *cat*+*s*, composed of the root morpheme *cat*, and the inflectional plural morpheme -*s*. However, the *phonology* of a noun does not directly determine whether it is singular or plural. For example, the nouns *rose* and *rows* share the same phonological structure, /ɹəʉz/[2], yet have differing morphological structures, one singular (*rose*), and the other plural (*row*+*s*).

Understanding plural morphology means that singular and plural nouns do not need to be learned individually and stored as separate lexical entries (with the exception of irregular nouns such as *tooth*/*teeth* and *mouse*/*mice*; for models of lexical storage/access see Levelt, Roelofs & Meyer, 1999; Fieder, Nickels & Biedermann, 2014). Rather, adult speakers of English are able to inflect a newly learnt word, such as *wug* into its appropriate, yet previously unheard plural form, *wug**s***, and are able to easily comprehend the number condition of a word upon hearing it for the first time (e.g., *wugs* = *wug*+*s* = plural; *wug* = *wug* = singular). While studies of children's speech reveal they understand the difference between singular and plural nouns from around the age of two (Brown, 1973; de Villiers & de Villiers, 1973), it remains unclear whether this understanding is based on plural morphology, and thus morphological

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[2] IPA symbols are Australian English; see Harrington, Cox & Evans (1997)

structure, or if young children instead rely on some phonological heuristic to categorise nouns as plural (e.g., this word ends in /s/, so it must be plural).

Children are sensitive to the conceptual difference between plural and singular from 22 months of age (Barner, Thalwitz, Wood, Yang & Carey, 2007; Li, Ogura, Barner, Yang & Carey, 2009), and are producing plural words in their spontaneous speech from the age of two (albeit often sporadically and inconstantly; Brown, 1973; de Villiers & de Villiers, 1973; Mervis & Johnson, 1991). Articulatory studies using an elicited imitation task also show that children aged 27 months have slightly different productions of the word-final /ks/ cluster in the morphologically simple (singular) word *box* /bɑks/ compared to the morphologically complex (plural) word *rocks* /ɹɑks/, suggesting that children this age have an emerging awareness of plural morphology in this potentially ambiguous cluster (Song, Demuth, Shattuck-Hufnagel & Ménard, 2013).

However, production and perception studies demonstrate that two-year-olds do not yet have *productive* knowledge of plural. For example, Zapf & Smith (2007) showed that two-year-olds are able to inflect some novel singular nouns with the plural morpheme, and decompose some novel plurals into singulars, but performance was far from robust. Many children required weeks of practice to correctly produce a handful of items, while others were simply unable to complete the task. Furthermore, in a recent perception experiment using the intermodal preferential looking (IPL) paradigm, Davies, Xu Rattanasone & Demuth (2017) showed that 24-month-olds comprehended novel plural nouns inflected with the voiceless allomorph /-s/, as in *cats* (e.g., in words such as *tep**s*** /tɛp**s**/ and *mip**s*** /mɪp**s**/), but not novel nouns inflected with the voiced allomorph /-z/, as in *dogs* (e.g., in words such as *kib**s*** /kɪb**z**/ and *gub**s*** /gɐb**z**/). They also found that the children in this study showed no awareness that the uninflected novel nouns were singular. That two-year-olds readily produce plural words in everyday speech, yet demonstrate challenges inflecting and identify novel singular and plural words in IPL tasks suggests either that their understanding of plural morphology is still emerging, or that they might be relying on another means to categorise singular and plural nouns.

While the exact mechanisms underlying the development of morphological representations is unclear, there is some evidence that phonology plays an important role in children's ability to produce and perceive plural words. In a combined production and comprehension task, Ettlinger & Zapf (2011) showed that two-year-olds more readily produce and understand familiar plural words with simple codas than those with complex codas, e.g., *keys* /ki:**z**/ vs. *dogs* /dɔ**gz**/. They also showed that familiar plural words with word-final falling sonority were more likely to be produced and understood than familiar plural words with word-final rising sonority, e.g., *spoons* /spu:**nz**/ was less challenging than *beds* /bɛ**dz**/. While these results do not necessarily show that children understand *morphological* structure, they do show that children are highly sensitive to the *phonological* structure of plural nouns, in both production and comprehension.

By the age of three, children begin to demonstrate a better understanding of English plural. An IPL paradigm testing children's plural comprehension showed that 36-month-olds, but not 24-month-olds, were reliably able to comprehend both plural and singular forms of novel nouns (Kouider, Halberda, Wood & Carey, 2006). That is, three-year-olds identified novel words such as *blickets* and *nools* as plural, and words such as *blicket* and *nool* as singular. However, it is still unclear whether three-year-olds have an adult-like understanding of morphological structure. On one hand, three-year-olds may indeed interpret novel words such as *blickets* as *blickets = blicket+s = plural*, and singular novels word as *blicket = blicket = singular*. On the other hand, children might not be decomposing these novel words into morphemes at all, but may instead be categorizing /s/ and /z/-final words as being plural. That is, three-year-olds may be paying attention to the *phonological* properties of a word in order to determine whether it is singular or plural. Indeed, this strategy was suggested by Berko (1958). In the original *wug* study, it was found 91% of 4- to 7-year-olds were able to appropriately inflect novel words with the segmental plural allomorph /-z/ (e.g., wug /wʌg/ → wugs /wʌgz/), whereas only 36% were able to appropriately inflect novel words with the syllabic plural /-əz/ (e.g., nizz /nɪz/ → nizzes /nɪzəz/). Production difficulty was unlikely the cause of this discrepancy, as 91% of these children were able to successfully produce the known word *glasses* (though see Mealings, Cox & Demuth (2013) for evidence that this may be relevant from younger children). Rather, Berko (1958) suggested that children's inability to inflect novel words with the syllabic plural /-əz/ was due to the fact that the singular novel words in this task already ended in an /s/ or /z/, and therefore children already interpreted them as being plural. That is, she suggested that children were paying attention to *phonological*, rather than *morphological* structure.

A closer look at the Kouider et al. (2006) results suggests that 36-month-olds' performance on the fricative-final singular words *spinge*, *ratch* and *douch* was at chance, though note that none were /s/- or /z/-final. Their results also show that children's performance on the least frequent plural allomorph, the syllabic plural /əz/, was not significantly above chance (though the study was not specifically designed to test this). Note that the syllabic plural is also the latest acquired by both typically developing children and those with specific language impairment (SLI) (Tomas, Demuth, Smith-Lock & Petocz, 2015; Tomas, Demuth & Petocz, 2017). In addition to the phonological issues mentioned above, this later acquisition in production could be further influence by the fact that the syllabic -es plural also has the lowest type and token frequency of all plural allomorphs young children hear (5% of children's plural morpheme input, see Davies et al., 2017), and occurs in an unstressed syllable, making it harder to produce than in a stressed syllable, as in *bees* (cf. Kirk & Demuth (2006) for discussion) .

The present study therefore employed a similar paradigm to Kouider et al. (2006) and Davies et al. (2017) in order to test whether children possess a productive morphological understanding of the plural, or if they are rather using a phonological (/s/ or /z/-final) heuristic. That is, we wanted to know if young children parse the *morphological* structure of novel nouns to determine their number conditions, or instead focus on the word's *phonological* structure to interpret fricative-final words as plural. To test this, we examined how children interpreted fricative-final CVs or CVz words, such as *koss* /kɔs/ and *nizz* /nɪz/, and compare this with their looking behavior when presented with a word like *kosses* /kɔsəz/ or *nizzes* /nɪzəz/. In English, regular CVs and CVz nouns must be singular. For example, a word such as *bus* /bɐs/ can only be interpreted as singular: if it were plural, the uninflected singular would be the phonotactically illegal form */bɐ/. English monosyllabic words cannot end in a short (lax, monomoraic) vowel. This is due to word-minimality constraints, requiring that any open class lexical item contain at least a certain amount of phonological content (cf. Demuth, Culbertson & Alter, 2006). Furthermore, children seem to be aware of this constraint by at least 2;6 years (cf. Miles, Yuen, Cox & Demuth, 2016). Thus, novel words with short vowels and the syllable structure CVs and CVz can give us insight as to how children process plural morphological structure. If children interpret novel CVs and CVz words as singular, this suggests that they are aware of the English word minimality constraints, and use this distributional information to help inform their morphological segmentation processes. However, if children are simply paying attention to the final consonant, and interpret fricative-final words as plural, these novel CVs and CVz will be interpreted as plural.

To explore this issue, we conducted a study with two groups of children, one aged 30 months and another aged 36 months. Participants were presented with a series of pictures displayed side-by-side, paired with novel words which contained either a fricative-final CVs or CVz (singular word) (e.g., *koss*, *nizz*), or a word inflected with the syllabic plural /-əz/

(e.g., *kosses*, *nizzes*). We predicted that both the 30-month-olds and 36-month-olds would show some sensitivity to the novel plural nouns, but were unsure about how children would interpret novel CVs/z singular nouns. If children understood the constraints on morphological structure, we would expect these words to be interpreted at singular. However, if children were instead only sensitive to phonological structure, and were using a fricative-final heuristic, we might expect them to interpret these words as plural.

METHOD

Participants

Participants were twenty 30-month-olds (9 girls, 11 boys), and twenty 36-month-olds (7 girls, 13 boys), all monolingual Australian English-speaking children. None had any reported hearing, speech or cognitive impairments. Participants were recruited from a university database to which parents had voluntarily signed up.

Children in the 30-month-old group had ages ranging from 129 to 137 weeks, with a mean age of 133 weeks (2;6.3 years). Two additional girls and one boy were excluded for failing to return sufficient trials due to fussiness and/or inattention. One more girl was excluded from the analysis for returning difference scores greater than three standard deviations from the mean (see results section).

Children in the 36-month-old group had ages ranging from 154 to 163 weeks, with a mean age of 158 weeks (3;0.2 years). An additional three boys were excluded for failing to return sufficient trials (minimum 50% practice, singular and plural trials; explained below) due to fussiness and/or inattention. A further boy and girl were excluded for returning difference scores greater than three standard deviations from the mean (see results section).

Auditory Stimuli

Target words for the novel test trials were composed of 12 monosyllabic, fricative-final novel word stems. Half of the word stems were /s/-final and half were /z/-final. Each word stem was recorded as both a CVC singular word (with no inflection) and as a CVCəz word (with the syllabic plural morpheme /əz/; see Table 1). Because CVz words containing long vowels and diphthongs can be both singular (e.g., *cheese* /ʧiːz/) and plural (e.g., *bees* /biːz/), only the short vowels /æ/, /e/, /ɪ/ and /ɔ/ were used, ensuring that CVz words were phonotactically unambiguously singular.

Target words for the familiar and practice trials were familiar words. The target words in the familiar trials had a comparable phonotactic structure to the novel trials, and contained the words *rose(s)*, *horse(s)*, and *bus(es)* in both singular and plural inflected forms. Practice trials had only singular words: *dog*, *cat* and *bird*.

The stimuli were produced by a female native speaker of Australian English using child-directed speech, and were recorded in a sound-attenuated room. Each stimulus was recorded with the carrier phrase "*Look at the X*" as a complete utterance (e.g., "*Look at the koss*"). During the experiment, each child heard three singular novel words ending with /s/, three ending with /z/, and six inflected syllabic plural words ending in the /-əz/ morpheme. Audio was digitally recorded using Cool Edit Pro 2.0, and sampled at 48 kHz. Stimuli with singular novel words were 1445 ms in duration, and plural stimuli were on average 1591 ms in duration. The /-əz/ morpheme was 517 ms in duration.

Table 1: Singular and Plural Auditory Stimulus Items

Singular		Plural	
Bess	/bes/	Besses	/besəz/
Dass	/dæs/	Dasses	/dæsəz/
Dozz	/dɔz/	Dozzes	/dɔzəz/
Giss	/gɪs/	Gisses	/gɪsəz/
Gozz	/gɔz/	Gozzes	/gɔzəz/
Kazz	/kæz/	Kazzes	/kæzəz/
Koss	/kɔs/	Kosses	/kɔsəz/
Nass	/næs/	Nasses	/næsəz/
Nizz	/nɪz/	Nizzes	/nɪzəz/
Pezz	/pez/	Pezzes	/pezəz/
Poss	/pɔs/	Posses	/pɔsəz/
Tizz	/tɪz/	Tizzes	/tɪzəz/

Visual Stimuli

Visual stimuli for the novel test trials contained 16 novel cartoon animals. The animals were depicted with happy faces and closed eyes, and were designed to not resemble any real or fictional animals (see Figure 1). Each visual stimulus depicted either one animal (for singular pictures) or five identical smaller animals (for plural pictures) against an off-white background. Each complete picture measured 23.3 cm by 27.7 cm. Singular and plural animal depictions were size matched to 179.3 cm^2, or 27.8% of the surface area of each picture. Two versions of each picture were created, one in solid red and the other solid blue. Colour variation across trials was designed to make the experiment more interesting for the children. During the experiment, only pictures of the same colour were displayed side-by-side in a trial.

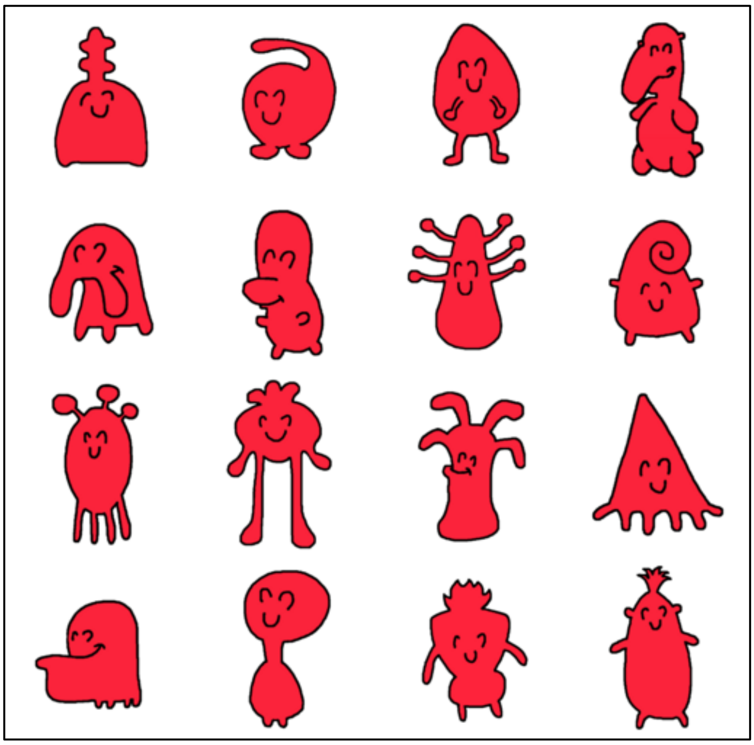

Figure 1: Items used in novel trials

Visual stimuli for familiar trials and practice trials contained drawings of 10 familiar objects, six used in the familiar trials (*bus*, *house*, *rose*, *tree*, *horse* and *bear*) and four used in the practice trials (*dog*, *cat*, *bird* and *cow*). Both singular and plural pictures were used in the familiar trials, but only singular pictures were used for the practice trials. Known pictures were displayed in realistic colours for the object (e.g., a brown horse, a yellow bus).

To ensure the child's continued interest in attending to the procedure, every picture (both novel and familiar) also had a "dancing" animation. During each trial, only the target pictures for that trial danced at the end of the trial (explained further below). The animated pictures also danced during a character parade at the beginning and the middle of each experiment.

Apparatus

A Tobii x120 Eye Tracker (Tobii Technology, Danderyd, Sweden) was used to record participant looking behaviour. The eye tracker was positioned approximately 60 cm in front of the child and tilted at a 30° angle. The eye tracker recorded gaze data from both eyes at a sample rate of 120Hz. Visual stimuli were presented on a widescreen 27" LG Flatron W2753VC monitor, positioned 15 cm behind the eye tracker.

Auditory stimuli were played through two Edifer USB M1250 computer speakers positioned either side of the monitor. Experimental media were presented through Tobii Studio (3.2.3) as .AVI files, encoded in MPEG-4 at 24 frames-per-second, and displayed at 1080 x 1920 pixels at 81.6 pixels-per-inch. Audio was 128-bit MPEG Audio at 48 kHz played at a normal speech level (≈ 65 dBA).

Procedure

Parent and child were invited into a small test room to watch a short video. Parents wore opaque glasses to prevent their gaze from being recorded, and to ensure they are blind to the task and not interfering with their child's responses. Parents were told they could encourage their children to "*watch the movie*", or "*look at the screen*" if their child started getting distracted or fussy. However, they were instructed to not repeat any of the audio stimuli, or use number-indicative pronouns such as "that" or "those". Each child was seated facing forward, on the parent's lap, approximately 75 cm in front of the monitor and 60 cm from the eye tracker.

Each participant watched 18 trials in total including three practice trials, three known trials and twelve novel trials. Each experiment began first with practice trials containing pictures of familiar animals/objects. Practice trials displayed two singular animals side-by-side (e.g., *cat* vs. *bird*), and the target was always singular. Across the four experimental versions built, practice trials were always presented in the same order with the same target picture (underlined): *dog* vs. *cow, cat* vs. *bird* and *bird* vs. *cow*.

The known trials were played throughout the experiment to maintain children's attention using familiar animals/objects and to ensure that the child is doing the task. The known trials displayed both a singular picture and a plural picture (e.g., *bear* vs. *horses*), and the target could either be singular or plural. Known trials had no set order across different experimental versions, however the target pictures *bus(es)*, *rose(s)* or *horse(s)* were always yoked to the distractor pictures *house(s)*, *tree(s)* and *bear(s)*, respectively.

Novel trials also displayed both a singular and plural picture side-by-side, one depicting a solitary novel animal (singular picture) and one depicting five identical instantiations of another novel animal (plural picture). The auditory stimulus was either singular or plural and corresponded to number condition of the target picture. While the practice and known trials provided an indication of whether children understood the task, the novel trials examined children's understanding of plural morphology.

Each practice, familiar and novel test trial was composed of five phases: (1) the pre-auditory stimulus phase, (2) the gaze-centering phase, (3) the auditory stimulus phase, (4) the post-auditory stimulus phase, and (5) the animation phase (see Figure 2).

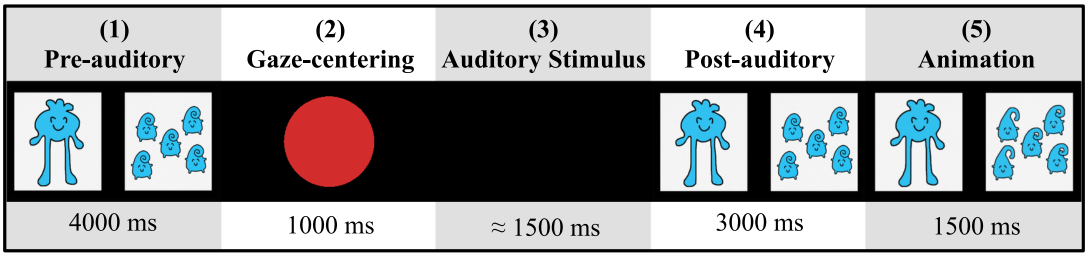

Figure 2: Novel trial test phases

During the **pre-auditory stimulus phase**, participants were shown two pictures side-by-side on the screen. After 1250 ms, one picture blinked on the screen followed by the other picture (a blink was created by having the pictures disappear briefly for 250 ms, then reappear). This sequential blinking was intended to encourage children to look at both pictures. Across the experiment, the order of blinking was counterbalanced across left versus right sides, singular versus plural picture, and target versus distractor. After blinking, both pictures then remained on the screen for another 2000 ms. They then disappeared.

Following this was the **gaze-centering phase**, where a looming red ball was presented in the middle of the screen which grew and shrank against a black background for 1000 ms to maintain the children's attention.

Next was the **auditory stimulus phase**, where a recorded voice encouraged the children to "*look at the X*". This phase ended 300 ms after the offset of the audio.

The pictures reappeared at the beginning of the **post-auditory stimulus phase**, and remained for 3000 ms. This was followed by the **animation phase,** where the target picture became animated and danced to music for 1500 ms. The dancing encouraged children to maintain their gaze towards the target picture during the post-auditory phase. Music and movement also helped to keep children interested in the task.

In addition to the trials, children also watched two character parades, one at the start of the experiment, and one during the middle (after the eighth trial) of the experiment. During the character parade at the beginning of the experiment, each animal or object from the first half of the experiment was displayed on the screen dancing to music. Each animated picture was presented alone for 3000 ms, in the same colour, number condition and side of the screen in which it appeared in the test trials. In the middle of the experiment a second parade was presented. The character parades presented each picture in a fun context, without competition for attention from another picture, and helped children maintain attention throughout the task.

Design

Four pseudo-randomized versions of the experiment were constructed to ensure there were no stimulus presentation order effects. Visual stimuli were counterbalanced for (a) whether they were presented as a plural or singular picture, and (b) whether they were presented as a target or distractor. Across the four different versions, no two novel animals (regardless of number condition) were ever displayed next to each other more than once. No novel target word (regardless of number inflection) was ever presented with any novel animal (again, regardless of number condition) more than once.

Data Analysis

Raw looking data were converted into fixations using the IVT fixation filter in Tobii Studio (3.2.3). Using the default IVT fixation filter settings, fixation points were averaged across both eyes over a three-sample window, and missing data points were interpolated for up to 60 ms. Fixations shorter than 75 ms were discarded. Areas of interest (AOIs) were defined for 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 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. Participants were excluded from the analysis if they failed to return at least two practice trials (in order to return a mean value to assess their understanding of the IPL task), and at least 50% of the singular and 50% of the plural trials.

Two dependent measures were used in this analysis: *proportion looks to target* and *difference score*. Proportion looks to target was calculated by dividing the total time spent fixating on the target picture by the sum fixation time of both the target and distractor pictures, excluding any time not spent looking at either picture. The difference score was calculated by subtracting the proportion looks to target during the **pre-auditory phrase** from the **post-auditory phase**, and multiplying by one hundred to make a percentage. The difference score indicates the amount of change in children's looking preference towards the target picture after hearing the auditory stimulus. The difference score therefore uses preference for the target item during the pre-auditory phase as a within-subjects control/baseline.

Two types of analyses were conducted. The first examined changes in proportion of looks to target (the post- minus pre-auditory stimulus difference score). This measure provides a gross indication of changes in looking behaviour across trials and evaluates whether children can identify singular and plural items. If they can, this should be indicated by a positive difference score (i.e., greater than chance). The second analysis examined changes in proportion of looks to target across time. This time course analysis was conducted over the 3000 ms post-auditory phase, and provides more fine-grained information on processing time.

RESULTS

To evaluate children's ability to perform the task, analyses were first carried out on children's difference scores from the practice and known trials. Because these trials presented children with familiar pictures and stimuli (singular vs. singular for practice trials; singular vs. plural for known trials) it was expected that they would return significantly positive scores compared to chance (positive shifts to target during post-auditory phase). With alpha set at 0.05, planned t-tests compared difference scores to chance (zero). As expected, 30-month-olds returned positive scores significantly above chance M=22.8 ($t(19) = 3.56$, $p < .01$) for practice trials and $M = 22.70$ ($t(19) = 6.78$, $p < .01$) for known trials. Similarly, 36-month-olds returned positive scores significantly above chance of $M = 22.8$ ($t(19) = 4.39$, $p < .01$) for practice trials and $M = 22.70$ ($t(19) = 6.01$, $p < .01$) for known trials.

With this providing an indication that children could perform the task, the proportion of looks to target and difference scores were then calculated for the novel trials. During the pre-auditory phase, children's proportion looks to either singular or plural pictures, across both age groups, was not significantly different to chance (30-month-olds: ($t(19) = 1.14$, $p = .27$); 36-month-olds: ($t(19) = 1.13$, $p = .27$). Figure 3 shows the proportion looks to the target for both age groups in the pre- and post-auditory stimulus phases, and individual children's looking preference shifts.

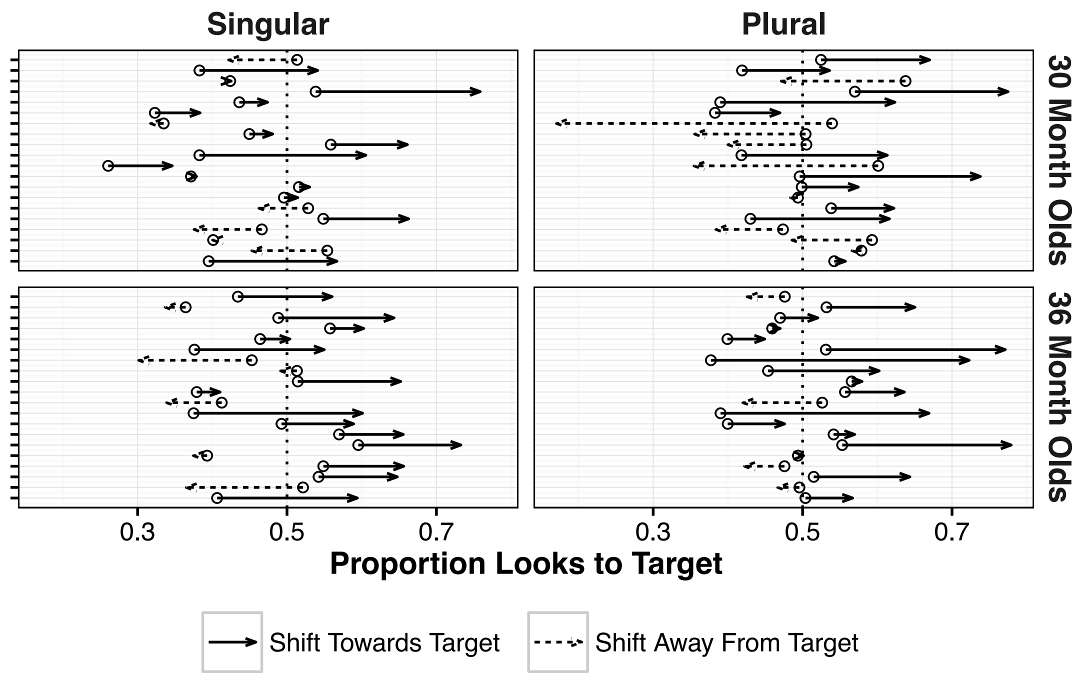

Figure 3: Changes in proportion of looks to target after auditory stimulus for each child.

Difference scores were then calculated for the novel trials. With alpha set to 0.05, planned *t*-tests then compared difference scores to chance (zero) for novel singular and plural trials. Children in the 30-month-old group returned a positive mean score of M = 4.4 for singular trials. However, for singular trials the result was ($t(19) = 2.00$, $p = .06$) with a medium effect size (Cohen's d = .44); plural trials returned a positive difference score of $M = 1.7$. However, this was not significant ($t(19) = 0.43$, $p = .67$). In contrast, children in the 36-month-old age group returned significantly positive difference scores for both singular and plural trials, with values of 6.0 ($t(19) = 2.51$, $p = .02$) and 8.1 ($t(19) = 3.08$, $p < .01$) respectively (see figure 4).

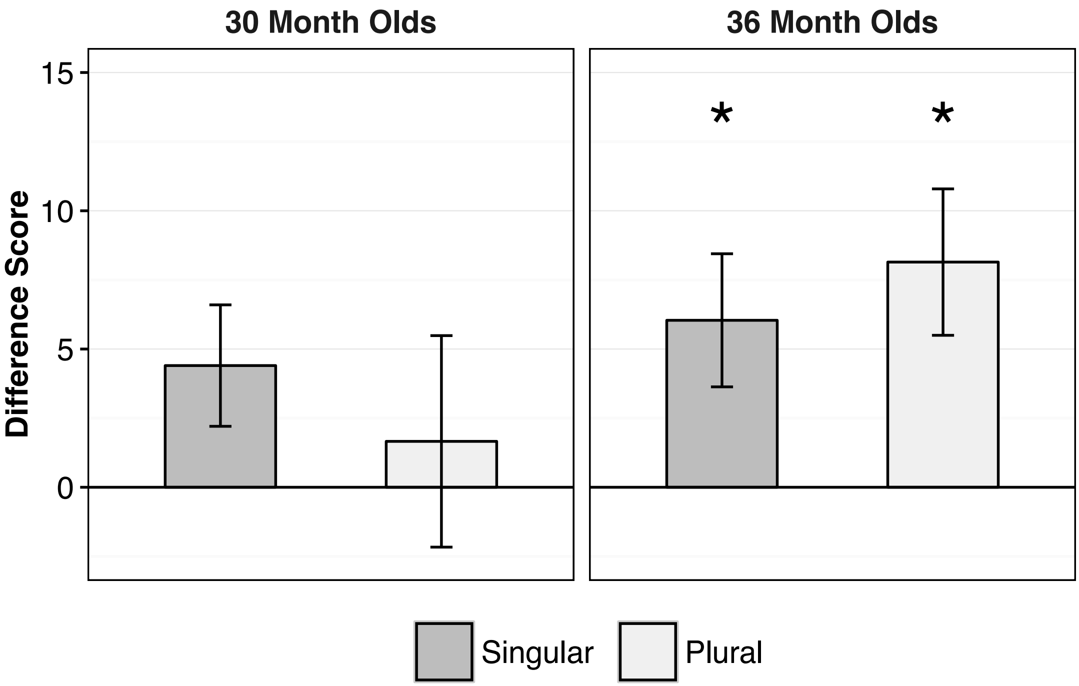

Figure 4: Difference scores for singular and plural trials. Error bars ± 1 S.E.; **p* ≤ .02

To ensure that no training effects arose from the animation phase in the novel trials, Pearson product-moment correlation coefficients were calculated for children's difference scores by trial number. No correlation was found for either the 30-month-olds (df = 197, r = -.03, p = .62) or the 36-month-olds (df = 205, r = .10, p = .16).

Cluster based permutation analyses were then carried out on children's proportion looks to target during the post-auditory phase to provide more detailed information on changes in children's looking behaviour over time. The analysis was conducted using the open-source program FieldTrip (Oostenveld, Fries, Maric & Schoffelen, 2011) in MatLab (R2014b, 8.4.0.150421). The analysis window was set to 8.3 ms (120 Hz), and at each time point a one-tailed *t*-test comparing proportion of looks to target to chance (zero). With alpha set at 0.05, adjacent significant time points were grouped together into a cluster. Proportion looks to target were transformed via an arcsin square function to better fit *t*-test assumptions (see Dautriche, Swingley & Christophe, 2015). For each test across age group and number condition, 1000 randomized simulations were conducted.

For the 30-month-olds, no significant time window was found for the singular trials. However, a significant cluster was found for the novel plural trials in the time window 2350 – 3000 ms (p = .02); within this window, proportion of looks to target plural items were significantly above chance. This shows that 30-month-olds systematically fixated more upon the target picture from 2350 ms after the onset until the end of the post-auditory phase. For the 36-month-olds, a significant cluster was found for the singular novel trials in the time window between 917 – 1350 ms (p = .02), and a significant cluster was found for the plural novel trials in the time window between 2125 – 3000 ms (p < .01). This shows that, while 36-month-olds systematically fixated more upon both singular and plural targets compared to chance, they were much faster to fixate upon singular targets (figure 5).

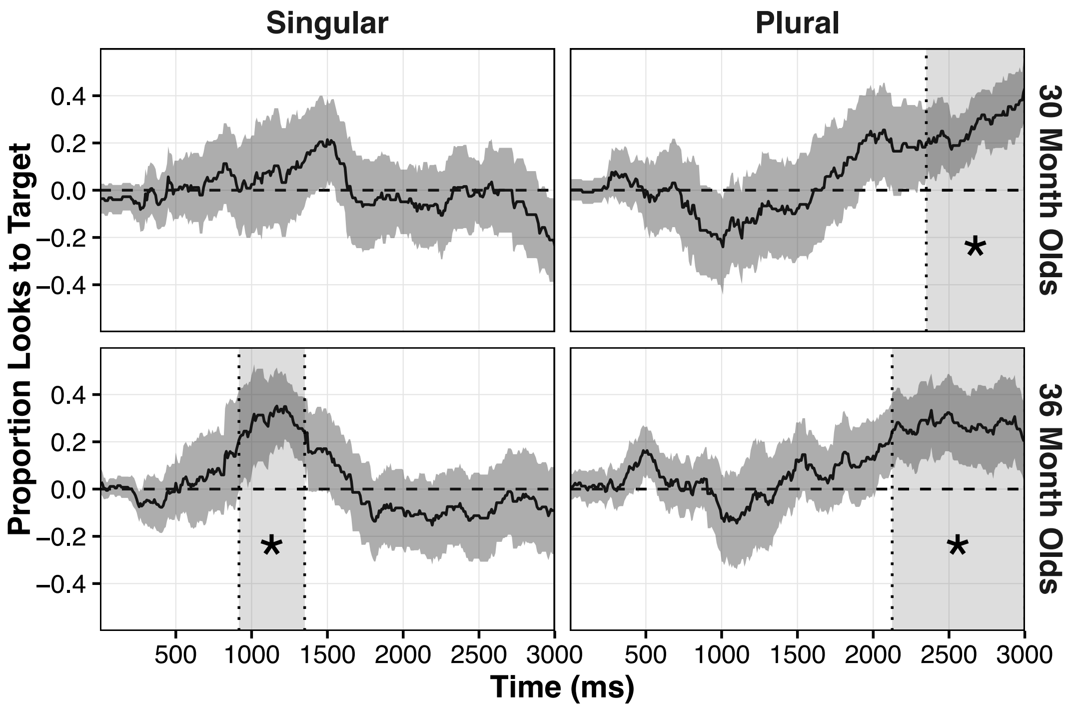

Figure 5: Proportion of looks to target during post auditory stimulus phase. Shaded area ± 95% C.I.; *$p \leq .02$

DISCUSSION

The goal of this study was to determine if and when young children develop an understanding of how sounds (in this case fricatives) map to singular and plural meanings. An intermodal preferential looking experiment was carried out to determine whether 30- and 36-month-olds would demonstrate an understanding of morphological structure by interpreting novel CVs/z words as singular and CVCəz as plural, or whether instead they would use a fricative-final plural strategy in which they would interpret both novel word types as being plural.

Children aged 30 months did not significantly shift their looking preference towards the singular target picture after hearing a fricative-final novel singular word, and did not significantly shift their looking preference towards the target plural picture after hearing a novel word inflected with plural /əz/. This suggests that children at this age may be confused about the number condition of fricative-final singular words; while the difference score was trending towards significance, this appears to be driven by four participants with large difference scores. Time course analysis revealed that at no point during the critical window did children turn their attention significantly towards the singular picture. As a group, there was thus no convincing evidence that 30-month-olds interpret fricative-final words as singular. The difference scores also suggested that children at this age have not yet acquired an understanding of the syllabic plural morpheme /əz/, however the *time course analysis* showed that, after the reappearance of the novel pictures during the test phase, the 30-month-olds began to fixate on the target picture in the plural /-əz/ trials after around 2350 ms, and continued to do so till the end of the 3000 ms trial. This suggests that 30-month-olds may have an *emerging sensitivity to plural /əz/, but that the online processing of this information may be slow*. It is possible that if the 3000 ms post-auditory stimulus phase of this experiment had been longer, a significantly positive difference score might have been found. Alternatively, this looking behavior could simply be due to children's attraction towards the plural picture. However, if this were the case, we might have expected more consistent looks towards the plural picture in the singular condition as well.

Children aged 36 months, on the other hand, significantly shifted their looking preference towards both the singular target picture after hearing a fricative-final novel word, and towards the plural target picture following novel words ending in /əz/. This provides robust evidence that 36-month-olds do not rely on a fricative-final plural strategy, but rather possess an understanding of morphological structure, and a mental representation of the syllabic plural allomorph /əz/. This finding is consistent with that of Kouider et al. (2007) for 36-month-olds, showing sensitivity to more varied plural morphemes, and to less ambiguous singular forms (i.e., not ending in a sibilant).

Time course analysis for the 36-month-olds in the present study also revealed that children of this age were faster to fixate upon the target picture in singular trials compared to plural trials. After the reappearance of the pictures (during the post-auditory phase, which took place 300 ms after the offset of a fricative-final singular novel word), children took roughly 900 ms to fixate upon the target picture in singular trials. In contrast, time course analysis showed that it took the same children more than twice as long (2100 ms) to fixate upon the plural target picture (which appeared 300 ms after the offset of the plural allomorph /əz/, at the end of the second syllable of the novel word). This difference in time taken to fixate on singular vs. plural targets could reflect the extra processing required to interpret the morphologically complex plural word in comparison to the monomorphemic singular word. This could be further evidence that children are indeed analyzing morphologically complex words, and identifying their constituent morphemes, but that this involves more processing time. Note also that the 36-month-olds fixated upon plural target pictures about 250 ms faster than the 30-month-olds, suggesting a gradually developing sensitivity to these low frequency plural allomorphs.

Children's fixation times for plural novel words appears to be very slow, especially in comparison to other research employing children's looking-measures. For example, in a study looking at the lexical representations of much younger children aged 14 to 21 months, Swingley and Aslin (2000) found it took children only around 367 ms to process mispronunciations of familiar words. While there are of course many differences between that study and the present study (such as the use of known words rather than novel words, and the fact that the Swingley and Aslin study examined children's sensitivity to segmental changes rather than morphological changes), the differences in fixation time may reflect different cognitive processes involved in phonological/lexical vs. morphological processing.

The results of the present study also show that young children do not construe fricative-final words as being plural; neither the 30-month-olds nor the 36-month-olds gave any indication of interpreting the singular novel words as referring to the plural picture, even though these ended in /s/ or /z/. Some have argued that 'singular' is actually semantically more difficult than the 'plural' (Sauerland, Anderssen, & Yatsushiro, 2005). In IPL studies, Davies et al. (2017) and Kouider et al. (2006) both showed that 24-month-olds are not yet sensitive to CVC stop-final singular words, and Arias-Trejo et al. (2014) showed that Mexican Spanish-speaking 24-month-olds also fail to comprehend singular novel words (note that noun endings mark gender in Spanish, which may have some effect on the course of acquisition of nominal morphology). Yet children in all these studies showed sensitivity to (at least some forms of) the plural. In English, nouns are typically inflected for plural number, yet this is a language-specific phenomenon that children must learn: Bantu languages mark both singular and plural, and Mandarin marks neither. Perhaps 30-month-olds have an emerging semantic understanding of the singular as they learn the various allomorphic representations of plural. This would be interesting to explore cross-linguistically, in morphologically rich languages.

In sum, the present study shows that English-speaking children may have an emerging understanding of plural morphological structure at 30 months, and that this becomes much more robust by the age of three, even for the least frequent form of the plural morpheme, the syllabic /əz/. This raises many questions, then, about why this morpheme is so late acquired in both perception and production, in both typically developing and language delayed populations (cf. Tomas et al., 2017). The findings presented here also raise many questions regarding how and when an awareness of morphology develops in other languages (e.g., Russian: Tomas, de Vijver, Petocz & Demuth, 2017), and other populations, such as bilinguals or those with hearing loss, who can find particular sounds/morphemes hard to perceive.

ACKNOWLEDGEMENTS

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CHAPTER 4: PRE-SCHOOLERS' EMERGING UNDERSTANDING OF NUMBER AND AGREEMENT

This chapter comprises the following paper in preparation:

Davies, B., Xu Rattanasone, N. & Demuth, K. (in prep). Pre-schoolers emerging understanding of number and agreement.

All components of this paper, both experimental and written, have been completed by me, with advice from the co-authors (my supervisors) when needed.

ABSTRACT

Children acquiring English are reported to use singular and plural nouns (*cat*/*cats*) and verbs (*is*/*are*) in their speech from before the age of three (Brown, 1973). Yet, while studies using indirect measures (e.g., eye-tracking) suggest children understand the concepts of morphological structure and subject-verb agreement, tasks eliciting direct responses show mixed results, raising questions about pre-schoolers' productive knowledge of singular/plural. The present study therefore employed a forced choice task to examine 3- and 4-year-olds' (N=116) comprehension of novel singular and plural words. Children demonstrated understanding of morphological structure for nouns, but ignored subject-verb agreement information altogether. Their proficiency with plural nouns increased with age, yet singulars did not. The theoretical and practical implications for sentence processing are discussed.

INTRODUCTION

Acquiring a first language is no simple task. Infants are exposed to a continuous stream of acoustic input from which they must gradually extract meaningful units, such as words and morphemes. Despite the complexity of this task, children are prodigious word-learners. Halfway through their second year of life, some are producing upwards of nine new words a day (Nelson, 1973; Goldfield & Reznick, 1990). Yet while children excel at acquiring words from a young age, they struggle with the discrete meaningful units of language that are smaller than words: *grammatical morphemes*. The English plural, for example, is a grammatical morpheme often consisting of a single segment, such as the voiceless fricative /-s/ on the end of a noun like *wombats* /ˈwɔmbætsͅ/[3]. It is crucial that children develop an understanding of what it means when the plural morpheme is attached to the end of a word, but also what it means when the plural morpheme is absent, (i.e., *wombat*). Even though children begin to reliably produce *plural words* somewhere between their second and third birthdays (Brown, 1973; de Villiers & de Villiers, 1973, Mervis & Johnson, 1991), some may still be omitting the *plural morpheme* on newly-learnt words at the age of seven (Berko, 1958; Graves & Kozoil, 1971). This raises questions about the nature of children's early representations of both singular and plural, and about how and when children acquire a productive understanding of plural morphology.

Acquiring language involves mapping meaning to an associated linguistic form. One of the challenges for learning grammatical morphemes is that they often have more than one surface form (allomorphs). This is potentially problematic, as children acquiring languages such as English have been shown to have a reluctance to mapping one meaning to more than one linguistic form (*mutual exclusivity bias*; see Merriman, Bowman & MacWhinney, 1989).

[3] IPA transcriptions are for Australian English (see Harrington, Cox and Evans, 1997)

The English plural is a good example of a grammatical morpheme with three *allomorphic variants*: the syllabic plural allomorph /-əz/, and the two segmental plural allomorphs /-s/ and /-z/. There are three mutually exclusive phonological contexts in which these plural allomorphs arise. The syllabic plural allomorph /-əz/ attaches onto sibilant-final nouns (i.e., /s, z, ʃ, ʒ, t͡ʃ, d͡ʒ/), such as in *buses* /ˈbɐs<u>əz</u>/, *roses* /ˈɹəʉz<u>əz</u>/ and *churches* /ˈt͡ʃɜːt͡ʃ<u>əz</u>/. The voiceless segmental allomorph /-s/ attaches onto nouns which end with a voiceless consonant (i.e., /p, t, k, f/), such as in *caps* /k^{h}æp<u>s</u>/, *wombats* /ˈwɔmbæt<u>s</u>/ and *socks* /sɔk<u>s</u>/. The voiced segmental allomorph /-z/ attaches onto vowels or any other voiced segment, such as in *zoos* /zuː<u>z</u>/, *dogs* /dɔg<u>z</u>/ and *penguins* /ˈp^{h}eŋgwɪn<u>z</u>/. In order to fully acquire and use the plural morpheme, children need to first gain an understanding of phonological processes underlying plural allomorphic variation, which requires a sensitivity to the phonological context at the end of the noun. For example, adult speakers of English know that, due to allomorphic variation, the plural form of *eye* /ɑe/ is not *ice* /ɑe<u>s</u>/, but *eyes* /ɑe<u>z</u>/, and the plural form of *pea* /piː/ is not *peace* /piː<u>s</u>/, but *peas* /piː<u>z</u>/.

Allomorphic variation affects the course of children's plural morpheme development. In children's spontaneous speech, the syllabic plural /-əz/ is mastered later than its segmental counterparts, /-s/ and /-z/ (Brown, 1973). Even 4- to 7-year-olds have difficulty inflecting both real nouns (e.g., *bush* /bʊʃ/ → *bushes* /ˈbʊʃ<u>əz</u>/) and novel nouns (e.g., *tizz* /tɪz/ → *tizzes* /ˈtɪzəz/) with the syllabic plural /-əz/ (Berko, 1958; Graves & Kozoil, 1971; Matthews & Theakston, 2006). Children with specific language impairment (SLI) also demonstrate difficulty producing /-əz/ (Tomas, Demuth, Smith-Lock & Petocz, 2015; Tomas, Demuth & Petocz, 2017). In an Intermodal Preferential Looking task (IPL; see Golinkoff, Hirsh-Pasek, Cauley & Gordon, 1987), 36-month-olds understood the syllabic plural /-əz/ on novel nouns, whereas younger children at 30 months did not (Davies, Xu Rattanasone & Demuth, in prep).

There are also differences in the order of which plural allomorphs are comprehended. At 24 months of age, children understand the voiceless segmental allomorph /-s/, but not the voiced segmental allomorph /-z/ (Davies, Xu Rattanasone & Demuth, 2017). IPL findings suggest that earlier perceptual sensitivity to plural /-s/ is due to its longer duration compared to plural /-z/, and hence its greater perceptual salience (Davies et al., 2017). However, despite the fact that /-əz/ is the most acoustically salient of the plural allomorphs, it is also the least frequent in children's input by a large margin (≈ 6% by type and token; Davies et al., 2017), helping to explain why it is the last acquired form in both perception and production. However, all forms of the plural are comprehended by 3 years, as evidenced by data from IPL tasks. It might therefore be predicted that allomorphic variation will not affect comprehension in older children.

What may be potentially more challenging is acquiring a morpheme with no surface form at all. This is the case with the English singular. While some languages explicitly mark both singular and plural nouns with a grammatical morpheme (e.g., Bantu languages like Sesotho: mo-sadi = *woman*, ba-sadi = *women*; Demuth, 1992; Demuth & Weschler, 2012), the singular in English is typically marked by the absence of the plural morpheme (e.g., *cat_* = singular, *cat+s* = plural). Yet this is merely an arbitrary fact about English. In languages such as Bayso, for example, the absence of a plural morpheme simply means that number is not specified (e.g., lúban = *one or more lions*, lubán-jaa = *a few lions*; Corbett, 2000). However, acquisition of the morphologically unmarked singular has been somewhat overlooked in the literature, as it is difficult to gauge children's understanding of the singular from looking at their speech. In a novel word production task, children aged 17–28 months showed no difference when producing singular vs. plural forms of novel nouns (Zapf & Smith, 2007). However, many of the children's errors in such tasks are errors of omission (Brown, 1973; de Villiers & de Villiers 1973; Mervis & Johnson, 1991; Matthews, Theakson & MacWhinney, 2006). It is therefore difficult to assess errors for the English singular in production tasks, as there is no morpheme to omit.

Studies of children's language comprehension, on the other hand, suggest that children may need to gain an understanding of the plural before acquiring an understanding of singular. Novel-word IPL tasks show English-speaking children understand both the plural morpheme (across its three allomorphs) and the singular at 36 months of age (Kouider, Halberda, Wood & Carey, 2006; Davies et al., in prep). However, while 24-month-olds demonstrate an understanding of the plural allomorph /-s/, they do not yet show comprehension of the singular (Davies, et al., 2017). A similar pattern has been found in Mexican Spanish, where singular nouns are marked through the absence of the plural morpheme (e.g., Spanish: gato_ = *cat*, gatos = *cats*). Thus, like their English-speaking counterparts, Mexican Spanish-speaking 24-month-olds demonstrate an understanding of the plural morpheme, but no understanding of the singular (Arias-Trejo, Cantrell, Smith & Canto, 2014). In her classic *wug* study, Berko (1958) suggested that children's difficulty in inflecting novel words with the syllabic plural allomorph /-əz/ could be due to their inability to identify fricative-final novel words (e.g., *nizz*) as being singular. Although recent IPL research has shown that 36-month-olds *are* able to interpret fricative final words as singular (Davies et al., in prep), it is not known how this compares to other singular forms. In the current study, therefore, children were tested on their comprehension of novel plural words with all three allomorphs, but also on novel singular words with both stop-final (e.g., *dup*) and fricative-final (e.g., *koss*) consonants.

Children's comprehension of singular and plural nouns might also be aided by other words in the sentence. English verbs, for example, agree in number with the subject noun (e.g., *the wombat is/was happy*, *the wombats are/were happy*), and English determiners often agree with the number of their head noun (e.g., *a/that/this wombat*, *some/those/these wombats*). For some irregular nouns in English, agreement is the only way to determine number (e.g., *look at that/those sheep*, *the fish is/are happy*). Agreement may therefore help children to acquire grammatical morphemes. While children do appear to be sensitive to English subject-verb agreement violations before the age of two (16 months: Soderstrom, White, Conwell & Morgan, 2007; 22 months: Sundara, Demuth & Kuhl, 2011), it is not clear whether children at this age understand subject-verb agreement in terms of actual meaning, or are simply sensitive to patterns in their speech input. However, results from IPL and manual search tasks show that 24-month-olds are better at identifying novel noun number when verbal and determiner agreement are used (e.g., *there are some blickets* vs. *look at the blickets*; Kouider at al., 2006; Wood, Kouider & Carey, 2009), and 30-month-olds are able to use plural copula subject-verb agreement (*are*) to facilitate comprehension of plural subject nouns (Lukyanenko & Fisher, 2016). Furthermore, 3-year-olds can use *is*/*are* number information to identify target pictures before they are explicitly named (Deevy, Leonard & Marchman, 2017). However, using a looking task with children aged 28–46 month, Legendre et al. (2014) failed to show understanding of subject-verb agreement. Note, however, that Legendre et al. (2014) tested children's comprehension of 3rd person singular (3SG), while Kouider at al., (2006), Wood, Kouider & Carey, (2009), Lukyanenko & Fisher, (2016) and Deevy, Leonard & Marchman, (2017) all tested the copula. While children are sensitive to 3SG from an early age (Soderstrom, et al., 2007; Sundara, Demuth & Kuhl, 2011), they may not understand its meaning until much later. Indeed, 3SG is acquired in children's spontaneous speech much later than the copula. This could be due to the fact that not only is the copula highly frequent in children's input, but it also changes its surface form entirely to agree with its subject noun (e.g., *is*, *are*, *was*, *were*). The current study therefore tested children's comprehension of novel-noun number using copula subject-verb agreement. Specifically, we tested whether children would have a comprehension advantage when both copula subject-verb agreement (i.e., *is* and *are*) and plural morphology were present in a sentence, as opposed to sentences with just nominal plural morphology or just copula subject-verb agreement.

Previous IPL studies have shown that an understanding of both the singular and plural emerges by 36 months of age (Kouider, et al., 2006; Davies et al., in prep). However, these studies measured children's understanding indirectly by analysing looking behaviour. It was therefore not known whether children would perform similarly if they were required to make an explicit decision, such as in a forced choice comprehension task. The current study therefore elicited explicit decisions from each participant through a forced choice task.

Likewise, previous studies of children's acquisition of 3SG have obtained different results from indirect and explicit behavioural measures. For example, a Head-Turn-Preference study demonstrated sensitivity to the presence or absence of 3SG from 16 months (Soderstrom, et at., 2007), yet children as old as six years struggled to apply this sensitivity in a pointing task (de Villiers & Johnson, 2007; Johnson, de Villiers & Seymour, 2005). In other words, indirect behaviour suggests an early understanding of 3SG, while explicit response suggests comprehension occurs much later. Naigles (2002) and Soderstrom (2008) argue that these differences are not due to the use of different methods, but rather that direct tasks are more challenging because they require children to integrate abstract forms with concrete meanings. In a similar way, 14-month-olds, who show sensitivity to phonemic contrasts (Werker & Tees, 1984; Kuhl, 2004), exhibit challenges in applying this knowledge in the context of more complex picture referents in a word-learning task (Stager & Werker, 1997).

The current study therefore tested 3- and 4-year-olds' knowledge of plural marking using a forced choice novel-word comprehension task that was based on the experimental design used by Kouider et al., (2006) and Davies et al., (2017; in prep). The task was presented on an iPad at the children's preschools (Xu Rattanasone, Davies, Schembri, Andronos & Demuth, 2017). Like the previous plural IPL studies, the present study employed novel words, with all nouns occurring utterance-finally. Importantly, however, it also required children to make an explicit choice of which referent matched the auditory stimulus they heard. For each trial, children were presented with two pictures side by side. One picture depicted a single novel animal (or object), and the other depicted five identical instantiations of a different animal (or object). All items were controlled for animacy across the pictures displayed. Children were given auditory instructions which included the stimulus word, for example, *touch the dup* (for singular trials) or *touch the teps* (for plural trials). The use of novel words and novel pictures ensured that children were being tested on their understanding of *plural morphology* and not their understanding of already learnt plural words.

RESEARCH QUESTIONS AND HYPOTHESES

Research Question One: *Does allomorphic variation affect children's comprehension of singular and plural novel nouns?*

Because comprehension of the plural requires realising when a noun contains a plural morpheme, and comprehension of the singular requires realising when that plural morpheme is absent, it is crucial for children to have a good understanding of allomorphy and the word-final phonological contexts in which these allomorphs occur. Children were therefore tested on their understanding of the segmental plural allomorphs /-s/ and /-z/ and of the syllabic plural allomorph /-əz/. Children were also tested on their understanding of the singular word-forms to which those allomorphs attach. Three hypotheses were tested:

- **Hypothesis One (H1):** By 36 months of age, children demonstrate an understanding of all three plural allomorphs in IPL tasks (Kouider et al., 2006; Davies et al., in prep). We therefore predicted that three- and four-year-olds would be able to successfully identify novel words inflected with all three allomorphs in an explicit forced choice task.

- **Hypothesis Two (H2):** Children are better able to inflect stop-final words (e.g., *wug*) than fricative-final words (e.g., *nizz*) for plural. Berko (1958) argued that this may be due to children misconstruing fricative-final words as being already inflected for plural. However, this would mean that young children apply some sort of heuristic to identify plurals (e.g., *wombats* ends with a fricative = plural). However, since results from IPL tasks suggest that children do interpret words like *nizz* and *koss* as singular by 36 months of age, we predicted they would be equally good at comprehending fricative-final and stop-final singular words.
- **Hypothesis Three (H3):** At 24 and 30 months, infants do not appear to be sensitive to the singular, possibly due to the overt vs. null marking. However, sensitivity to both singular and plural is in place by 36 months (Kouider et al., 2006; Davies et al., in prep). We therefore predicted good performance on both, but possibly greater accuracy for novel plural nouns over novel singular nouns in a forced choice task.

Research Question Two: *Do children use copula subject-verb agreement information in comprehension of plural morphology?*

Verbal morphology provides additional cues as to the number of the subject noun through subject-verb agreement. Because the copula (*is*, *are*, etc.) is acquired early in children's speech (Brown, 1973; de Villiers & de Villiers, 1973) we tested children's comprehension of copula subject-verb agreement in a forced choice task. Children were tested on their comprehension of (1) sentences containing both copula subject-verb agreement and nominal morphology (e.g., *where is the tup*? / *where are the tups*?); (2) sentences with nominal plural morphology only (e.g., *find the dup!* / *find the dups!*); and (3) sentences where copula subject-verb agreement was the only reliable cue for number (e.g., *where is the dax*? / *where are the dacks*?). In condition (3), the novel nouns were all /ks/-final, which is an ambiguous from in English, as it is common in both singular words (e.g., *box*, *fox*) and plural words (e.g., *clocks*, *socks*). Two hypotheses were tested:

- **Hypothesis Four (H4):** Given that 3-year-olds can use *is*/*are* number information to identify target pictures before they are explicitly named (Deevy, Leonard & Marchman, 2017), we predicted that the children in our study would be more accurate in trials with copula subject-verb agreement than in trials without.
- **Hypothesis Five (H5):** Given H4, we also predicted that children would use the copula to help resolve number ambiguity in novel words ending in /ks/ clusters (e.g., *dax*), which can either be singular (e.g., *box*, *fox*) or plural (e.g., *socks*, *clocks*)

METHOD

Participants

Participants included 58 3-year-olds (35 girls, 23 boys; range = 36–37 months; mean = 41.6 months) and 58 4-year-olds (29 girls, 29 boys; range = 48–59 months, mean = 53.3 months). They were recruited from 26 preschools across greater Sydney, New South Wales, Australia. Permission forms and language history questionnaires were filled out by parents before testing. The language history questionnaire requested information on children's language exposure, their postcode (to estimate socioeconomic status), maternal education, as well as information on any hearing impairments and/or developmental disorders.

All participants were considered English monolinguals, and had fewer than 10 hours' exposure to other language(s) per week, if any. Those languages included: Afrikaans, Armenian, Bengali, Cantonese, Dutch, French, German, Gujarati, Hebrew, Italian, Japanese, Malay, Malayalam, Mandarin, Polish, Portuguese, Russian, Spanish, Tagalog, Tongan and Turkish.

Each participant's family socioeconomic status was approximated using the Socio-Economic Index for Areas (SEIFA) Index of Relative Advantage/Disadvantage (ABS, 2013). The SEIFA Index of Relative Advantage/Disadvantage provides a measure of the average socio-economic characteristics of households within a given postcode, with a possible range of 500 to 1300, a mean of 1000, and a distribution in which roughly two-thirds of the scores lie between 900 and 1100. Participants in the current study had a mean score of 1088.44, (range = 1002–1164), putting them, on average, in the 82nd percentile for the state (median = 84, range = 53–100). The highest maternal educational level attainment reported for participants were postgraduate degree (32.8%), university degree (47.4%), trade college certification (14.6%) and high school certificate (5.2%).

All of the children included in the present analysis passed the PLS-5 Language Screener (Zimmerman, Steiner & Pond, 2011). Four 3-year-olds and three 4-year-olds did report speech difficulties, including a lisp, a slight stutter, a cleft palate requiring speech therapy, or other minor speech production issues. Also included was one 4-year-old was diagnosed with "mild autism" a few weeks after participating. No participants had any reported hearing loss (note there is mandatory new-born hearing screening in Australia), however, 17 3-year-olds and 20 4-year-olds did report having had ear infections in the past.

A total of seven additional 3-year-olds were excluded from the analysis, including three who failed the PLS-5 Language Screener and 4 who did not complete all the test trials. A total of four additional 4-year-olds were also excluded from the analysis, including two who failed the PLS-5 Language Screener, and two who failed to complete all test trials.

Equipment

The experiment was run on an Apple iPad Air 2 (240 × 169.5 mm, with a 2048 × 1536 resolution at 264 dpi). Children listened to the auditory stimuli through Sennheiser HD 280 pro headphones. The software was built with the Serenity Engine, a multiplatform engine written in C using the OpenGL library (Budziszewski, 2003; see Xu Rattanasone et al., 2016).

Auditory Stimuli and Preparation

The auditory stimuli were digitally recorded using Cool Edit Pro 2.0 (at 48 kHz) in a sound-attenuated room over a single session. They were produced in a child-friendly register by a female native speaker of Australian English experienced in working with children. The complete stimulus set contained 72 novel words, which were half singular and half plural (see Table 1). All novel words had early-acquired onset stops (i.e., /p/, /b/, /t/, /d/, /k/, /g/, /m/ and /n/; see Smit et al., 1990), and Australian-English short vowels (i.e., /ɪ/, /e/, /æ/, /ɐ/ and /ɔ/; Harrington, Cox & Evans, 1997). The complete set of novel words is presented in Table 1.

Table 1: Singular and plural novel auditory stimuli used in test trials

	Segmental Allomorph Trials		**Syllabic Allomorph Trials**		**Copula Trials**		
	singular	***plural***	***singular***	***plural***	***singular***	***plural***	
voiceless	*dup* /dɐp/	*dups* /dɐps/	*koss* /kɔs/	*kosses* /kɔsəz/	*dax* /dæks/	*dacks* /dæks/	***ambiguous***
	bip /bɪp/	*bips* /bɪps/	*nass* /næs/	*nasses* /næsəz/	*gex* /geks/	*gecks* /geks/	
	tep /tep/	*teps* /teps/	*poss* /pɔs/	*posses* /pɔsəz/	*gox* /gɔks/	*gocks* /gɔks/	
	mup /mɐp/	*mups* /mɐps/	*dass* /dæs/	*dasses* /dæsəz/	*bix* /bɪks/	*bicks* /bɪks/	
	noop /nʊp/	*noops* /nʊps/	*bess* /bes/	*besses* /besəz/	*nux* /nɐks/	*nucks* /nɐks/	
	gop /gɔp/	*gops* /gɔps/	*giss* /gɪs/	*gisses* /gɪsəz/	*poox* /pʊks/	*pooks* /pʊks/	
voiced	*pab* /pæb/	*pabs* /pæbz/	*niz* /nɪz/	*nizzes* /nɪzəz/	*tup* /tɐp/	*tups* /tɐps/	***unambiguous***
	tib /tɪb/	*tibs* /tɪbz/	*kez* /kez/	*kezzes* /kezəz/	*doop* /dʊp/	*doops* /dʊps/	
	geb /geb/	*gebs* /gebz/	*moz* /mɔz/	*mozzes* /mɔzəz/	*gip* /gɪp/	*gips* /gɪps/	
	mub /mɐb/	*mubs* /mɐbz/	*tiz* /tɪz/	*tizzes* /tɪzəz/	*mep* /mep/	*meps* /meps/	
	koob /kʊb/	*koobs* /kʊbz/	*doz* /dɔz/	*dozzes* /dɔzəz/	*dap* /dæp/	*daps* /dæps/	
	tob /tɔb/	*tobs* /tɔbz/	*paz* /pæz/	*pazzes* /pæzəz/	*nop* /nɔp/	*nops* /nɔps/	

There were also 18 familiar words, nine singular and nine plural. The familiar words were included to keep children engaged and provided a measure of attentiveness. The complete set of familiar words included eight with and without segmental plural allomorphy (*bat/bats*, *crab/crabs, mop/mops, pig/pigs*) and six with and without syllabic plural allomorphy (*bus/buses, horse/horses*, *rose/roses*). Just as with the novel words, each participant was either presented with the singular or the plural form of a given word, but not both. The familiar words used in the copula trials, however, were always presented as either singular (*box* and *fox*) or plural (*clocks* and *ducks*). Additionally, there were five words recorded for the training trials (three familiar, two novel), all of which were singular (*dog, bird, cat, nug,* and *mib*).

Auditory stimuli were presented to participants within a carrier phrase. The copula trials had the carrier phrases *where is the X?* (for singular) and *where are the X?* (for plural); all other trials had the carrier phrase *touch the X!*, regardless of number.

While all of the auditory stimuli were initially recorded as entire phrases, the final stimuli were all spliced in order to control for any phonetic variation (using Praat; Boersma & Weenink, 2016). Spliced stimuli were composed of three parts:

	Carrier phrase	+	**Target word**	+	**Coda release**	
e.g.,	*touch*	+	*the dup*	+	/ps/	(plural)
e.g.,	*where is*	+	*the tep*	+	/p/	(singular)

One version of each carrier phrase was spliced into the final stimuli set. The spliced target word consisted of the determiner (*the*) and the CVC word (novel or familiar), with the coda burst release removed. With the exception of the syllabic allomorph trials, the same recorded version of any given target word was spliced into both singular and plural conditions (e.g., *mop*/*mops*; *dup*/*dups*). Due to the different vowel and frication durations of monosyllabic singular and disyllabic plural words (e.g., *koss* vs. *kosses*), target word splicing controls across singular and plural trials could not be done for syllabic plural trials. One version of each coda burst (/p/, /b/, /ps/, /bz/ and /ks/) was spliced into the appropriate target words. Similarly, one version of the syllabic plural allomorph /-əz/ was spliced onto all syllabic plural targets.

Visual Stimuli

The visual stimuli were 24 novel inanimate objects and 48 novel cartoon animals, all depicted with closed eyes and happy faces. They did not resemble any real or any fictional characters. For familiar word trials, 22 real objects/animals were depicted. These were *bat, bear, box, bug, bus, cake, clock, cow, crab, duck, frog, fox, hat, horse, house, mop, pig, rat, rose, shirt, snake and tree.* Visual stimuli were constructed as both single object/animal (singular) pictures and five object/animal (plural) pictures, with animacy controlled within each condition and across conditions. For the training trials, only singular animals were used. Figure 1 shows examples of familiar/novel, animal/object trials.

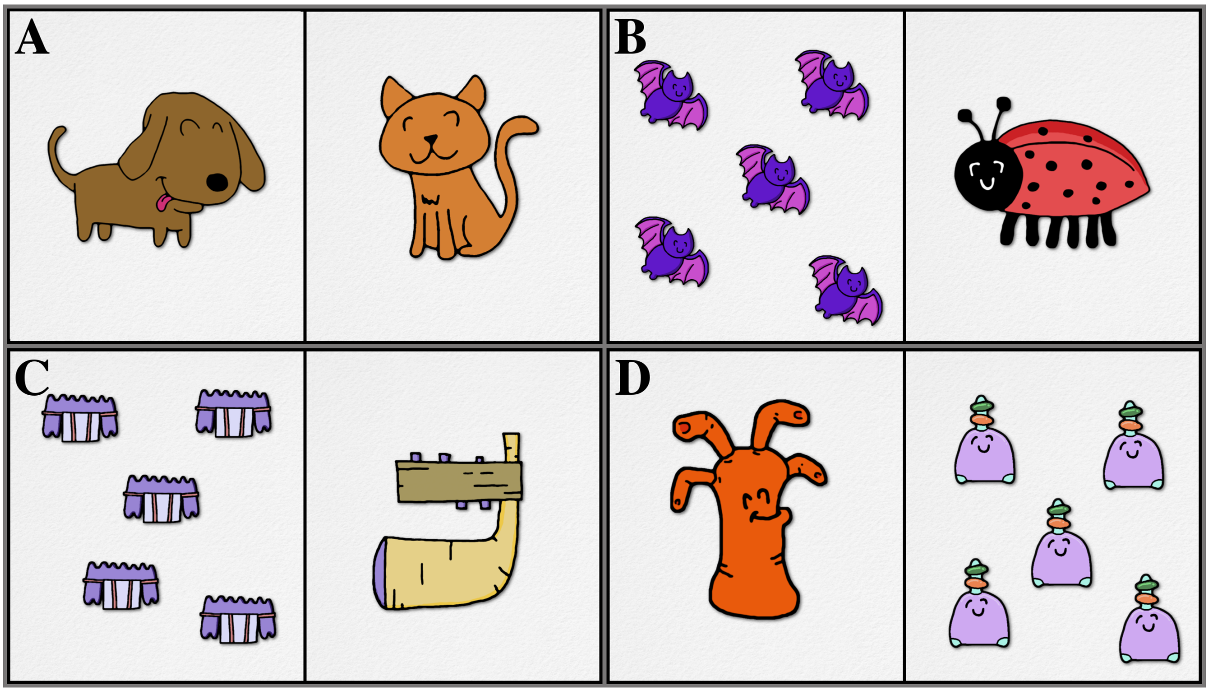

Figure 1: Examples of visual stimuli during trials: (A) training trial, (B) familiar animal test trial, (C) novel object test trial, (D) novel animal test trial

Procedure

Children were tested in a quiet area of their preschool. They wore headphones, which helped minimize noisy distractions. The headphones also prevented the experimenters from hearing the stimuli so they were blind to the condition being presented. The experiment was conducted on an Apple iPad Air 2. To ensure the relevant plural morphemes could be heard, children were first played /s/ and /əz/ spliced from the stimuli. When the experimenter determined that children could hear both segments, the experiment proceeded (volume was adjusted if needed).

Children were first provided with training trials. These initial five trials introduced children to the iPad app, and tested their understanding of the alternative forced choice paradigm. All of the pictures presented in the training trials were singular. The first two trials were *dog* vs. *cat* and *cow* vs. *bird*. After the pictures were displayed for 2 seconds, children heard audio instructions to *touch the dog*, and then *touch the bird*. The third trial contained a picture of a cat next to an unknown picture (*novel animal A*), with the audio instructions *touch the cat*. The fourth and fifth trials were *dog* vs. *novel animal A*, and *bird* vs. *novel animal B,* and the auditory stimuli were *touch the nug* and *touch the mib*. Upon touching a picture, an audible *chirrup* would play, and the chosen picture would flash. Flashing happened regardless of whether the child chose the target or the distractor picture. While no positive or negative feedback was provided to the participant during training, the experimenters provided children with positive encouragement, e.g., "good try" or "keep up the good work" if they appeared shy, confused or unsure.

The training trials were followed by 47 test trials which were identical in procedure to the training trials except that children were shown one picture depicting an unknown solitary object/animal (singular), and another depicting five different unknown objects/animals (plural). The auditory stimulus contained a nonce word that either had a CVC phonological form (e.g., *dup*) to indicate a singular target, or an inflected CVCs/CVCz/CVCəz form (e.g., *dups*/*degs*/*kosses*) to indicate a plural target. The use of unknown pictures and nonce words ensured that understanding of plural morphology or copula subject-verb agreement was tested.

There were 16 segmental allomorph trials (12 novel and 4 known), which tested children's understanding of segmental plural allomorphs /-s/ and /-z/ (e.g., *dup* vs. *dup**s***; *deg* vs. *deg**z***). There were 15 syllabic allomorph trials (12 novel and 3 known), which tested children's understanding of the syllabic plural allomorph /-əz/ (e.g., *koss* vs. *koss**es***), and if they could correctly identify the number condition of novel singular words ending in /-s/ and /-z/. There were 16 copula trials (12 novel, 4 known), which tested children's understanding of copula number agreement (i.e., *is* vs. *are*). There were four types of copula trials: singular and plural trials with unambiguous noun inflection, and singular and plural trials with ambiguous noun inflection. In the trials with unambiguous noun inflection, both a plural morpheme and the copula marked number (e.g., *where* ***is*** *the tup?* vs. *where* ***are*** *the tu**ps***?). In the trials with ambiguous noun inflection, target nonce words contained /ks/ coda clusters, which are number-ambiguous (e.g., *fox* /fɔks/ vs. *socks* /sɔks/; *where* ***is*** *the dax?* /dæks/ vs. *where* ***are*** *the dacks?* /dæks/).

Design

To avoid order of presentation effects, and any potential picture preference effects, four pseudo-randomized counterbalanced versions of the experiment were constructed. Across the four versions, each object/animal was used differently. For example, a novel animal would be a singular target in version one, a singular distractor in version two, a plural target in version three and a plural distractor in version four. If any two novel animals/objects were displayed together in any trial, they would not be displayed together in any other trial in any other version (regardless of singular/plural depiction). Each novel animal/object was displayed on the left in two versions, and on the right for the other two. Novel animal/objects appeared in different trial numbers in each version.

To avoid any potentially unforeseen associations between visual and auditory stimuli (see Maurer, Pathman & Mondloch, 2006), the presentation of novel words alongside novel animal/objects was similarly controlled across the four versions. If a novel word was used with a novel animal/object in a trial in one version, that word (regardless of its singular/plural inflection) would not appear in any other trial with that same animal/object in any other version, regardless of the animal/object's number condition, or whether it was a target or distractor. Each novel word was singular in two versions and plural in the other two. Each novel word was also presented in a different trial number for each version. The different trial types (segmental, syllabic and copula) were presented to children in blocks, and the order of these blocks were counterbalanced across participants.

RESULTS

Statistical analyses were performed in *R* (R Core Team, 2016). To establish that children understood the forced choice paradigm and were attending to the task, planned *t*-tests compared 3- and 4-year-olds' performance on the training and familiar word trials to chance (50%). As expected, children performed significantly above chance on the training trials (3-year-olds: $t(57) = 22.40$, $p < .001$; 4-year-olds: $t(57) = 71.50$, $p < .001$), as well as on the familiar word trials (3-year-olds: $t(57) = 28.60$, $p < .001$; 4-year-olds: $t(57) = 56.78$, $p < .001$).

Research Question One: *Does allomorphic variation affect children's comprehension of singular and plural novel nouns?*

Planned *t*-tests compared 3- and 4-year-olds' accuracy to chance (50%) for singular and plural novel nouns, across segmental and syllabic allomorph types by age. To control for familywise error rate, *p* values were adjusted using the Holm-Bonferroni method

(Holm, 1979). The planned *t*-tests revealed that both age groups responded correctly above chance for all conditions (see Table 2).

Table 2: Planned *t*-tests of accuracy vs. chance for singular and plural novel nouns, across segmental and syllabic allomorph types, by age (Holm adjusted)

Segmental Plural		df	*t* statistic	*p* value
Singular	3-year-olds	57	3.59	<.01 **
e.g., find the dup/pab	4-year-olds	57	5.24	<.001 ***
Plural	3-year-olds	57	2.68	.02 *
e.g., find the dups/pabs	4-year-olds	57	11.46	<.001 ***
Syllabic Plural				
Singular	3-year-olds	57	2.1	.04 *
e.g., find the koss/nizz	4-year-olds	57	3.75	<.01 **
Plural	3-year-olds	57	5.4	<.001 ***
e.g., find the kosses/nizzes	4-year-olds	57	11.86	<.001 ***

A binomial generalized linear mixed-effect model was then fitted over the segmental and syllabic test trials across age and number. The model tested H1-H3, whether segmental vs. syllabic allomorphic variation affected children's comprehension of plural, whether fricative-final singular words were more difficult than stop-final singular words, and whether children were more accurate with plural than singular trials. The logistic model was fitted using the *glmer* function in the *lme4* package (Bates, Mächler, Bolker & Walker, 2015). Fixed effects and interactions (intercepts underlined) included in the model were *Allomorph* (<u>segmental</u>, syllabic), *Number* (<u>singular</u>, plural), and *Age in Years* (<u>3-year-olds</u>, 4-year-olds). To achieve optimal generalisability, the model included a maximal random effects structure (Barr, Levy, Scheepers, & Tily, 2013). Random slopes of *Subject* (by *Age in Years*) for fixed effects were included (*Allomorph* and *Number*). This helped to account for any singular/plural biases that might have occurred. To account for potential item effects, random intercepts for *Auditory*

Stimulus, *Target Picture* and *Distractor Picture* were included. A random slope and intercept for *Selected Side* by *Subject* was also included to account for any left or right side selection bias any individual participant may have had. Two significant two-way interactions were revealed: *Allomorph* x *Number* (syllabic, plural: $z = 2.58$, $p = .01$) and *Number* x *Age in Years* (plural, 4-year-olds: $z = 2.42$, $p = .02$) (Figure 2).

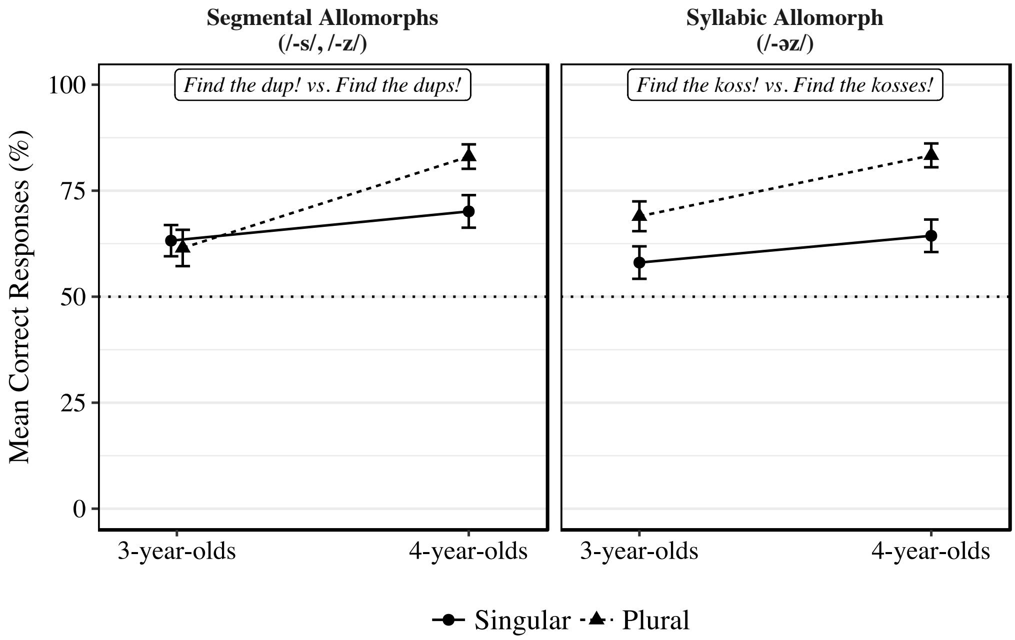

Figure 2: Segmental and syllabic allomorphs, by number and age. Error bars ± 1SE

Post hoc comparisons were performed using the *lsmeans* package (Lenth, 2016), which corrects for alpha using the Tukey-HSD method. Post hoc comparisons revealed significant differences driven by 4-year-olds' relative proficiency of plural trials. Thus, the 4-year-olds' plural trials were significantly better than all other trial types, and no other significant differences were discovered between any other trials. Post hoc comparisons are presented in Table 3.

Table 3: Post-hoc comparisons for a generalised mixed liner effects model comparing number, allomorph and age. Alpha corrected using Tukey-HSD.

Post-hoc comparison	***z***	***p***
3-year-olds, segmental, singular vs. 3-year-olds, syllabic, singular	1.579	.76
3-year-olds, segmental, singular vs. 3-year-olds, segmental, plural	0.323	1
3-year-olds, segmental, singular vs. 3-year-olds, syllabic, plural	-1	.97
3-year-olds, segmental, singular vs. 4-year-olds, segmental, singular	-1.526	.79
3-year-olds, segmental, singular vs. 4-year-olds, syllabic, singular	-0.33	1
3-year-olds, segmental, singular vs. 4-year-olds, segmental, plural	-4.109	<.01 **
3-year-olds, segmental, singular vs. 4-year-olds, syllabic, plural	-3.92	<.01 **
3-year-olds, syllabic, singular vs. 3-year-olds, segmental, plural	-0.704	1
3-year-olds, syllabic, singular vs. 3-year-olds, syllabic, plural	-2.056	.44
3-year-olds, syllabic, singular vs. 4-year-olds, segmental, singular	-2.416	.23
3-year-olds, syllabic, singular vs. 4-year-olds, syllabic, singular	-1.285	.9
3-year-olds, syllabic, singular vs. 4-year-olds, segmental, plural	-4.921	<.001 ***
3-year-olds, syllabic, singular vs. 4-year-olds, syllabic, plural	-4.942	<.001 ***
3-year-olds, segmental, plural vs. 3-year-olds, syllabic, plural	-1.822	.61
3-year-olds, segmental, plural vs. 4-year-olds, segmental, singular	-1.789	.63
3-year-olds, segmental, plural vs. 4-year-olds, syllabic, singular	-0.605	1
3-year-olds, segmental, plural vs. 4-year-olds, segmental, plural	-4.425	<.001 ***
3-year-olds, segmental, plural vs. 4-year-olds, syllabic, plural	-4.239	<.001 ***
3-year-olds, syllabic, plural vs. 4-year-olds, segmental, singular	-0.704	1
3-year-olds, syllabic, plural vs. 4-year-olds, syllabic, singular	0.526	1
3-year-olds, syllabic, plural vs. 4-year-olds, segmental, plural	-3.432	.01 *
3-year-olds, syllabic, plural vs. 4-year-olds, syllabic, plural	-3.401	.02 *
4-year-olds, segmental, singular vs. 4-year-olds, syllabic, singular	1.845	.59
4-year-olds, segmental, singular vs. 4-year-olds, segmental, plural	-2.92	.07 .
4-year-olds, segmental, singular vs. 4-year-olds, syllabic, plural	-2.612	.15
4-year-olds, syllabic, singular vs. 4-year-olds, segmental, plural	-3.859	<.01 **
4-year-olds, syllabic, singular vs. 4-year-olds, syllabic, plural	-3.865	<.01 **
4-year-olds, segmental, plural vs. 4-year-olds, syllabic, plural	0.473	1

In order to better capture the effect of age on children's comprehension, Pearson correlation tests were performed to compare participants' *Age in Months* to their *Number of Correct Responses*, by *Allomorph* (segmental, syllabic) and *Number* (singular, plural). Plural trials were significant (segmental: r = .32 $p < .001$; syllabic r = .33, $p < .001$), but singular trials were not (segmental: r = .09, $p = .32$; syllabic r = .12, $p = .22$).

Results show that H1 holds. Children are equally able to identify novel plural nouns regardless of whether the plural allomorph was segmental or syllabic. Results also show H2 holds. Children are equally able to identify novel singular nouns regardless of whether it is stop- or fricative-final. Results show that H3 partially holds. While there was no accuracy difference between singular and plural trials for 3-year-olds, 4-year-olds were significantly better at identifying novel nouns inflected with the syllabic plural allomorph than novel fricative-final singular nouns. Results also show that children get better with plurals with age, but not singulars.

Research Question Two: *Do children use copula subject-verb agreement to assist their comprehension of plural morphology?*

Planned *t*-tests were performed to compare the copula trials to chance (Holm-Bonferroni corrected). All conditions were found to be different from chance, however both 3-year-olds and 4-year-olds were significantly *below* chance for the ambiguous singular condition (Table 4). That is, in trials where the auditory stimuli were of the form *where is the dax*, they selected the plural picture, suggesting they interpreted /ks/-final novel nouns as being inflected for plural, despite subject-verb agreement with the singular copula *is*.

Table 4: Planned *t*-tests of accuracy vs. chance for copula trials with ambiguous and unambiguous noun morphology, by age (Holm adjusted)

Copula with Ambiguous Morphology		df	*t* statistic	*p* value
Singular	3-year-olds	57	-2.53	.02 *
e.g., where is the dax?	4-year-olds	57	-5.87	<.001 ***
Plural	3-year-olds	57	5.14	<.001 ***
e.g., where are the dacks	4-year-olds	57	12.31	<.001 ***
Copula with Unambiguous Morphology				
Singular	3-year-olds	57	2.76	.03 *
e.g., where is the tup?	4-year-olds	57	5.95	.02 *
Plural	3-year-olds	57	3.15	<.001 ***
e.g., where are the tups?	4-year-olds	57	10.80	<.001 ***

A binomial generalized linear mixed-effect model was then constructed to look at the effect of copula subject-verb agreement on children's comprehension of singular and plural. The model compared ambiguous and unambiguous trials from the copula test block to one another, as well as to voiceless singular and plural trials from the segmental test block. Noun morphology in this model included morpheme only (e.g., *find the dup!* / *find the dups!*), unambiguous morphology (e.g., *where is the tup?* / *where are the tups?*), and ambiguous morphology (e.g., *where is the dax?* / *where are the dacks?*). Fixed effects and interactions (intercepts underlined) included in the model were *Morphology* (<u>morpheme only</u>, unambiguous, ambiguous), *Number* (<u>singular</u>, plural), and *Age in Years* (<u>3-year-olds</u>, 4-year-olds). Like the previous model, in order to achieve optimal generalisability, a maximal random effects structure was included (Barr, Levy, Scheepers, & Tily, 2013). Random slopes of *Subject* (by *Age in Years*) for fixed effects were included (*Allomorph* and *Number*). Random intercepts for *Auditory Stimulus*, *Target Picture* and *Distractor Picture* were included, as well as a random slope and intercept for *Selected Side* by *Subject.* A main effect was discovered for Morphology (ambiguous: $z = -4.07$, $p < .001$). Three significant two-way interactions were revealed: *Morphology* x *Number* (ambiguous, plural: $z = 3.85$, $p < .001$), *Morphology* x *Age in Years* (ambiguous, 4-year-olds: $z = -2.68$, $p < .01$) and *Number* x *Age in Years* (plural, 4-year-olds: $z = -2.47$, $p = .01$) (Figure 3).

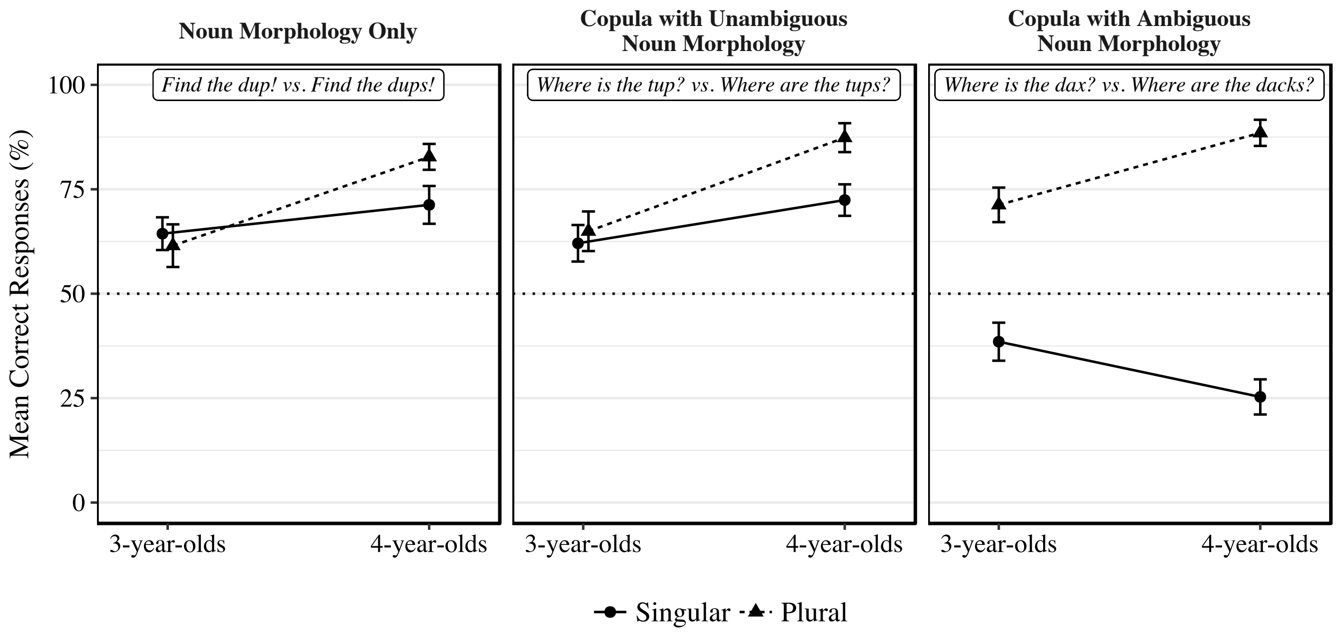

Figure 3: Children's accuracy by number and age for trials with noun morphology only, and with copula subject-verb agreement with unambiguous and ambiguous noun morphology. Error bars ± 1SE

Post hoc comparisons were performed using the *lsmeans* package (Lenth, 2016), correcting for alpha using the Tukey-HSD method (Table 4). Similar to the previous results, post hoc comparisons showed significant differences driven by 4-year-olds' proficiency in plural trials. Interestingly though, children were not significantly more accurate in trials with copula subject-verb agreement and unambiguous noun morphology than in trials with noun morphology only. Most of the significant comparisons were due to the ambiguous singular trials. Because children disregarded the copula altogether on singular copula trials with ambiguous noun morphology (/ks/-final words; e.g., *dax*), these trials were recorded as incorrect, and thus were significantly different to all other trials.

The results show that neither H4 or H5 holds. There is no evidence that children are more accurate at identifying the number condition of novel nouns with the assistance of copula subject-verb agreement. Furthermore, it does not appear that children paid any attention to the singular copula *is* at all, preferring instead to interpret number-ambiguous /ks/ cluster-final words as plural

Table 4: Post-hoc comparisons comparing number, morphology and age.

Post-hoc comparison	*z*	*p*
3-year-olds, morphology only, singular vs. 3-year-olds, unambiguous, singular	0.5	1
3-year-olds, morphology only, singular vs. 3-year-olds, ambiguous, singular	4.07	<.01, **
3-year-olds, morphology only, singular vs. 3-year-olds, morphology only, plural	-0.25	1
3-year-olds, morphology only, singular vs. 3-year-olds, unambiguous, plural	-1.07	1
3-year-olds, morphology only, singular vs. 3-year-olds, ambiguous, plural	-0.92	1
3-year-olds, morphology only, singular vs. 4-year-olds, morphology only, singular	-1.3	.98
3-year-olds, morphology only, singular vs. 4-year-olds, unambiguous, singular	-1.36	.97
3-year-olds, morphology only, singular vs. 4-year-olds, ambiguous, singular	5.82	<.001, ***
3-year-olds, morphology only, singular vs. 4-year-olds, morphology only, plural	-3.9	<.01, **
3-year-olds, morphology only, singular vs. 4-year-olds, unambiguous, plural	-4.71	<.01, **
3-year-olds, morphology only, singular vs. 4-year-olds, ambiguous, plural	-4.03	<.01, **
3-year-olds, unambiguous, singular vs. 3-year-olds, ambiguous, singular	3.83	<.01, **
3-year-olds, unambiguous, singular vs. 3-year-olds, morphology only, plural	-0.57	1
3-year-olds, unambiguous, singular vs. 3-year-olds, unambiguous, plural	-1.42	.96
3-year-olds, unambiguous, singular vs. 3-year-olds, ambiguous, plural	-1.34	.97
3-year-olds, unambiguous, singular vs. 4-year-olds, morphology only, singular	-1.58	.92
3-year-olds, unambiguous, singular vs. 4-year-olds, unambiguous, singular	-1.93	.74
3-year-olds, unambiguous, singular vs. 4-year-olds, ambiguous, singular	5.52	<.001, ***
3-year-olds, unambiguous, singular vs. 4-year-olds, morphology only, plural	-4.1	<.01, **
3-year-olds, unambiguous, singular vs. 4-year-olds, unambiguous, plural	-5.13	<.001, ***
3-year-olds, unambiguous, singular vs. 4-year-olds, ambiguous, plural	-4.53	<.01, **
3-year-olds, ambiguous, singular vs. 3-year-olds, morphology only, plural	-2.82	.17
3-year-olds, ambiguous, singular vs. 3-year-olds, unambiguous, plural	-3.69	.01, *
3-year-olds, ambiguous, singular vs. 3-year-olds, ambiguous, plural	-4.36	<.01, **
3-year-olds, ambiguous, singular vs. 4-year-olds, morphology only, singular	-4.95	<.001, ***
3-year-olds, ambiguous, singular vs. 4-year-olds, unambiguous, singular	-5.19	<.001, ***
3-year-olds, ambiguous, singular vs. 4-year-olds, ambiguous, singular	2.33	.46
3-year-olds, ambiguous, singular vs. 4-year-olds, morphology only, plural	-6.42	<.001, ***
3-year-olds, ambiguous, singular vs. 4-year-olds, unambiguous, plural	-7.41	<.001, ***
3-year-olds, ambiguous, singular vs. 4-year-olds, ambiguous, plural	-7.67	<.001, ***
3-year-olds, morphology only, plural vs. 3-year-olds, unambiguous, plural	-0.97	1
3-year-olds, morphology only, plural vs. 3-year-olds, ambiguous, plural	-0.61	1
3-year-olds, morphology only, plural vs. 4-year-olds, morphology only, singular	-0.71	1
3-year-olds, morphology only, plural vs. 4-year-olds, unambiguous, singular	-0.84	1
3-year-olds, morphology only, plural vs. 4-year-olds, ambiguous, singular	4.72	<.01, **
3-year-olds, morphology only, plural vs. 4-year-olds, morphology only, plural	-3.37	.04, *
3-year-olds, morphology only, plural vs. 4-year-olds, unambiguous, plural	-4	<.01, **
3-year-olds, morphology only, plural vs. 4-year-olds, ambiguous, plural	-3.13	.08
3-year-olds, unambiguous, plural vs. 3-year-olds, ambiguous, plural	0.29	1
3-year-olds, unambiguous, plural vs. 4-year-olds, morphology only, singular	0	1
3-year-olds, unambiguous, plural vs. 4-year-olds, unambiguous, singular	-0.16	1
3-year-olds, unambiguous, plural vs. 4-year-olds, ambiguous, singular	5.75	<.001, ***
3-year-olds, unambiguous, plural vs. 4-year-olds, morphology only, plural	-2.75	.2
3-year-olds, unambiguous, plural vs. 4-year-olds, unambiguous, plural	-3.78	<.01, **
3-year-olds, unambiguous, plural vs. 4-year-olds, ambiguous, plural	-2.6	.28
3-year-olds, ambiguous, plural vs. 4-year-olds, morphology only, singular	-0.27	1
3-year-olds, ambiguous, plural vs. 4-year-olds, unambiguous, singular	-0.47	1
3-year-olds, ambiguous, plural vs. 4-year-olds, ambiguous, singular	6.95	<.001, ***
3-year-olds, ambiguous, plural vs. 4-year-olds, morphology only, plural	-3.21	.06
3-year-olds, ambiguous, plural vs. 4-year-olds, unambiguous, plural	-4.13	0
3-year-olds, ambiguous, plural vs. 4-year-olds, ambiguous, plural	-3.5	.02, *
4-year-olds, morphology only, singular vs. 4-year-olds, unambiguous, singular	-0.22	1
4-year-olds, morphology only, singular vs. 4-year-olds, ambiguous, singular	7	<.001, ***
4-year-olds, morphology only, singular vs. 4-year-olds, morphology only, plural	-3.26	.05, *
4-year-olds, morphology only, singular vs. 4-year-olds, unambiguous, plural	-4.09	<.01, **
4-year-olds, morphology only, singular vs. 4-year-olds, ambiguous, plural	-2.97	.12
4-year-olds, unambiguous, singular vs. 4-year-olds, ambiguous, singular	7.47	<.001, ***
4-year-olds, unambiguous, singular vs. 4-year-olds, morphology only, plural	-2.92	.14
4-year-olds, unambiguous, singular vs. 4-year-olds, unambiguous, plural	-4.02	<.01, **
4-year-olds, unambiguous, singular vs. 4-year-olds, ambiguous, plural	-2.82	.17
4-year-olds, ambiguous, singular vs. 4-year-olds, morphology only, plural	-6.96	<.001, ***
4-year-olds, ambiguous, singular vs. 4-year-olds, unambiguous, plural	-7.89	<.001, ***
4-year-olds, ambiguous, singular vs. 4-year-olds, ambiguous, plural	-8.48	<.001, ***
4-year-olds, morphology only, plural vs. 4-year-olds, unambiguous, plural	-1.11	.99
4-year-olds, morphology only, plural vs. 4-year-olds, ambiguous, plural	0.69	1

DISCUSSION

The current study examined 3- and 4-year-olds' comprehension of English singular and plural in a forced choice task presented on an iPad during preschool. Rather than allowing children to use their lexical knowledge (in which properties of singular and plural might already be specified), the present task used novel words and novel pictures in order to probe children's understanding of morphological and agreement cues. The current study sought to answer two research questions.

The first research question was whether allomorphic variation would affect children's comprehension of singular and plural novel nouns. Previous research has shown that children's early understanding of the plural morpheme is affected by allomorphic variation, with sensitivity to /-s/ at 24 months (Davies et al., in prep), and to the syllabic plural allomorph /-əz/ at 36 months (Kouider et al., 2006; Davies et al., 2017). The same pattern of acquisition has been found in production studies (Berko, 1958; Graves & Kozoil, 1971; Brown, 1973; de Villiers & de Villiers, 1973; Matthews & Theakston, 2006; Mealings, Cox & Demuth, 2013). The present study, however, shows that 3- and 4-year-olds have no problem comprehending /-əz/ in comparison to /-s/ and /-z/. Thus, as was predicted in H1, while certain properties of plural allomorphy may affect children's order of acquisition, this does not appear to influence children's plural comprehension once the allomorph is learnt.

The current study also tested whether children were better able to identify some novel singular words than others. Berko (1958) suggested that children struggle to inflect novel words with the syllabic plural /-əz/ because they misinterpret fricative-final words as already being plural. However, the current study found that children were equally able to identifying fricative-final singulars (e.g., *koss, nizz*) and stop-final singulars (e.g., *dup*, *pab*). Thus, by three years of age, children clearly have a good understanding of morphological structure, and understand that even if a word ends in an /s/ or /z/, it cannot be a plural if it is unable to be broken down into its constituent morphemes of *root+plural*.

The second research question examined the extent to which subject-verb agreement assisted children's comprehension of plural morphology. In the present study, children were tested to see to what extent verbal agreement would help them understand the number condition of a novel word. Previous research has shown that 3-year-olds can use copula subject-verb agreement to anticipate the number condition of upcoming nouns (Deevy, Leonard & Marchman, 2017; Lukyanenko & Fisher, 2016). It was therefore predicted that children would show greater accuracy in trials with copula subject-verb agreement than in those without. However, the children in the present study were no more accurate in trials with the copula (e.g., *where are the dups?*), than they were in trials with only nominal morphology (e.g., *find the dups!*). In trials with ambiguous noun morphology, where nouns ended in /ks/, children paid no attention to the singular copula *is* and instead treated all /ks/-final novel words as plural (*where is the dacks?*). This suggests that, children were primarily relying on singular/plural information at the end of the noun, and paid little attention to the number information on the verb.

These results contrast with studies showing that English-speaking 30-month-olds use copula subject-verb agreement in comprehending known words during an IPL tasks (Lukyanenko & Fisher, 2016) and that 3-year-olds use copula subject-verb agreement in anticipatory looking tasks (Deevy, Leonard & Marchman, 2017) and in speech (Brown, 1973; de Villiers & de Villiers, 1973). It is possible that the present study's use of novel words increased the processing load, thereby affecting children's performance. For example, in a forced choice task, children acquiring Mexican-Spanish were able to demonstrate an understanding of subject-verb agreement from around 40-50 months, yet this ability disappeared when the task employed novel words (Gonzalez-Gomez et al., 2017). This suggests that, although the 3- and 4-year-olds in the present study may have some ability to generalize plural morphology to novel forms, they are not yet able integrate number information from elsewhere in the sentence and employ it in making their conscious choice.

Alternatively, the language model children are listening to may actually be changing. It is well known that English speakers may use number agreement mismatch under certain conditions of non-adjacency (e.g., Bock & Miller, 1991), and it is not uncommon to hear instances of child-directed speech such as "*where's your shoes?*" and "*there's your toes!*". However, in these latter types of constructions, the copula in usually contracted, whereas in the current study it was not. There are, however, many examples of copula subject-verb agreement mismatches in everyday Australian English, including interviews on television and radio programming. Recent examples of uncontracted 'is' include: "*There is a million dollars in the bank account…", "There is still further investigations…",* and "*The key question is, what is those emission targets?".* It is therefore not clear if adult speakers of Australian English would interpret "*where is the dax?*" as plural, or not. This is an obvious area for further research.

Another discovery of this study was the difference between children's performance on singular versus plural novel words. Although 4-year-olds were significantly better than 3-year-olds at comprehending plural novel words, they were the same at comprehending *singular* novel words. Given the assumed tight relationship between singular and plural, we might have expected children's performance on both singular and plural trials to improve at the same rate. However, the results of the present study suggest that singular and plural are on separate developmental trajectories. Recall that the same finding has been reported for several IPL studies in both English (Kouider et al., 2006; Davies et al., 2017, in prep) and Spanish (Lukyanenko & Miller, in submission), where children showed no sensitivity to the singular until the age of 3. This may be due to semantics. Children may find the idea of a set of many (i.e. plural) simpler to grasp than a set of one (i.e., singular). Indeed, it has been suggested that the *plural* is the semantically 'unmarked' (or the default) form for nouns (Sauerland, Anderssen & Yatsushiro, 2005). However, it seems unlikely that children would find the singular harder to learn due to it being conceptually more difficult than the plural. Children are able to distinguish between one and many from 22 months (Barner, Thalwitz, Wood, Yang & Carey, 2007; Li, Ogura, Barner, Yang & Carey, 2009), and even rhesus macaques demonstrate an understanding (Barner, Wood, Hauser & Carey, 2007).

Overall, the results of this study show that children have a solid understanding of the plural morpheme from 3 years of age. Factors that affect their early acquisition, such as allomorphic variation, do not appear to be ongoing challenges, as no accuracy differences were found between the three surface forms of the plural (/-s/, /-z/, and /-əz/). However, children's use of subject-verb agreement appears to be limited at this age; they were no more accurate with copula subject-verb agreement than without, and appeared to ignore it altogether in the context of ambiguous nouns. Lastly, and most surprisingly, this study reveals that children's acquisition of singular and plural are on different developmental trajectories. This raises important questions about the very nature of morpheme acquisition, and suggests that null morphemes may take longer to learn. This may have important clinical implications for children who require speech and language therapy, such as those with hearing loss or with specific language impairment, as typically the focus is on children's use and comprehension of the plural.

The current study reveals that children are able to use their understanding of singular and plural to inform a conscious decision in a forced choice task. This has important theoretical and practical implications since portable (tablet) forced choice tasks, such as that used in the present study, provide many opportunities for both educators and clinicians to assess language development across populations (e.g., bilinguals, children with hearing loss, children with various types of developmental delay) without the need of a tightly-controlled lab settings.

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CHAPTER 5: HEARING LOSS AND THE ACQUISITION OF PLURAL MORPHOLOGY

This chapter comprises the following paper in preparation:

Davies, B., Xu Rattanasone, N., & Demuth, K. (in prep). Hearing loss and the acquisition of plural morphology.

All components of this paper, both experimental and written, have been completed by me, with advice from the co-authors (my supervisors) when needed.

ABSTRACT

Children's acquisition of grammatical morphology is affected by many factors, including the perceptibility of the morphemes in their speech input. This presents a challenge for children with hearing loss when acquiring the English plural, as the fricative phonemes /s/ and /z/ are particularly difficult for them to perceive (Pittman & Stelmachowicz, 2003). Despite studies showing late production (e.g., Koehlinger, Owen Van Horne & Moeller, 2013), there has been little study of how and when children with hearing loss *comprehend* the plural. The current study therefore employed a novel-word forced choice paradigm to investigate the comprehension of the plural morphemes (e.g., *teps*, *kosses*) by 39 3-5-year children with different degrees of hearing loss. It was found that even children with a unilateral loss were unable to demonstrate comprehension of the plural on novel words, raising many questions about when and how grammatical representations become productive for this population.

INTRODUCTION

The quantity (number of words) and quality (lexical and syntactic diversity) of children's language input is known to play an important role in predicting later language development (Hart & Risley, 1995; Hoff & Naigles, 2002; Hoff, 2003), with those immersed in richer linguistic environments tending to develop better language processing skills, and vice versa (Weisleder & Fernald, 2013). However, just as important for children's language development is their ability to perceive what is spoken to and around them. In other words, children's access to the speech signal plays a crucial role in language acquisition. In this regard, children with hearing loss (HL) are at a greater risk of language delay in comparison to their normal hearing (NH) peers. Some studies suggest that even a mild hearing loss can be enough to cause delay (e.g., Davis, Elfenbein, Schum & Bentler, 1986). Even with interventions such as hearing aids (HAs) and cochlear implants (CIs), children with HL are shown to experience delays in their vocabulary growth (Wake, et al., 2004; Ching et al., 2010; Percy-Smith et al., 2013) and phonological development (Briscoe, Bishop & Norbury, 2001; Delage & Tuller, 2007, Moeller et al., 2010; Nittrouer et al., 2014; Ching & Cupples, 2015). One particular area of concern for children with HL is their acquisition of inflectional morphology (Elfenbein, Hardin-Jones & Davis, 1994; Young & Killen, 2002; McGuckian & Henry, 2007; Moeller et al., 2010; Koehlinger et al., 2013). Inflectional morphemes comprised of hard to hear phonemes, such as /s/ and /z/, can prove to be especially difficult for children with HL (Stelmachowicz, Pittman, Hoover & Lewis, 2002; Pittman & Stelmachowicz, 2003; McGuckian & Henry, 2007; Koehlinger et al., 2015). The current study therefore investigates the effect of HL on English-speaking children's acquisition of plural morphemes.

Different grammatical morphemes are mastered in children's speech at stages of language development (Brown, 1973; de Villiers & de Villiers, 1973), possibly due to syntactic and/or semantic complexity. However, there is also growing evidence that the *perceptibility* of a given morpheme may influence acquisition, with increased duration in utterance-final syllables enhancing both comprehension and production (Hsieh, Leonard & Swanson, 1999; Sundara, Demuth & Kuhl, 2011; Davies, Xu Rattanasone & Demuth, 2017). For example, it has long been observed that the third person singular *-s* morpheme (3SG; e.g., *walk***s**, *eat***s**) has the same surface forms as the plural, but that children acquire the plural much earlier (Brown, 1973; de Villiers & de Villiers, 1973). Although there are many syntactic and semantic reasons for why this might be the case, the plural is also much more frequent in children's input, and because it more often occurs at the end of an utterance, the prosodic effect of phrase-final lengthening (increased duration) makes it easier to perceive and produce (Hsieh, Leonard & Swanson, 1999; Sundara, Demuth & Kuhl, 2011). These combined effects may facilitate learning the plural earlier than tense marking on verbs, which typically occur utterance medially in English.

Many inflectional morphemes in English (as well as other languages) have multiple surface forms, or *allomorphs*, which occur in different phonological contexts. The plural has three allomorphs: the voiceless segmental allomorph /-s/ (e.g., *cats* /k^{h}æts/, *locks*, /lɔks/); the voiced segmental /-z/ (e.g., *dogs* /dɔgz/, *shoes* /ʃu:z/); and the syllabic allomorph /-əz/ (e.g., buses /bɐsəz/; *bushes* /bʊʃəz/). Children's acquisition of plural morphology is affected by the frequency and perceptibility of the plural allomorphs. In a novel-word comprehension task, 24-month-olds demonstrated an understanding of the voiceless /-s/ allomorph but not the voiced /-z/ allomorph, arguably due to its greater duration and perceptual salience (Davies et al., 2017). Yet perceptual salience is not the only factor to affect children's acquisition. Input frequency also appears to play a role. The syllabic allomorph /-əz/ is much less frequent than /-s/ and /-z/, and only accounts for 6% of plural types and tokens in children's input (Davies et al., 2017). Despite its greater perceptual salience, its low frequency likely contributes to its later acquisition in both comprehension (Davies, Xu Rattanasone & Demuth, in prep.a) and production (Berko, 1958).

Given the important roles of both perceptual salience and frequency in NH children's acquisition of inflectional morphology, it is perhaps not surprising that children with HL struggle in this area of language development. Even with the amplification provided by hearing aids (HAs), children with HL can still have limited access to the speech environment around them, including speech sounds in the higher frequencies ranging from roughly 2,000 to 8,000 Hz, which are the most likely to be affected by HL (Pittman & Stelmachowicz, 2003). This makes it difficult to perceive speech sounds such as /s/, /z/, /t/, and /d/, all of which are important for a variety of English inflectional morphemes, such as past-tense (e.g., *walk**ed***), possessive (e.g., *the dog**'s** ball*), as well as 3SG and plural. Limited access to these speech sounds not only delays children's acquisition of inflectional morphology, but also affects the order in which morphemes are acquired (McGuckian & Henry, 2007). In an elicited and spontaneous speech study, children with sight to severe HL aged up to eight years were found to be much less likely than NH three-year-olds to produce inflectional morphemes with the hard-to-perceive /-s/ or /-z/ phonemes (e.g., possessive, 3SG and plural), yet they were much more likely to produce the perceptually salient verbal progressive morpheme (e.g., *runn**ing***). The limited access to fricatives not only affects children's production of plural, but their understanding of the plural as well. In a picture-pointing task, children had to identify plural words inflected with the segmental allomorphs /-s/ and /-z/. Again, while children with HL aged up to 13 years were able to do the task, they were less accurate and more variable than NH five-year-olds (Stelmachowicz, Pittman, Hoover & Lewis, 2002).

Limited access to /s/ and /z/ also affects children's production of allomorphic variants. An analysis of the speech of 51 children with HL aged 2;10 to 3;8 found that the more perceptually salient syllabic allomorph /-əz/ was correctly produced roughly five to eight times more often than its segmental /-s/ and /-z/ counterparts (Koehlinger et al., 2015). This is the opposite of what is observed for NH children (Brown, 1973). Furthermore, this phenomenon is not limited to English. In an elicitation and picture-naming study, 19 German-speaking children with HL aged 3;2 to 4;10 were prompted to inflect verbs with hard-to-perceive /-s/ and /-t/ morphemes (which are typically higher-pitched and fall around the 2000 Hz range, which is often most affected by HL), as well as an easier-to-perceive nasal /-n/ counterpart (which is typically lower-pitched, and falls into frequency ranges usually less-affected by HL). For example, the German verb *lachen* 'laugh' takes different inflectional morphemes depending on person and number (e.g., 2SG: *lach+s(t)*; 3 SG: *lach+t*; 1PL: *lach+(e)n*; 2PL: *lach+t*; 3PL: *lach+(e)n*). The children showed little difficulty with the perceptually salient /-n/ morphemes, yet struggled with /-s/ and /-t/ (Penke, Wimmer, Hennies, Hess & Rothweiler, 2016).

In Australia, children with a severe to profound HL may in fact get better access to /s/ and /z/ than those with mild to moderate losses, as they are more likely to receive a cochlear implant (CI), have it implanted early, and have follow-up therapy during the preschool years. Unlike HAs, CIs do not amplify the potentially limited frequencies available in children's residual hearing, but instead transmit sound directly to the auditory nerve via direct electric stimulation of the cochlea. While there is evidence to suggest that children fitted with CIs fare better than their HA-fitted counterparts (Tomblin et al., 1999), their acquisition of inflectional morphology still appears to be quite variable. A longitudinal study of 22 German-speaking children receiving CIs between the ages of 1;2 and 3;10, found that ten of the children could use inflected words around 18 months after implantation. They produced plural nouns as well as some verbal morphology, and appeared to be on the same trajectory, if slightly behind, their age-equivalent NH peers. However, the remaining twelve children, struggled to produce more than two-word utterances, let alone inflectional morphology, even after three years (Szagun, 2000; 2001).

Variable outcomes are also seen for children with CIs acquiring English. A study testing children's comprehension of spoken English grammar (Test for Reception of Grammar; Bishop, 1989) found that only two-thirds of children with CIs performed above the 25th percentile (Nikolopoulos, Dyar, Archbold & O'Donoghue, 2004). In a study of seven children, all with five years of CI experience, a battery of standardised tests revealed a weakness in grammatical morphology despite strong semantic knowledge (Young & Killen, 2002). Another test battery with 181 8- to 9-year-old children with CIs found that only 27% performed at or above their NH peers in the use of bound morphemes (Geers, Nicholas & Sedey, 2003). While some children with a CI acquire inflectional morphology, these studies suggest that this can be an ongoing problem for others.

One factor that may affect children with HL is the age at which they received their hearing device. Particularly in the case of children born with a profound HL, early intervention is crucial for their development of central auditory pathways (see Sharma & Campbell, 2011). Some studies suggest that that prelingually deaf children who receive CIs before their first birthday may gain (some) language skills comparable to their normal hearing peers (Tait, De Raeve & Nikolopoulos, 2007; Wie, 2010). Early CI implantation has been shown to long-term effects, as children who received their CIs during the critical window between the ages of 6 to 18 months, were found to have better speech perception and language skills over a decade later than those who received their CIs at a later age (Hunter, Kronenberger, Casellanos & Pisoni, 2017).

Another group of children with HL that may face challenges in acquiring inflectional morphology are those with a loss in only one ear, or unilateral HL. While some studies suggest that the language outcomes of children with unilateral HL is comparable to their NH peers (e.g., Klee & Davis-Dansky, 1986), other studies have found children with unilateral HL perform much worse on oral language tests (Lieu, Tye-Murray, Karzon & Piccirillo, 2010). A review of multiple studies found that speech and language delays were reasonably common for children with unilateral HL (Lieu, 2004). To date, there has been little research on the acquisition of inflectional morphology by children with unilateral HL. There is reason to believe, however, that even a loss in one ear may hinder these children's language development. In comparison to adults, NH children find it difficult to isolate speech from background noise (Nozza, Wagner & Crandell, 1988), yet children with unilateral HL find it even more challenging (Bess, Tharpe & Gibler, 1986). NH 2-year-olds find it challenging to perceive inflectional tense/agreement morphemes /-s/ and /-z/ on verbs when these occur utterance-medially (e.g., *Mary likes cake*) (Sundara, Demuth & Kuhl, 2011). We would therefore expect children with a unilateral HL to exhibit more challenges in the perception and subsequent learning of English inflectional morphology than their NH peers.

Thus, the research to date suggests that children with limited access to language input, including those with unilateral HL and amplification with HAs or CIs, exhibit not only delays in the acquisition of inflectional morphology, but a different order of acquisition compared to their NH peers. What is not clear, however, is what effect HL has on children's establishment of grammatical representations of morphological structure. Much of the research to date has focused on children's production and comprehension of familiar words. While this provides insight into children's speech, it reveals little about their underlying lexical and grammatical representations. For example, it is unclear if children with HL develop productive morphological representations, as in *cat+s*, or if they only understand singular and plural words as unanalysed lexical entries, such as *cat* and *cats* (like *mouse* and *mice*). Novel word paradigms have previously been used to probe NH children's understanding of plural morphology in production (Berko, 1958; Zapf & Smith, 2007) and comprehension tasks (Kouider et al., 2006; Davies, et al., 2017; in prep.a). For example, the only way to know that a novel word such as *wugs* means *more than one wug* is by realising that the word is composed of a referent (i.e., *wug*) and the plural morpheme /-*z*/. Therefore, the present study employed a forced choice novel word task to test whether children with HL have productive representations of plural morphological structure.

A recent study by Davies, Xu Rattanasone, Schembri, Andronos & Demuth (in prep.b) investigated the acquisition of English plural morphology by NH children using a forced choice novel word task presented on an iPad. NH children were presented with two pictures of unfamiliar animals or objects, one depicting a single object/individual (singular picture) and one depicting five identical objects/individuals (plural target). An auditory stimulus then instructed children to *Touch the [novel word]*. The novel word was either singular (e.g., *tep*, *nizz*) or inflected for plural (e.g., *teps*, *nizzes*). The study found that both 3-year-olds and 4-year-olds were able to do the task, and that children became more proficient at plural comprehension with age.

The present study therefore employed the same paradigm to probe the understanding of plural morphology by children with HL. It also examined the effect of perceptual salience (in the form of allomorphic variation) on children's comprehension the plural. Thus, it was predicted that children HL would show better comprehension of the perceptually more salient syllabic allomorph /-əz/, given that they also perform better with this morpheme in production (Koehlinger, et al., 2015). Children were therefore tested on trials with novel words inflected with both the segmental plural /-s/ and /-z/ (e.g., *touch the teps*/*degs*) and the syllabic plural /-əz/ (e.g., *touch the kosses*/*nizzes*). They were also tested on subject-verb agreement in the form of the copula *is* vs. *are (where is/are the [novel word]).* When used in their full (uncontracted) form, *is* and *are* are composed of an entire syllable, perhaps being easier to perceive than segmental plural inflections on the end of a noun. If so, we expected children to perform better on such sentences than those without a copula. To probe this issue further, we also used some novel nouns ending in the morphologically ambiguous /ks/ cluster (appearing in both singular words like *box* and *fox,* and plural words like *socks* and *clocks*), resulting in questions such as *where is the dax?* vs. *where are the dacks?* The current study therefore focuses on two research questions:

Research Question One: *To what extent does allomorphic variation and degree of hearing loss affect children's comprehension of novel singular and plural nouns?*

- Are children with HL generally better at identifying plural morphology on a newly heard or novel word, when that word is inflected with the more perceptually salient syllabic /-əz/ (e.g., *kosses*, *nizzes*) rather than segmental plural allomorphs /-s/ and /-z/ (e.g, *teps*, *degs*)?
- To what extent does the level of HL affect children's ability to identify the number condition of novel nouns across segmental and syllabic plural allomorphs? Will children with better (unaided) hearing thresholds (with better residual hearing) be better able to perform the task across all trials?
- Will there be a developmental effect? Will older children will perform better than younger children across all trials, or only for some allomorphs?
- Will there be an effect of hearing age? Will children who have had more experience with their hearing device (e.g., HA, CI) perform better in the task?

Research Question Two: *Do children with HL use copula subject-verb agreement to help comprehend novel singular and plural words, and does their degree of hearing loss affect this comprehension?*

- Can children with HL use copula subject-verb agreement (*is/are*) to determine the singular/plural number of the following newly heard or novel noun (*where is/are the [novel word*])?

- What effect does degree of HL have on children's ability to use copula agreement?
- Does age play a role in children's comprehension of copula agreement?
- Will children with more experience with their hearing device (e.g., HA, CI) better comprehend copula agreement?
- Will there be a relationship between children's performance on trials with copula agreement and their performance on trials testing plural morphology only?

METHOD

Participants

Thirty-nine children with HL participated in this study (mean age = 49.7 months; range: 36–82 months; female = 19, male = 20). Most were 3–5-year-olds. All participants were clients of *The Shepherd Centre*, an Australian charitable organisation that operates speech pathology and audiology clinics for pre-schoolers throughout New South Wales and the Australian Capital Territory. Participants' clinical and demographic information was provided by The Shepherd Centre through written parental consent, and is presented in Table 1.

The participants had varying degrees of hearing loss, different aetiologies and different device fittings. Note that the average four frequency loss reported for the three participants with Auditory Neuropathy Spectrum Disorder (ANSD) may only be representative of the date the audiogram was conducted, which was not on the same day as the study. The degree of hearing loss categorisation used in this study was as defined by Clark (1981). The number of months of 'ideal auditory access' (henceforth 'auditory access') was defined as the number of months since the participant's CI activation or HA fitting (this includes HL-15 with a bone anchored hearing aid; BAHA). For children with a unilateral fitting, or with no fitting, months of auditory access was defined as the same as their chronological age, as they had access through their better ear. All participants came from majority-English language environments, although six had some regular exposure to other languages. No participant had any diagnosed developmental delay.

As part of their regular therapy sessions, all children were tested using the *Ling Six Sound Test* (Ling, 1989), in which they repeat speech sounds (/m/, /a/, /u:/, /i:/, /ʃ/, /s/) produced by the therapist without visual cues (i.e. mouth covered). All participants (except HL-13, who had just started therapy sessions) successfully repeated /s/ in at least three out of the previous five therapy sessions. The majority had a repeat rate of 100%.

Table 1: Participant demographic and clinical information

ID	Sex	Age (months)	Aetiology	Laterality	Fitting type	Ideal auditory access (months)	Better ear average 4 frequency loss (dB)	Loss Degree (Clark, 1981)	Percent exposure to language other than English
HL-01	M	49	Sensorineural	Unilateral	CI(R)	49	0	Normal	-
HL-02	F	60	Mixed	Unilateral	none	60	3.8	Normal	-
HL-03	F	51	Sensorineural	Unilateral	none	51	8.8	Normal	20%
HL-04	M	41	Conductive	Unilateral	BAHA(R)	41	11.3	Normal	-
HL-05	M	36	Conductive	Unilateral	BAHA(L)	36	11.3	Normal	-
HL-06	M	36	Conductive	Unilateral	HA(L)	36	12.5	Normal	-
HL-07	M	63	Sensorineural	Unilateral	HA(L)	63	13.8	Normal	-
HL-08	F	53	Sensorineural	Unilateral	HA(L)	53	15	Normal	-
HL-09	F	64	Sensorineural	Unilateral	CI(R)	64	15	Normal	-
HL-10	F	42	ANSD	Unilateral	CI(R)	42	22.5	Slight	3%
HL-11	F	60	Conductive	Bilateral	HA	18	23.8	Slight	-
HL-12	F	41	Sensorineural	Unilateral	CI(L)	41	23.8	Slight	-
HL-13	F	72	Sensorineural	Bilateral	HA	8	25	Slight	-
HL-14	M	60	Sensorineural	Bilateral	HA	50	27.5	Mild	-
HL-15	M	38	Conductive	Bilateral	BAHA	11	28.8	Mild	-
HL-16	F	49	ANSD	Unilateral	none	49	28.8	Mild	-
HL-17	M	82	Sensorineural	Asymmetrical	HA(L),CI(R)	29	35	Mild	-
HL-18	F	39	Mixed	Bilateral	HA	37	37.5	Mild	-
HL-19	M	39	Sensorineural	Bilateral	HA	37	40	Mild	-
HL-20	M	41	Sensorineural	Bilateral	HA	40	41.3	Moderate	-
HL-21	F	38	Mixed	Bilateral	HA	36	41.3	Moderate	5%
HL-22	M	53	Mixed	Asymmetrical	HA(L), CI(R)	5	42.5	Moderate	-
HL-23	M	54	Sensorineural	Bilateral	HA	52	42.5	Moderate	-
HL-24	M	43	Sensorineural	Bilateral	HA	42	47.5	Moderate	-
HL-25	M	43	Sensorineural	Bilateral	HA	42	47.5	Moderate	-
HL-26	F	43	Sensorineural	Bilateral	HA	41	47.5	Moderate	20%
HL-27	F	52	Sensorineural	Bilateral	CI	39	55	Moderate	-
HL-28	F	60	Sensorineural	Bilateral	CI	34	56.3	Mod Severe	-
HL-29	F	39	Sensorineural	Bilateral	CI	4	57.8	Mod Severe	-
HL-30	M	56	Conductive	Bilateral	HA	30	66.3	Mod Severe	-
HL-31	F	41	Sensorineural	Bilateral	HA	40	67.5	Mod Severe	-
HL-32	F	44	Sensorineural	Bilateral	CI	27	70	Mod Severe	-
HL-33	M	61	Sensorineural	Bilateral	CI	44	72.5	Severe	-
HL-34	M	43	Sensorineural	Asymmetrical	HA(L), CI(R)	5	80	Severe	30%
HL-35	M	52	Sensorineural	Bilateral	CI	44	100	Profound	10%
HL-36	F	51	Sensorineural	Bilateral	CI	19	100	Profound	-
HL-37	M	51	ANSD	Bilateral	CI	41	100	Profound	-
HL-38	M	59	Sensorineural	Bilateral	CI	53	100	Profound	-
HL-39	F	39	Sensorineural	Bilateral	CI	34	100	Profound	-

Equipment

The experiment was performed on an Apple iPad Air 2 (240 × 169.5 mm, with a 2048 × 1536 resolution at 264 dpi). The auditory stimuli were played out of a bi-amplified GENELEC 8020A active monitoring loudspeaker. The experimental software was built using the Serenity Engine, a multiplatform engine written in C using the OpenGL library (Budziszewski, 2003; see Xu Rattanasone et al., 2016).

Auditory Stimuli and Preparation

The auditory stimuli were produced by a female speaker of Australian English using a child-directed speech register. The stimuli were recorded during a single session in a sound-treated room using the program Cool Edit Pro 2.0 (at 48 kHz). Each stimulus item consisted of a carrier phrase and a familiar or novel target word. The carrier phrase used for the training trials and the segmental and syllabic allomorph trials was "*touch [the target]*". The carrier phrases used for the copula subject-verb agreement trials were "*where <u>is/are</u> [the target]?*". The singular and plural familiar words used in the segmental allomorph trials were *bat(s)*, *pig(s), mop(s)* and *crab(s)*, and for the syllabic allomorph trials they were *horse(s)*, *bus(es)* and *rose(s).* For the copula trials, the singular familiar words were *fox* and *box*, while the plural familiar words were *ducks* and *clocks*. The training trials consisted of three singular familiar words, *dog, bird* and *cat*, and two singular novel words, *nug,* and *mib*. The novel words used in each test block are shown on table 2.

Table 2: Novel words used in the segmental, syllabic and copula trials

Morphology Trials						
Segmental Allomorph Trials (/-s/, /-z/)		**Syllabic Allomorph Trials (/-əz/)**		**Copula Trials**		
singular	***plural***	***singular***	***plural***	*singular*	*plural*	
dup /dɐp/	*dups* /dɐps/	*koss* /kɔs/	*kosses* /kɔsəz/	*dax* /dæks/	*dacks* /dæks/	***ambiguous***
bip /bɪp/	*bips* /bɪps/	*nass* /næs/	*nasses* /næsəz/	*gex* /geks/	*gecks* /geks/	
tep /tep/	*teps* /teps/	*poss* /pɔs/	*posses* /pɔsəz/	*gox* /gɔks/	*gocks* /gɔks/	
mup /mɐp/	*mups* /mɐps/	*dass* /dæs/	*dasses* /dæsəz/	*bix* /bɪks/	*bicks* /bɪks/	
noop /nʊp/	*noops* /nʊps/	*bess* /bes/	*besses* /besəz/	*nux* /nɐks/	*nucks* /nɐks/	
gop /gɔp/	*gops* /gɔps/	*giss* /gɪs/	*gisses* /gɪsəz/	*poox* /pʊks/	*pooks* /pʊks/	
pab /pæb/	*pabs* /pæbz/	*niz* /nɪz/	*nizzes* /nɪzəz/	*tup* /tɐp/	*tups* /tɐps/	***unambiguous***
tib /tɪb/	*tibs* /tɪbz/	*kez* /kez/	*kezzes* /kezəz/	*doop* /dʊp/	*doops* /dʊps/	
geb /geb/	*gebs* /gebz/	*moz* /mɔz/	*mozzes* /mɔzəz/	*gip* /gɪp/	*gips* /gɪps/	
mub /mɐb/	*mubs* /mɐbz/	*tiz* /tɪz/	*tizzes* /tɪzəz/	*mep* /mep/	*meps* /meps/	
koob /kʊb/	*koobs* /kʊbz/	*doz* /dɔz/	*dozzes* /dɔzəz/	*dap* /dæp/	*daps* /dæps/	
tob /tɔb/	*tobs* /tɔbz/	*paz* /pæz/	*pazzes* /pæzəz/	*nop* /nɔp/	*nops* /nɔps/	

The novel word onsets were all early-acquired oral or nasal stops (/p/, /b/, /t/, /d/, /k/, /g/, /m/ and /n/; see Smit et al., 1990), and the vowels were all Australian English short vowels (/ɪ/, /e/, /æ/, /ɐ/ and /ɔ/; see Harrington, Cox & Evans, 1997).

While each stimulus item was originally recorded in its entirety, the stimuli presented to participants were spliced to control for phonetic variation. Splicing was performed using Praat (Boersma & Weenink, 2016). One spliced version of each carrier phrase was used in the experiment. For the segmental allomorph trials and the copula trials, target words were composed of two spliced parts, *word-stem* and *coda.* The word-stem splice included the determiner *the*. One version for each word-stem was used (e.g., *the pig, the tup, the deg,* etc.) in both singular and plural contexts, and one version for each coda was used (e.g., /p/, /b/, /ps/, /bz/, /ks/, etc.). For the syllabic allomorph trials, target word-stems were not spliced across singular and plural conditions due to differences in vowel and frication durations of monosyllabic singular vs, disyllabic plural words (e.g., *koss* vs. *kosses*; *bus* vs. *buses*). However, all of the plural target words had the same spliced version of the syllabic plural allomorph /əz/. Two phoneticians specialising in Australian English vetted the spliced stimuli to ensure they sounded like naturally produced speech,

Visual Stimuli

The visual stimuli contained child-friendly cartoon depictions of objects and animals. There were a total of 24 novel objects, 48 novel animals and 22 familiar objects/animals (*bat*, *bear, bus*, *box*, *bug*, *cake*, *clock*, *cow*, *crab*, *duck*, *fox*, *frog*, *hat*, *horse*, *house*, *mop*, *pig*, *rat*, *rose*, *shirt*, *snake*, and *tree*). Singular pictures displayed a single object/animal, while plural pictures displayed five identical objects/animals. Each test trial consisted of a singular picture and a plural picture displayed alongside one another. Only singular pictures were used in training trials. In the novel trials, pictures were matched for animacy. Figure 1 shows examples for each condition.

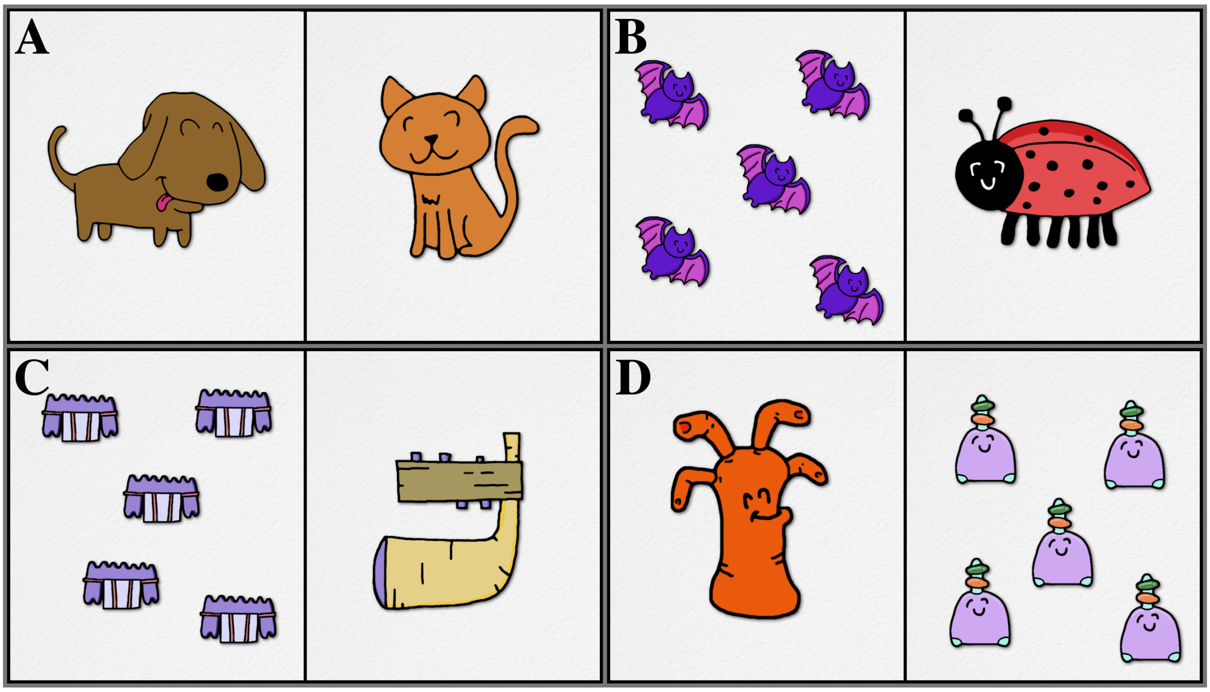


Figure 1: Examples of (A) training trial, (B) familiar word trial, (C) novel object trial, (D) novel animal trial

Procedure

Children were tested during their regular speech-therapy session by their usual therapist. Before starting the experiment, children were asked to repeat the /s/ and /əz/ sounds that had been spliced from the stimuli. The speaker volume was adjusted until the therapist was convinced that both segments could be heard clearly. This ensured that children were able to perceive the relevant plural morphemes during the task.

The basic procedure was the same for every trial. Children were presented with two pictures alongside each other. After two seconds the auditory stimulus played, which instructed them to *"touch the [target]"*, or asked them *"where is the [target]?/where are the [targets]?"* for the copula trials. The picture that the child selected would flash, and a *chirrup* sound would play. The flashing occurred regardless of whether the child selected the target or the distractor picture. While no positive or negative feedback was provided during the experiment, children were given positive encouragement if they appeared shy, confused or unsure (e.g., *"good try"* or *"keep up the good work"*).

The first five trials were training trials. This introduced children to the experimental paradigm and familiarised them with the iPad. The pictures presented in the training trials were all singular. The first two trials contained familiar words, i.e., <u>dog</u> vs. *cat* and *cow* vs. *bird*. The third trial contained the target picture *cat* next to a novel picture (*novel animal A*). The fourth and fifth trials were *dog* vs. *novel animal A*, and *bird* vs. *novel animal B,* with the auditory stimuli "*touch the nug*" and "*touch the mib*".

Upon completing the training trials, participants progressed to the test trials, which depicted singular pictures alongside plural pictures. The auditory stimuli were all CVC or CVks for singular words (e.g., *dup, dax*) and CVCs/CVCz/CVCəz for plural words (e.g., *dups*/*dacks*/*kosses*). The use of novel pictures and words ensured that children were being tested on their *productive* understanding of plural morphology, and not on previously learned lexical representations. Thus, above chance performance would provide evidence for established morphological representations.

There were 47 test trials, consisting of three different trial types which were presented in blocks: the segmental allomorph trials (16 trials; 12 novel, 4 familiar), the syllabic allomorph trials (15 trials; 12 novel, 3 familiar) and the copula (16 trials; 12 novel, 4 familiar). The order of presentation was counterbalanced across participants. The segmental trials examined children's understanding of the segmental plural allomorphs /-s/ and /-z/ (e.g., *dup* vs. *dup**s***; *deg* vs. *deg**z***). The syllabic trials examined children's understanding of the syllabic plural allomorph /-əz/ (e.g., *koss* vs. *koss**es***). The copula trials tested children's understanding of copula number agreement (i.e., *is* vs. *are*) where the noun had either unambiguous nominal inflection (e.g., "*where **is** the tup_?*" vs. "*where **are** the tu**ps***?") or ambiguous /ks/ nominal inflection (e.g., box /bɔks/ vs. clocks /klɔks/; "*where **is** the dax?"* /dæks/ vs. "*where **are** the dacks?"* /dæks/).

Design

Four pseudo-randomized counterbalanced versions of each trial block were constructed, each containing 24 novel objects/animals. Across the four versions, any given novel animal would be a singular target, a singular distractor, a plural target and a plural distractor. The presentation of novel words alongside novel animal/objects was also controlled across the four versions. If a novel word was presented in a trial with any given novel animal/object, that word (regardless of its singular/plural inflection) would not appear in any other trial with that same animal/object in any other version, regardless of the number condition, or whether it was a target or distractor.

RESULTS

The following statistical analyses were performed in *R* (R Core Team, 2016).

Degree of Hearing Loss and Types of Hearing Device Fittings of Participants

To analyse the effect of hearing loss on children's acquisition of plural morphology, participants were divided into three groups based on their degree of HL (Clark, 1981): Normal to Slight (0–25 dB; N = 13), Mild to Moderate (26–55 dB; N = 14) and Moderately Severe to Profound (56–100 dB; N = 12). Participants could also divided into three groups based on their hearing device fitting: Unilateral, for children with unilateral HL one or fewer fitted devices; HA, for children with bilateral hearing aids or bone anchored hearing aids; and CI, for children with bilateral or bimodal cochlear implants. As device groupings were largely captured by HL groupings (Figure 2) , children's hearing device fittings were not included as factors in the analyses.

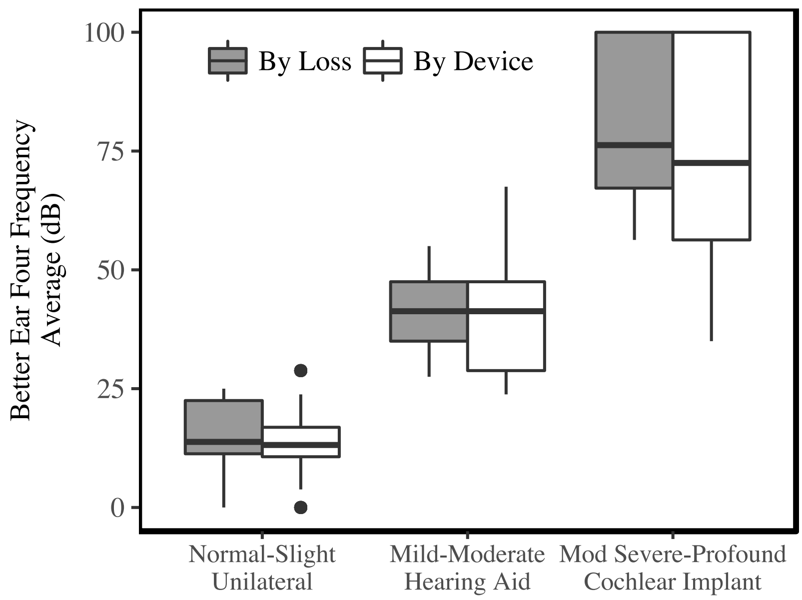


Figure 2: Participant groups by degree of hearing loss and hearing device type.

Performance on Familiar Word Trials

To ensure children understood the task, planned *t* tests compared participants' mean accuracy for the training trials and the singular and plural *familiar word* trials to chance (50%). To control for multiple comparisons, *p*-values were adjusted using the Holm-Bonferroni method (Holm, 1979), using the base R *p.adjust* function. As expected, all conditions in each group were significantly different to chance (Normal-Slight: training: $t(12) = 17.23$, $p < .001$; singular familiar: $t(12) = 22.52$, $p < .001$; plural familiar: $t(12) = 11.52$, $p < .001$; Mild-Moderate: training: $t(13) = 18.65$, $p < .001$; singular familiar: $t(13) = 12.00$, $p < .001$; plural familiar: $t(13) = 12.73$, $p < .001$; Mod Severe-Profound: training: $t(11) = 29.00$, $p < .001$; singular familiar: $t(11) = 8.14$, $p < .001$; plural familiar: $t(11) = 7.90$, $p < .001$) (Figure 3). With this taken as evidence that children were attending to the task and listening to the auditory stimuli, the segmental and syllabic allomorph trials were analysed to address research question one.

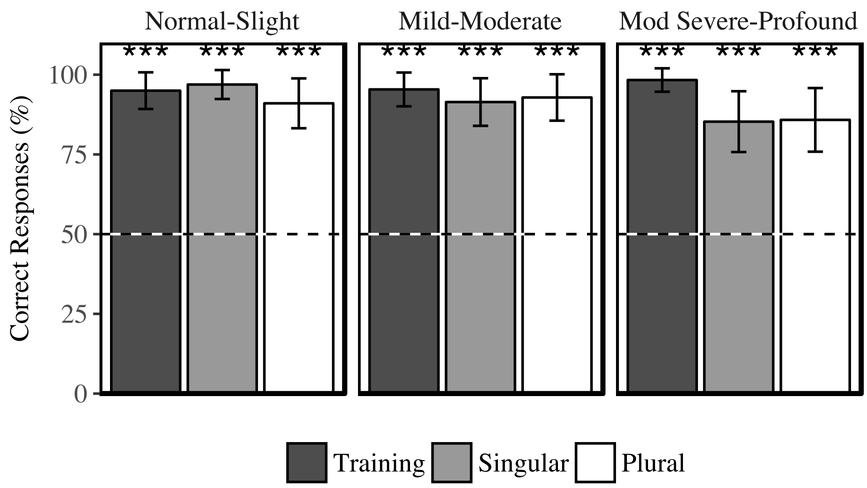


Figure 3: Mean correct responses for training and singular/plural familiar word trials, by degree of HL. Error bars ± 95%CI. ******p* **< .001

Research Question One: *To what extent does allomorphic variation and degree of hearing loss affect children's comprehension of novel singular and plural nouns?*

To address this question, and to see whether children with HL would comprehend singular and plural novel words, all participant scores were examined across the segmental and syllabic allomorph trials. Planned *t*-test compared each condition to chance (50%). With alpha adjusted, segmental singular was found to be significantly above chance ($t(38) = 3.25$, $p < .01$), however, no other trial type was significantly different to chance (segmental plural: $t(38) = 1.51$, $p = .41$; syllabic singular: $t(38) = 1.33$, $p = .41$; syllabic plural: $t(38) = 0.94$, $p = .41$). This means that, as a group, children with HL were no better than chance at identifying the number condition of novel words inflected with the plural morpheme, regardless of the allomorph. Children were, however, able to identify CVC novel singular words (Figure 4).

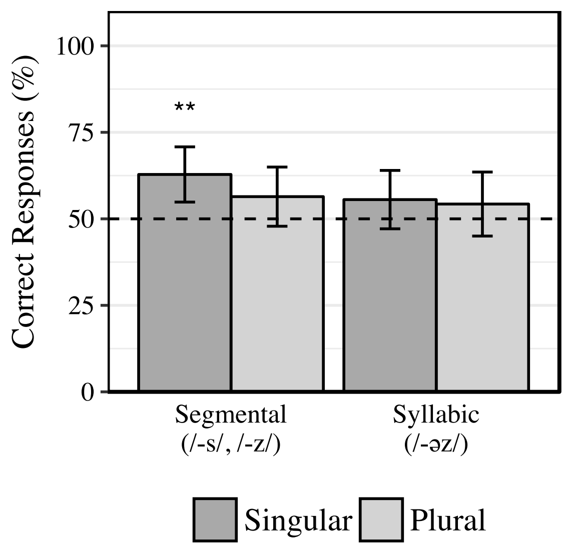


Figure 4: Mean correct responses for morphology trials by allomorph and number. Error bars ± 95%CI. *****p* **< .01**

To better compare children's performance in the segmental allomorph to their performance in the syllabic allomorph, while taking into consideration their degree of HL, a binomial generalized linear mixed-effect model was fitted over the morphology trials. The logistic model was fitted using the *glmer* function in the *lme4* package (Bates, Mächler, Bolker & Walker, 2015). The fixed effects and interactions (intercepts underlined) were *Allomorph* (<u>segmental</u>, syllabic) and *Number* (<u>singular</u>, plural). *HL Group* (<u>normal-slight</u>, mild-moderate, mod severe-profound) was a fixed effect. The model included a maximal random effects structure to achieve maximal generalisability (Barr, Levy, Scheepers, & Tily, 2013). Random slopes of *Subject* (by *HL Group*) for fixed effects were included (*Allomorph* and *Number*). To account for potential item effects, random intercepts for *Auditory Stimulus*, *Target Picture* and *Distractor Picture* were included. A random slope and intercept for *Selected Side* by *Subject* was also included to account for any side selection bias any given child may have had. One main effect was discovered, for *HL Group* (Mod Severe-Profound: $z = -2.23$, $p = .03$). This shows that there was no difference between segmental and syllabic plural allomorph but that

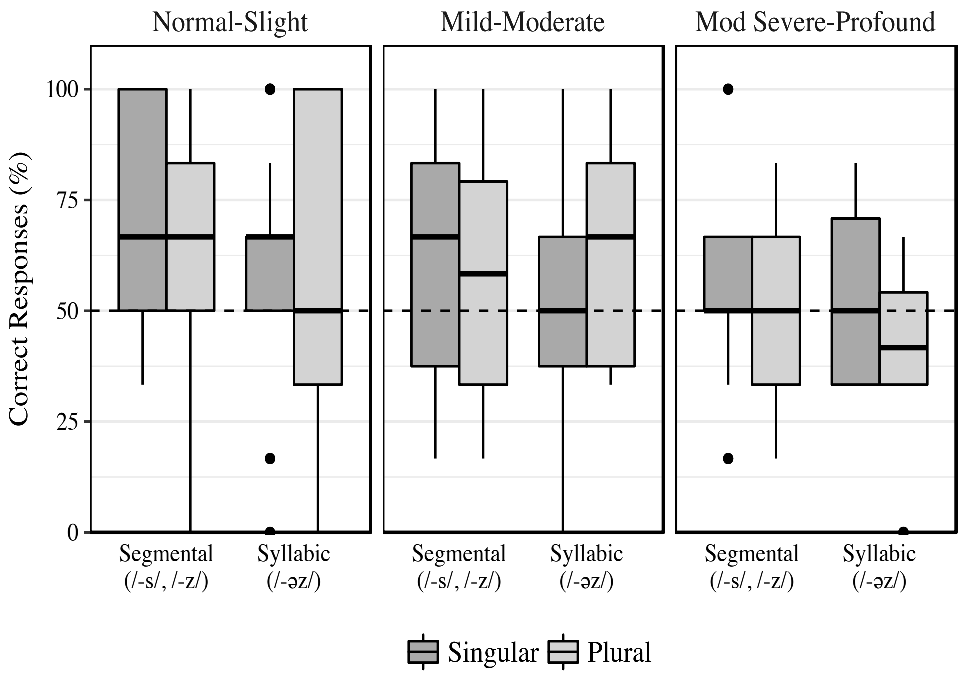


Figure 5: Correct responses for morphology trials, by number, allomorph and degree of HL.

degree of HL does affect children's comprehension of the plural. Figure 5 shows responses by degree of HL.

To further investigate the main effect discovered for *HL Group*, a Pearson's correlation test compared children's better-ear four-frequency average loss to their total score for all of the morphology trials. A significant negative correlation was discovered (r = -.35, $p < .03$), showing that the lesser the degree of hearing loss, the better children's performance (Figure 6).

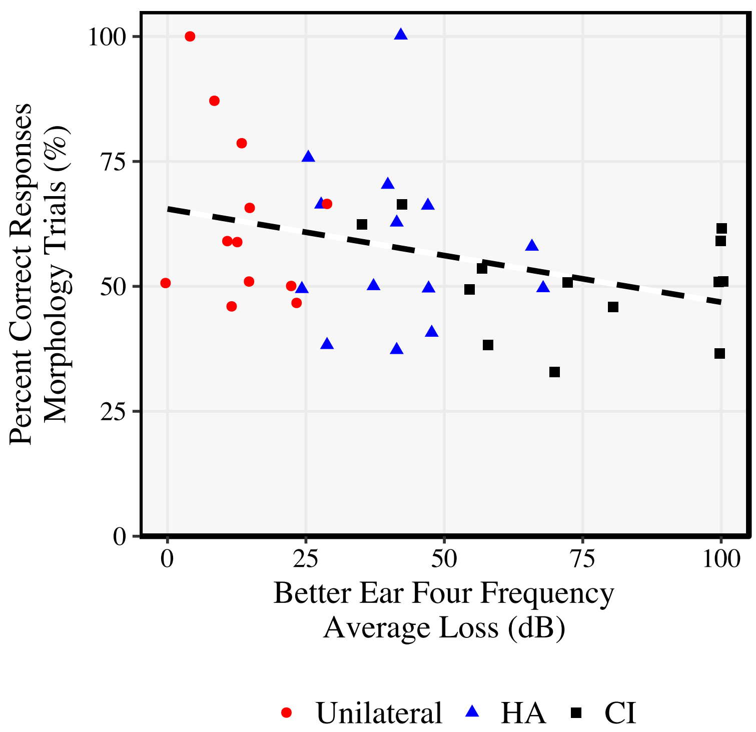


Figure 6: Correlation between children's correct responses for all morphology trials and their better ear four frequency average loss. r = -.35; *p* = .03*

To investigate the relationship between children's age and their comprehension of novel noun morphology, as well as the relationship between their comprehension and number of months of auditory access (hearing device use), Pearson's correlation tests compared the age and auditory access (in months) to their total score for all of the morphology trials. Both *Age* (r = .46; $p < .01$) and *Access* (r = .42, $p < .01$) were found to have significant positive correlations with children's scores (Figure 7).

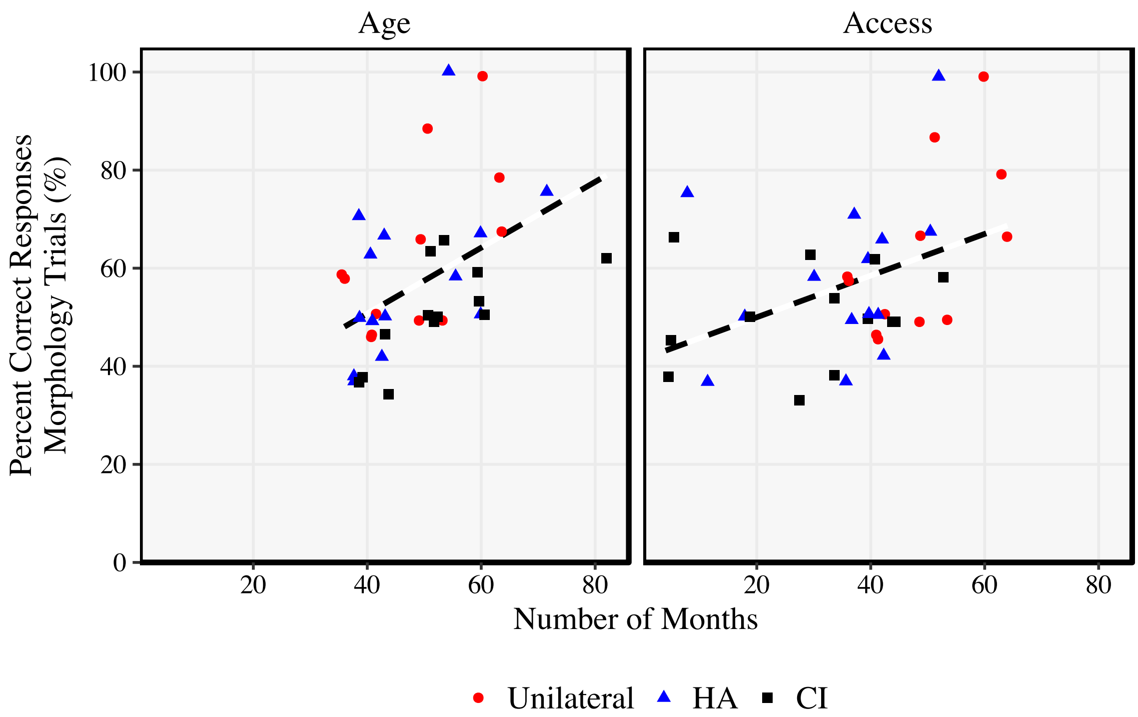


Figure 7: Correlations between children's correct responses for morphology trials and their age and months of auditory access. Age: r = .46, *p* < .01; Access r = .42, *p* < .01****

Overall, planned *t*-tests reveal children did not appear to understand either segmental or syllabic plural inflections, and the linear mixed effects logistic model revealed no differences between allomorphs. However, the correlations show that children with better access to sound did better overall, and that children performed better with a longer duration of access to speech input, as a function of chronological age and longer time since amplification. Because of the heterogeneity of the HL group in this analysis, Figure 8 better illustrates each individual child's performance for the segmental and syllabic, singular and plural novel trials in detail.

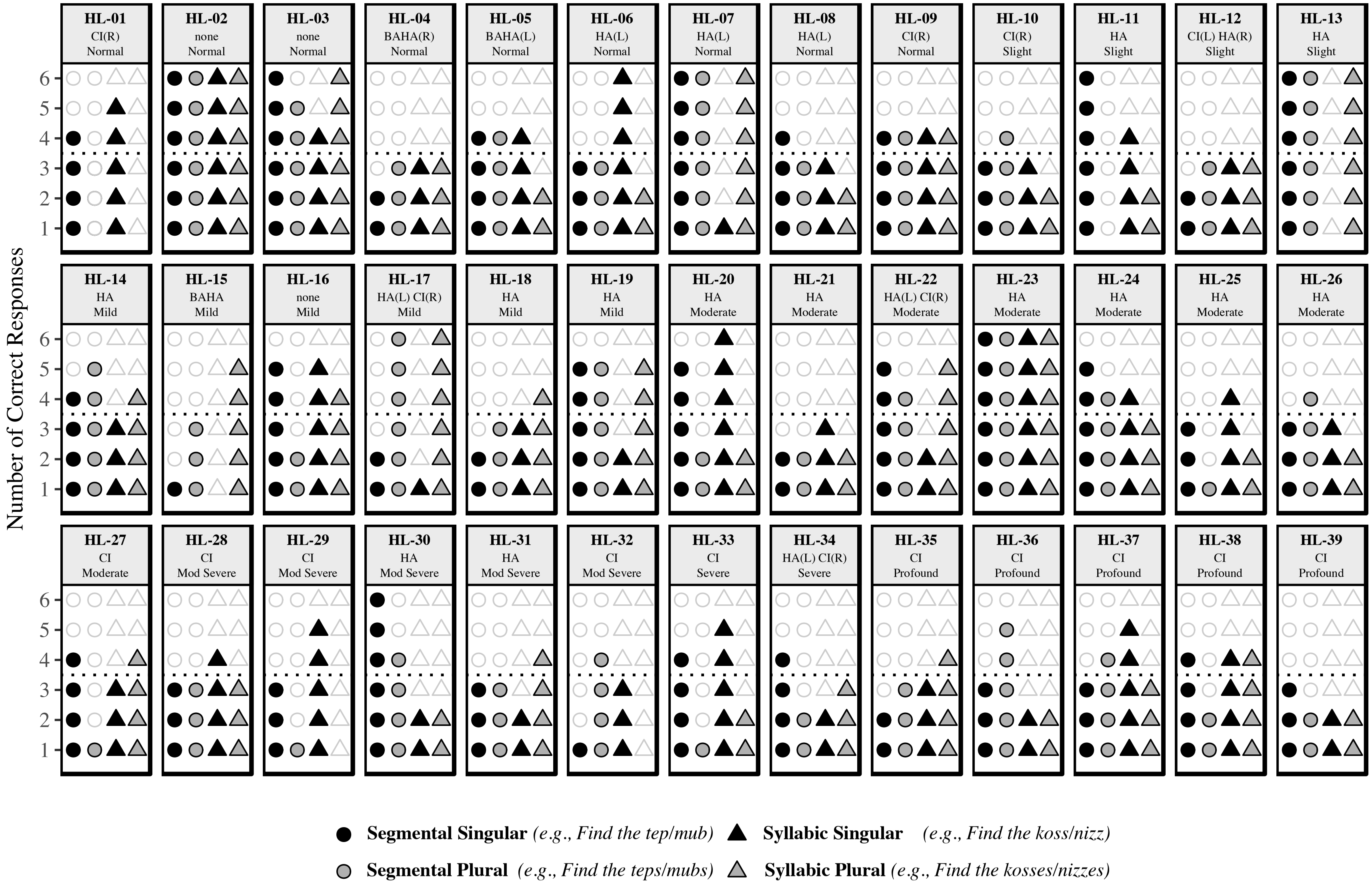


Figure 8: Participants' individual performances in the segmental and syllabic allomorph trials. Filled in shapes indicate correct responses (out of six for each condition).

Research Question Two: *Do children with HL use copula subject-verb agreement to help comprehend novel singular and plural words, and does their degree of hearing loss affect this comprehension?*

To address this question, and see if children with HL used copula information to help them comprehend singular and plural novel words, all participant group scores were averaged for both the singular and plural conditions for both the unambiguous (*Where is the tep?* / *Where are the teps?*) and ambiguous (*Where is the dax?* / *Where are the dacks?*) noun morphology. Planned *t*-test compared each condition to chance (50%). No condition was found to be significantly different from chance (unambiguous singular: $t(38) = 1.75$, $p = .17$ unambiguous plural: $t(38) = 1.95$, $p = .17$; ambiguous singular: $t(38) = -0.55$, $p = .58$; ambiguous plural: $t(38) = 2.13$, $p = .16$). This indicates that children with HL, as a group are not using copula information to help them determine the number of the noun (Figure 9).

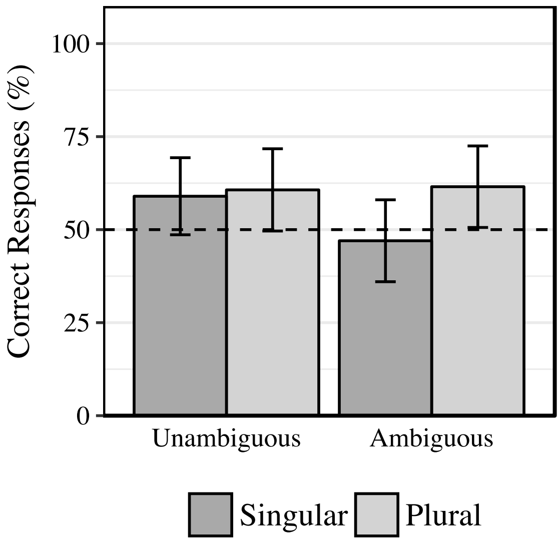


Figure 9: Mean correct responses for copula trials by number and noun morphology ambiguity. Error bars ± 95%CI

To better compare children's performance in the copula trials with unambiguous and ambiguous noun morphology, while again taking into consideration their degree of HL, a binomial generalized linear mixed-effect model was fitted over the copula trials using the *glmer* function in the *lme4* package (Bates, Mächler, Bolker & Walker, 2015). The fixed effects and interactions (intercepts underlined) were *Morpheme* (unambiguous, ambiguous) and *Number* (singular, plural). *HL Group* (normal-slight, mild-moderate, mod severe-profound) was a fixed effect. To achieve maximal generalisability, the model again included a maximal random effects structure (Barr, Levy, Scheepers, & Tily, 2013). Random slopes of *Subject* (by *HL Group*) for fixed effects were included (*Morpheme* and *Number*). Potential item effects were accounted for with random intercepts included for *Auditory Stimulus*, *Target Picture* and *Distractor Picture*. A random slope and intercept for *Selected Side* by *Subject* was also included. One significant main effect and one trending main effect were discovered for *HL Group* (Mild-Moderate: z = -2.02, p = .04; Mod Severe-Profound: z = -1.77, p = .07). A trending main effect was found for *Morpheme* (ambiguous: z = -1.79, p = .07). Although there is much variability for each group, Figure 10 shows that degree of HL also affected children's accuracy, using copula information to a greater degree with ambiguous nouns.

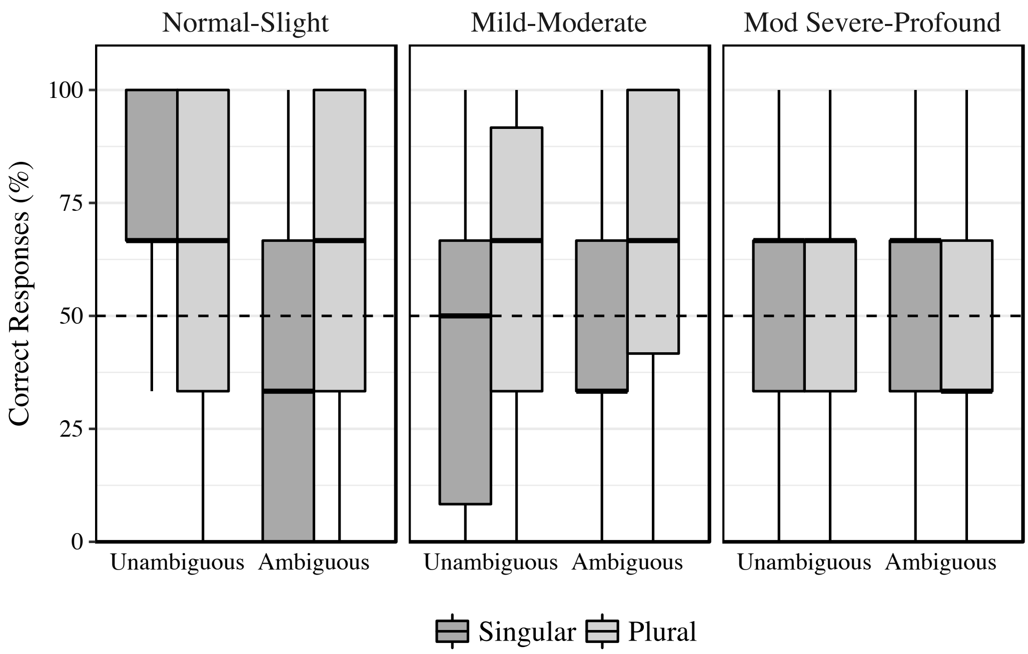


Figure 10: Correct responses for copula trials, by noun morphology ambiguity, number and degree of HL.

To better investigate the effect that degree of HL has on children's comprehension of copula subject-verb agreement, a Pearson's correlation test compared children's better ear four frequency average loss to their correct responses in the copula trials. Since previous study with NH children (Davies et al., in prep.b) had shown that participants systematically chose the plural distractor picture, the ambiguous singular trials were not included in the two subsequent tests. A significant negative correlation was discovered between children's better ear four frequency average loss and percentage correct responses ($r = -.33$, $p < .04$), showing that children with a milder loss generally performed better (Figure 11).

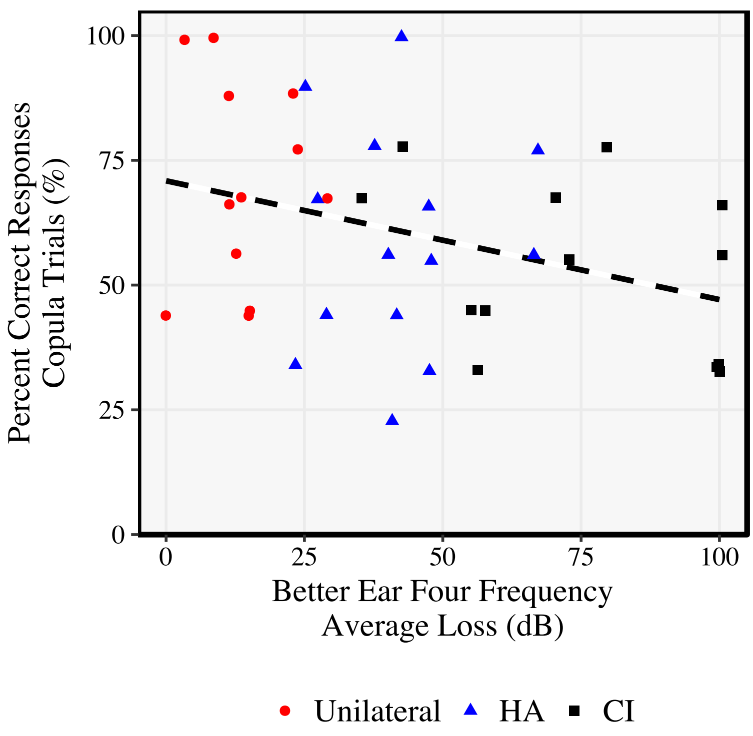


Figure 11: Correlation between children's correct responses for copula trials and their better ear four frequency average loss. r = -.33; *p* = .04*

To investigate the relationship between children's age and their comprehension of copula number, as well as the relationship between their comprehension and months of speech access through their hearing device, Pearson's correlation tests compared the age and auditory access (in months) of children with HL to their total scores for all copula trials. Surprisingly, neither age (r = .04; $p = .78$) nor access (r = .09, $p = .88$) were significant (Figure 12).

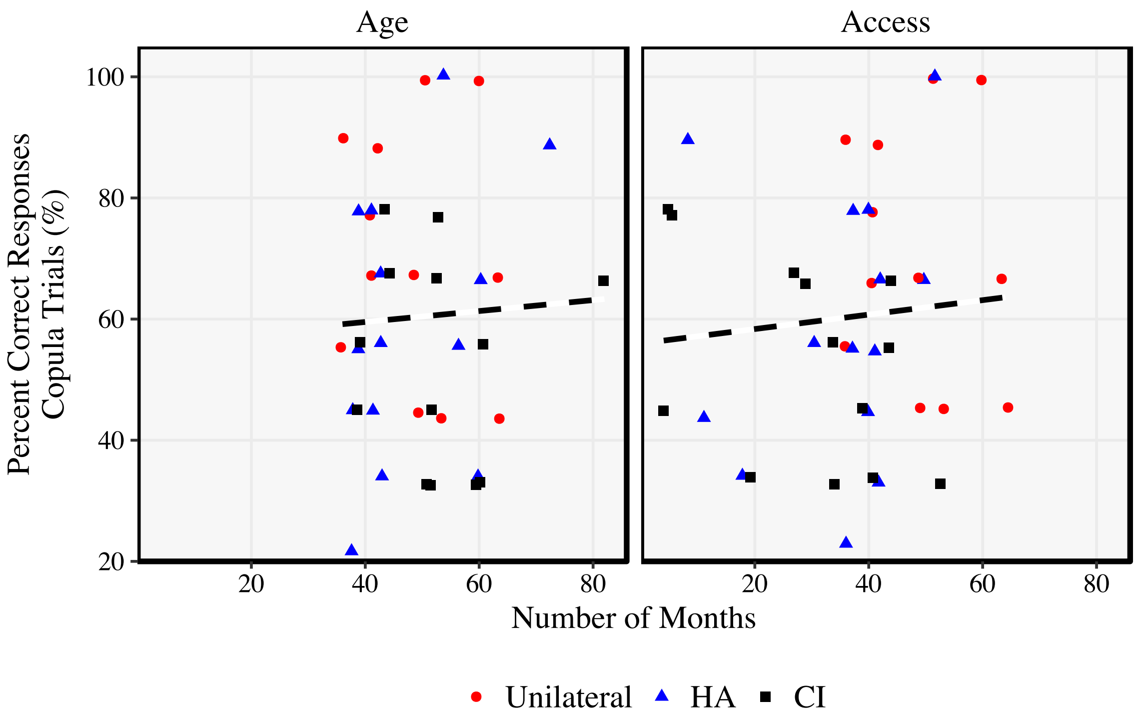


Figure 12: Correlations between children's correct responses for copula trials and their age and months of ideal speech access.

Finally, a Pearson's correlation test examined the relationship between children's performance on the nominal morphology trials and the copula trials. A positive correlation was discovered (r = .48, $p < .01$) (Figure 13), showing that individuals who did relatively well in the morphology trials also did relatively well in the copula trials, and vice versa. A paired *t*-test furthermore revealed no significant difference between the trial types ($t(38) = 1.03$, $p = .32$).

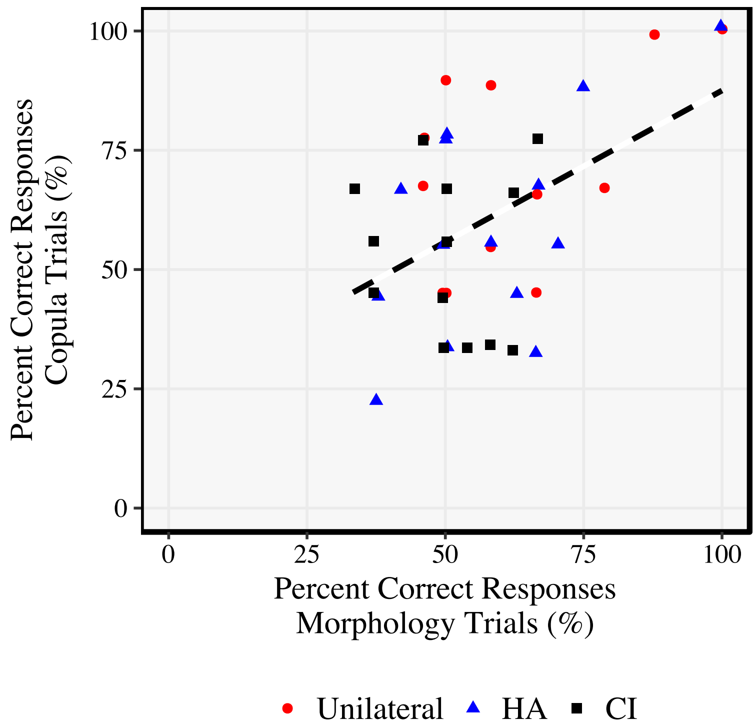
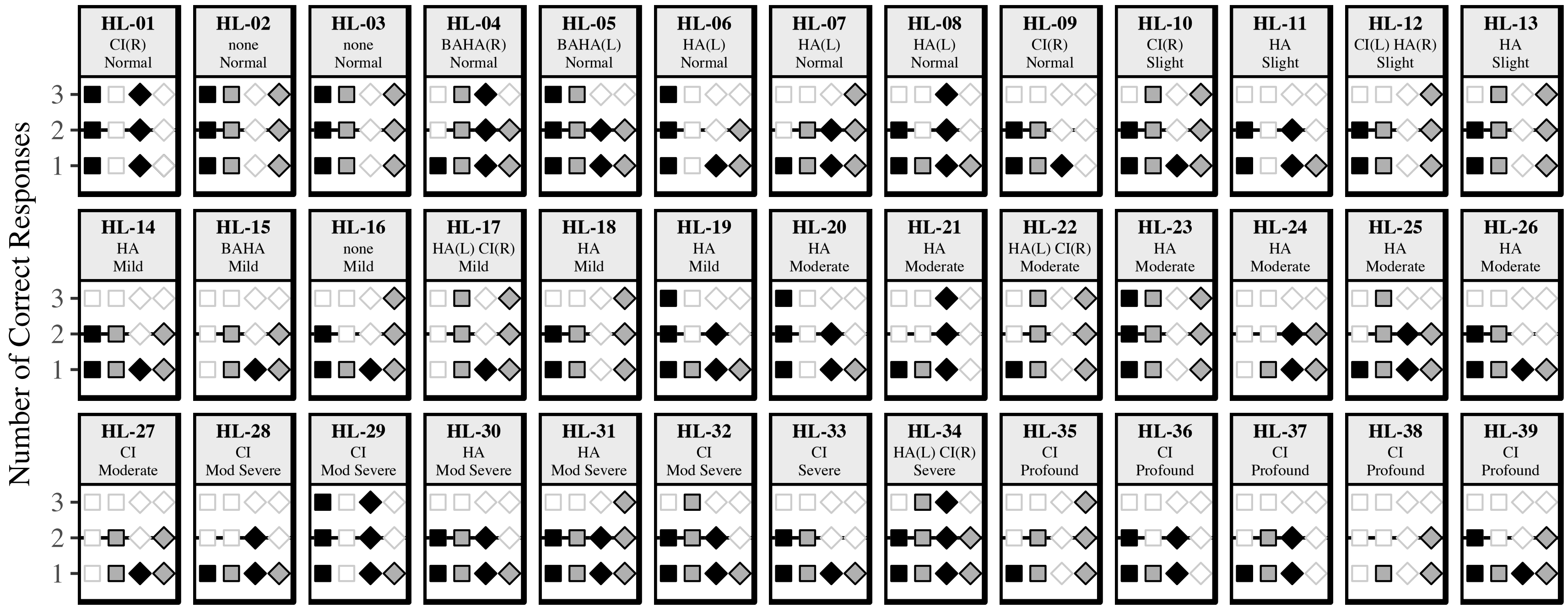


Figure 13: Correlations between copula trials and morphology trials.
r = .48, *p* < .01**

In sum, as a group, children with HL did not use copula subject-verb agreement to comprehend the number of novel nouns. However, there was a relationship between the degree of hearing loss and performance in these trials, with those with better hearing performing better. However, there does not seem to be a relationship between performance and age or the duration of speech access through their hearing device. Figure 14 shows individual children's performances for the copula trials.



■ **Unambiguous Singular** *(e.g., Where is the tup?)* ◆ **Ambiguous Singular** *(e.g., Where is the dax?)*

□ **Unambiguous Plural** *(e.g., Where are the tups)* ◇ **Ambiguous Plural** *(e.g., Where are the dacks?)*

Figure 14: Participants' individual performances in the copula trials. Filled in shapes indicate correct responses (out of three for each condition)

DISCUSSION

The present study examined the comprehension of inflectional morphology by pre-schoolers with hearing loss (HL). Specifically, it examined children's understanding of the English plural. This is a critical issue as it is well known that children with HL face challenges with perceiving fricative sounds that contain high frequency noise, as found in the English plural. It is also critical as plurals play an important part in the grammar of English (and many other languages), potentially impacting higher levels of language and discourse function.

In a forced choice task using novel words and pictures, children's comprehension of the segmental (/-s/ and /-z/) and syllabic (/-əz/) plural allomorphs was tested, as well as their attention to number information in the copula subject-verb agreement (*is* and *are*). Novel words and pictures were used to test children's productive ability to use morphological and agreement cues with words they had never heard before. The results suggest that, at least as a group, these pre-schoolers were unable to use either plural morphology or copula subject-verb agreement information to identify the number condition of novel nouns.

Children's acquisition of inflectional morphology can be affected by the perceptibility of the morphemes in their speech input (Hsieh, Leonard & Swanson, 1999, Sundara, Demuth & Kuhl, 2011). Because children with HL have particular difficulty perceiving phonemes such as /s/ and /z/ (Pittman & Stelmachowicz, 2003), it was hypothesised that they may struggle to comprehend novel nouns inflected with the segmental plural allomorphs /-s/ and /-z/. However, because the syllabic plural is much easier for children with HL to perceive, the question was raised as to whether they would be able to comprehend novel nouns inflected with /-əz/. Indeed, previous research has shown that in their day-to-day speech, children with HL master words inflected with the syllabic plural earlier than words inflected with the segmental allomorphs (Koehlinger et al., 2015). However, the present study found no evidence that, as group, preschool-aged children with HL understand either the segmental or the syllabic plural allomorphs on novel words.

This result is concerning, as NH children at this age are able to apply their understanding of English plural morphology to help them comprehend novel words in an identical forced choice task (Davies et al., in prep.b). The current results therefore suggest that, as a group, children with HL are delayed in their acquisition of English inflectional plural morphology, at least in the case of novel, or previously unheard words. While the results do show that the children with a lesser degree of HL tended to do better than those with severe or profound loss, it is still concerning that the majority of the children with a unilateral HL, most of whom had normal hearing in one ear, demonstrated only marginal evidence of understanding plural morphology. Some older children, and children who had had auditory access through their hearing device for longer tended to perform better on the task, but others performed at chance (e.g., HL-28, HL-39) or displayed a bias by predominately selected all plural or all singular pictures regardless of auditory stimuli (e.g., HL-01, HL-17). A few participants demonstrated a good understanding of plural morphology across the board (e.g., HL-02, HL-03, HL-17), but both HL-07 and HL-13 consistently chose plural pictures for all /s/- and /z/-final novel word stimuli, even for forms such as *koss* and *nizz* that cannot be morphologically decomposed (e.g., *koss* ≠ **ko*+*s*). The word-final fricatives could have been interpreted by the children as plural marking, which was not indicated by results in an earlier study with 3-year-olds with NH (e.g. *bus, rose*; Davies et al., in prep.a,b). Even children with early-fitted CIs, who have otherwise been shown to have promising language outcomes (Dettman, et al., 2007), performed at chance on this task.

However, as a group, children with HL are able to identify stop-final novel CVC words as singular (e.g., *tep*, *deg*). This is an intriguing finding, as previous IPL tasks have suggested that toddlers acquire an understanding of singular forms *after* having acquired the comprehend the plural (Davies et al., 2017). Furthermore, NH 4-year-olds were found to be significantly better at identifying novel plural forms than novel singular forms in a task identical to the present one (Davies et al., in prep.b). Results from the current study, however, seem to suggest that the opposite may be true for children with HL. Perhaps children with HL are more certain about the identity of stop final words than they are for words ending in a fricative. However, closer inspection of the individual results suggests that this may be being driven by roughly five or so children with a singular picture bias (e.g., HL-01, HL-11, HL-20, HL-29 and HL-33) . Data from more participants will help address this issue.

The present study also looked at children's understanding of copula (*is*/*are*) subject-verb agreement with the following noun. Because children with HL may have variable access to plural morphemes on the ends of nouns (Pittman & Stelmachowicz, 2003), it was hypothesised that they might pay more attention to the more perceptually salient copula. However, there was little evidence that the pre-schoolers in the current study understand copula information during this task. Nonetheless participants HL-02, HL-03, HL-13 and HL-23 all correctly identified trials with plural stimuli such as *where are the tups?* and *where are the dacks?* as having a plural target, as well as trials with singular stimuli such as *where is the tup?* as having a singular target. The first two participants had unilateral hearing loss, and the others had mild to moderate hearing loss. However, in the singular copula trials with ambiguous noun morphology stimuli, such as *where is the dax?* these participants also identified the target as being plural, ignoring the copula information. In this respect they behaved identically to their NH peers (Davies et al., in prep.b). Participants HL-05 and HL-34 also correctly interpret *where are the tups?* and *where are the dacks?* as plural, and *where is the tup?* as singular. They also interpreted *where is the dax?* as being *singular*, suggesting that at least *some* children with HL do rely on the copula to provide cues to number in a sentence.

Interestingly, while there was again a negative correlation between children's degree of HL and their performance in the copula trials, no correlations were found between children's performance and their age or length of ideal auditory access. It is not clear why this is the case. It is possible that children such as HL-34, who showed no evidence of understanding inflectional plural morphology, but did show evidence of understanding copula subject-verb agreement, is lifting the scores of the poorer performers and thus flattening out the correlation. What is clear, however, is that as a group, pre-schoolers with HL failed to demonstrate comprehension of either plural morphology or copula subject-verb agreement in this forced choice novel word task. Did the children in this study do poorly because they lack a solid understanding of plural morphology? Or did other factors make the task too difficult for them to adequately be able to demonstrate their knowledge? Given there was a significant correlation between age and performance on the morphology trials, it is likely that a robust understanding of plural morphology will be found with older children.

One aspect of the study that may have made the task challenges was the use of novel words. In a forced choice task with NH Mexican-Spanish speaking children aged 40-50 months it was shown that their understanding of subject-verb agreement with familiar words vanished with the introduction of novel words (Gonzalez-Gomez et al., 2017). This could mean that children with HL do have an understanding of inflectional plural morphology and copula subject-verb agreement, but that the current task was simply too demanding. Note, however, that their NH peers had little difficulty with this task (Davies, et al., in prep.b). Indeed, in studies that implement novel word tasks, such as in word-learning and fast-mapping paradigms, NH children outperform children with HL. This suggests that encountering words for the first time is generally more challenging for children with HL, perhaps increasing the working memory load due to children's difficulty encoding phonological information (Gilbertson & Kamhi, 1995; Lederberg, Prezbindowski & Spencer, 2000). Another reason the current task may have been challenging for the children with HL is that the stimuli were presented through a speaker, rather than with a live voice. Children with HL do show a comprehension advantage when they receive visual alongside auditory cues (Bergeson, Pisoni & Davis, 2003), so perhaps the absence of a human interlocutor put children with HL at a disadvantage in interpreting the auditory stimulus cues.

The results of this study suggest that it may take some children with HL longer to establish robust grammatical representations. The plural morpheme studied here is an early acquired inflectional morpheme, raising questions about when and how other grammatical morphemes are learned. The plural results also have implications for the development and use of lexical representations, which is known to be slow, even for older children with much longer use of devices (McMurray, Farris-Trimble, Seedorff, & Rigler, 2016). Tools like the one used in this study are very useful for conducting research on children's development knowledge or grammar; it is hoped that they may also be useful as a therapeutic tool, providing children with HL with the practice needed to expand their knowledge of language.

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CHAPTER 6: THESIS DISCUSSION

General Discussion

This thesis explored children's gradually developing understanding of the singular and the plural in English, and examined how children acquire representations of morphological structure. Even though children use plural nouns appropriately in their everyday speech by the age of two (Brown, 1973; de Villiers & de Villiers, 1973; Mervis & Johnson, 1991), the four studies presented in this thesis suggest that children's acquisition of plural morphology does not stop at their second birthday. Indeed, at the age of two, children's understanding of morphological structure (e.g., *cats* vs. *cat+s*) appears to be limited to the voiceless segmental plural allomorph /-s/. Children thus appear to initially acquire the English plural morpheme allomorph by allomorph, and their understanding morphological structure gets gradually better over time. By the age of three, they are able to comprehend novel singular nouns as well. However, in contrast to their increasing proficiency with plural forms, children do not seem to get better with singulars at the same rate. Furthermore, despite previous research indicating that children can use copula subject-verb agreement (*is*, *are*) to assist their comprehension of singular and plural forms (Kouider et al., 2006; Lukyanenko & Fisher, 2016; Deevy, Leonard & Marchman, 2017), the study presented in chapter four suggests that children ignore the copula altogether when determining the number condition of a noun, at least when morphological cues are present on the noun itself. Finally, this thesis demonstrates the detrimental effect hearing loss has on children's acquisition of plural morphology.

Allomorphic variation of the English plural

This thesis examined whether allomorphic variation had an effect on children's acquisition of plural morphology. The findings suggest that both perceptual salience and input frequency play a role in how children initially acquire plural allomorphs. By roughly the age of three, however, children have developed representations for all three plural allomorphs, and are equally competent at identifying novel words inflected with /-s/, /-z/ or /-əz/. However, for children with hearing loss, there is little evidence that allomorphic variation plays a role in comprehension, as children aged 3 to 7 years (with a few exceptions) provided little evidence of having any understanding of plural morphology. However, this thesis did not carry out IPL studies with the children with hearing loss. This would be an interesting follow-up study to pursue.

For children with normal hearing, their initial understanding of plural morphology appears to be restricted to the segmental voiceless plural allomorph /-s/. In chapter two, 24-month-olds' understanding of plural morphology was explored through a novel word IPL task. The results showed children were able to comprehend novel words inflected with the voiceless plural allomorph /-s/ (e.g., *dups* /dɐps/), but did not demonstrate comprehension of novel words inflected with voiced plural allomorph /-z/ (e.g., *degs* /degz/). Indeed, a previous IPL experiment had similarly suggested that children acquire an understanding of plural /-s/ before the other plural allomorphs /-z/ and /-əz/, but the result in that experiment only trended towards significance, as it was not specifically exploring allomorphic variation (Kouider et al., 2006). A subsequent analysis of a child language corpus (the Providence Corpus; Demuth, Culbertson & Alter, 2006) suggested this comprehension difference could not be driven by input frequency, as plural /-s/ was found to be three times less frequent in children's input than plural /-z/.

However, an acoustic analysis on the experimental stimuli showed that the voiceless plural /-s/ stimuli had a longer closure and burst+frication duration than the voiced plural /-z/ stimuli. The acoustic differences found between /s/ and /z/ were unlikely idiosyncratic to those experimental stimuli in particular, as similar duration differences have been previously reported (Crystal & House, 1988; Stevens et al., 1992). The findings in chapter two therefore suggest that children's better comprehension of plural /-s/ is due to its greater perceptual salience.

These results are not the first to show that perceptual salience plays a role in children's comprehension of inflectional morphemes. Utterance position also affects the duration and perceptual salience of grammatical morphemes. Children have been shown to be more aware of morphemes in the perceptually salient utterance-final position than the less salient utterance-medial position (Sundara, Demuth & Kuhl, 2011). What has been demonstrated for the first time in this thesis, however, is that the acoustic differences between different allomorphs plays an important role in when and how children comprehend different versions of a particular morpheme.

Even though perceptual salience affects children's acquisition of plural allomorphs, it cannot be the only driving factor. In chapter three, an IPL experiment tested 30- and 36-month-old children's comprehension of novel words inflected with the syllabic plural allomorph /-əz/ (e.g., *kosses*, /kɔsəz/). The results show that 36-month-olds understand plural /-əz/, but that 30-month-olds (probably) do not. That is, the results show that children acquire an understanding of the syllabic plural /-əz/ a full year after first demonstrating an understanding of voiceless plural /-s/. Furthermore, analysis of children's looking behaviour suggests that online comprehension of syllabic plural /-əz/ on novel nouns happens quite slowly, as it took the children over two seconds to shift their gaze significantly towards the target plural picture. This could demonstrate that young children's processing of morphologically complex novel words is slower than that for morphologically simple words, However, it is not clear if any differences would be found between the processing times of /-s/, /-z/ and /-əz/. This is also an interesting area for further research.

Taken together, chapters two and three of this thesis suggest that children's acquisition of plural allomorphs is driven by a combination of perceptual salience and input frequency.

The corpus analysis found that the syllabic plural allomorph /-əz/ only accounted for roughly 6% of the plural inflections that children received in their input, by type and token. Perhaps, as suggested by Marcus et al. (1991), children first acquire fully inflected words as whole units, only to later reanalyse them into complex morphological structures after receiving sufficient evidence to do so. In that vein, perhaps children are late to generalise plural /-əz/ into a productive form because it occurs so infrequently in their input, even though it is easily perceptible.

Despite evidence that children acquire an understanding of plural morphology in an allomorph-by-allomorph fashion, it appears that once children have acquired all of the English plural allomorphs, they are equally able to comprehend them. In chapter four, children aged between 3 and 5 years showed few problems in identifying novel words inflected with /-s/, /-z/ and /-əz/ in a forced choice task. However, it is worth noting that even though children were able to do the task, and could generally identify novel words such as *dups* and *kosses* as being plural, the younger children did not perform at ceiling. However, as children got older, their accuracy increased for the plural trials. While this may simply show that children get better at forced choice tasks with age (although their performance on the singular trials did not improve), it is perhaps evidence that children's acquisition of plural morphology is a gradual process, rather than a sudden eureka moment.

Finally, chapter five investigated whether allomorphic variation would have an effect on plural comprehension for pre-schoolers with hearing loss. A previous study looking at the effect of allomorphic variation on children's production found that children with hearing loss were more likely to produce plural words inflected with the syllabic plural /-əz/ than its segmental counterparts, /-s/ and /-z/ (Koehlinger et al., 2015). However, in the novel word forced choice task presented in chapter five, no evidence was found to suggest that children with hearing loss were better able to comprehend one plural allomorph over another. In fact, children's performance for the most part was no different to chance, regardless of allomorph, or indeed whether the target was singular or plural. The results of this study thus raise questions about if and when children with hearing loss develop representations of morphological structure.

MORPHOLOGICAL STRUCTURE AND THE ENGLISH SINGULAR

This thesis also explored children's developing understanding of the English singular. Because the singular in English is marked by the absence of the plural morpheme, it was thought that children might acquire an understanding of the singular only after acquiring the plural. In other words, for children to notice that a plural morpheme is absent from the end of a noun, they need to know that it could be there, but it is not.

Indeed, the results in chapter two indicate that while 24-month-olds have some understanding of plural morphology on novel nouns (albeit limited to the voiceless plural allomorph /-s/), they show no understanding of novel singular nouns. However, by at least 36 months of age, children have been reported to able to understand novel singular forms (Kouider et al. 2006). Yet, it was unclear whether children's performance in that task was due to an understanding of morphological structure. Indeed, Berko (1958) suggested that children's early understanding of plural morphology might not be based on morphological structure at all, but rather on an /s/- or /z/-final heuristic in which all words ending in /s/ or /z/ are be regarded as plural, and all others as singular.

Therefore, in chapter three, 30- and 36-month-olds were tested on whether they would be able to comprehend singular novel words such as *koss* /kɔs/ and *nizz* /nɪz/. Despite ending with the fricatives /s/ and /z/, these novel words cannot be plural, as the morphological structures of ko+s and ni+z would result in the phonotactically illegal singular words *ko (*/kɔ/) and **ni* (*/nɪ/), both ending in an illicit short (lax) vowel. Results showed that

36-month-olds successfully identified these words as singulars, demonstrating that they have a good understanding of both singular and plural morphological structure. Furthermore, while 30-month-olds did not appear to interpret these forms as singular, they did not interpret them as plural either, disproving any /s/- or /z/-final heuristic hypothesis. Analysis of children's looking behaviour in this task revealed that the 36-month-olds shifted their gaze significantly towards the singular target picture roughly a second after hearing the novel word. This is over a full second earlier than they shifted their gaze towards the plural target picture. This could perhaps suggest that, despite predictions above to the contrary, the singular is in fact easier (or at least quicker) for children to process.

In chapter four, 3-year-olds were found to be equally accurate at identifying novel singular words and novel plural words in a forced choice task. However, by 4 years of age, children were significantly better at identifying novel plurals compared to singulars. Thus, while children got gradually better at identifying plurals with age, their ability to identify singular novel words appeared to plateau. It is unclear what is behind this result, with further investigation needed. One possibility is that this flat developmental trajectory may be due to children's evolving understanding of the complexity of uninflected wordforms. Uninflected nouns are not always semantically singular. For example, mass nouns (e.g., *chocolate*, *water, milk*) have the same uninflected form as singulars, yet do not indicate a referent of one. Similarly, group nouns (e.g., *pack*, *group*, *herd*) do not indicate a referent of one, in fact quite the opposite. As they get older, children may be more aware of the alternative meanings of uninflected nouns other than singular, which may impact upon their performance in forced-choice tasks such as the one presented in chapter four. Future studies looking at adult populations could help clarify this issue.

Overall, however, these results show that the singular cannot simply be regarded as the flip side of the plural. Chapter three thus reveals potential processing differences between children's comprehension of singular and plural, and chapter four suggests these two conditions are on separate developmental trajectories.

PLURAL MORPHOLOGY AND COPULA SUBJECT-VERB AGREEMENT

It was predicted that children's comprehension of singular and plural nouns would be assisted via copula subject-verb agreement (i.e., *is*, *are*). Previous research has shown children as young as 30 months are able to use the copula to help facilitate comprehension of plural nouns (Lukyanenko & Fisher, 2016), and three-year-olds can use the copula to help identify singular and plural pictures before these are even named (Deevy, Leonard & Marchman, 2017). In the forced choice task in chapter four, it was predicted the children would be more accurate in trials with copula subject-verb agreement than in trials without. Furthermore, it was predicted that children would use the copula to help resolve number ambiguity in novel words ending in /ks/ clusters (e.g., *dax*), which can either be singular (e.g., *box*, *fox*) or plural (e.g., *socks*, *clocks*).

The results, however, found that children ignored the form of the copular to determine the referent. Children were no more accurate in trials with copula agreement than they were without. In trials with novel words ending in /ks/ clusters, children routinely selected the plural picture, regardless of the copula number. That is, children chose the plural picture regardless of whether the stimulus was "*Where is the dax?"* or *"Where are the dacks?"*. Because the children appeared to exclusively rely on nominal morphology for number cues, and ignore the copula altogether, it is unclear what relationship exists between children's representations of nouns and verbs when it comes to their comprehension of singular and plural.

These findings sit awkwardly with previous research both 24-month-olds (Kouider et al., 2006) and 30-month-olds (Lukyanenko & Fisher, 2016) can use determiner and copula agreement respectively to identify singular and plural novel nouns. However, scant evidence was discovered for this in the current forced choice task. Perhaps as children develop a more robust understanding of morphological structure, they rely more on nominal morphology as their primary cue to number.

HEARING LOSS AND THE ACQUISITION OF PLURAL MORPHOLOGY

Hearing loss is a known obstacle to children's acquisition of plural morphology, as children's access to high frequency fricative sounds such as /s/ and /z/ is often disproportionately affected (Stelmachowicz, Pittman, Hoover & Lewis, 2002; Pittman & Stelmachowicz, 2003). Children with hearing loss suffer delays in both production and comprehension of plural morphology (Young & Killen, 2002; McGuckian & Henry, 2007; Moeller et al., 2010; Koehlinger et al., 2013). In chapter five, a novel word forced choice task explored what effect hearing loss had on children's representations of morphological structure. As previous research has shown that children master the syllabic plural allomorph /-əz/ in their speech before the segmental allomorphs /-s/ and /-z/ (Koehlinger et al., 2015), it was thought that children with hearing loss aged 3 to 7 might at least be able to comprehend novel words inflected with that allomorph. However, the results of this study suggest that even a unilateral loss is enough to affect children's acquisition of English singular and plural. While some children did demonstrate an understanding of plural morphology, many did not, especially those with a more severe hearing loss. Furthermore, some children showed patterns that were quite different from their normal hearing peers. For example, at least two children interpreted novel singular words such as *koss* and *nizz* as being plural.

The results of this study suggest that children with hearing loss may not yet have established robust representations of morphological structure. While they may be able to use plural words such as *cats* and *dogs* in their day-to-day speech, these words are unlikely to be understood as being morphologically complex, but rather as simple lexical items meaning *more than one cat* and *more than one dog*. Children's performance, although no different to chance overall, did appear to improve with age. Similarly, children's performance appeared to improve with longer duration of use of a hearing device, such as a hearing aid or cochlear implant. This might suggest that children with hearing loss may eventually catch up to their normal hearing peers. This is another area for further research.

BROAD THEORETICAL IMPLICATIONS

While the studies presented in this thesis focused specifically on children's acquisition of English plural morphology, overall they also contribute in some small way towards answering broader theoretical questions regarding the status of morphological representation and its acquisition in general. In dual-route models of morphological representation, acquisition is seen to be driven by domain-specific language phenomena, such as the syntactic and sematic characteristics of a given morpheme (e.g., Marcus et al., 1992; Clahsen, Rothweiler, & Woest, 1992; Clahsen, Aveledo & Roca, 2002; Pinker, 1999). On the other hand, usage-based and connectionist models see morpheme acquisition driven by domain-general properties, and for the most part argue that input frequency plays the most important role (e.g., Bybee & Slobin, 1982; Köpcke, 1998; Bybee, 2001; Plunkett & Marchman, 1991; Dąbrowska, 2004). Because the experiments presented in this thesis employed novel word paradigms, it cannot be claimed that these results *strongly* support one model over the other. However, that being said, these results lend support towards a model of morphological representation that is rule-based rather than one based on input frequency. In chapter two, children were found to be sensitive to plural inflected with the less-frequent voiceless /-s/ plural allomorph than the much more frequent /-z/ plural allomorph. In chapters three and four, children were shown to comprehend novel singular words such as *koss* and *nizz* even though singulars ending with fricatives are relatively rare in English. Furthermore, in chapter four, children interpreted words such as *dax* as plural, even though /ks/-final singular words are present in children's input. Taken together, these studies provide evidence that children are sensitive to the morphological structure of words (or at least in this case, novel ones), which does suggest they have representations of the rules that govern these structures. However, whether children are employing language-domain specific rules in order to complete these novel word tasks, or are instead using more domain-general reasoning skills, is not clear.

STUDY LIMITATIONS

This thesis aimed to investigate children's acquisition of the singular and plural in English, with particular attention on children's understanding of morphological structure. In order to do this, the studies in this thesis employed a novel word paradigm. The use of novel words meant that children were only being assessed on their knowledge of morphological structure, and not their lexical representations. For example, the only way for a child to know that a word such as *teps* is plural is by comprehending its morphological structure as *tep+s*. However, while novel words are certainly useful in this regard, they do make the task difficult for young children. Indeed, there is evidence that the use of novel words can hinder children's ability to demonstrate their linguistic knowledge (e.g., Gonzalez-Gomez et al., 2017). The difficulty of novel words is potentially behind the somewhat confusing results returned by the 30-year-old children in the chapter three study. Even though children at this age did not demonstrate an understanding of the syllabic plural /-əz/ via their difference scores, analysis of their looking behaviour suggested that they may have an emerging understanding of the plural. Without the added difficulty of novel words, children at this age might have been able to convincingly demonstrate a better understanding.

In order to test children with hearing loss during their regular clinical visits, chapter five employed a forced choice paradigm delivered on an iPad. While this design was certainly convenient for data-collection, and offers opportunities to be developed into a clinical tool, it is possible that eliciting direct responses increased the cognitive demands on young participants. If children with hearing loss were instead tested using a more sensitive IPL paradigm, such as those employed in chapters two and three, we might see some evidence of singular and plural comprehension.

All of the studies in this thesis assessed children's comprehension only. It is interesting to note that the results of chapters two and three seem to show that children's comprehension matches previous results found about children's production. Just as /-s/ is understood much earlier than /-əz/, children master production of /s/ earlier than morphological /əz/ (Smit, 1993; Mealings, Cox & Demuth, 2013). More investigation is needed into the link between children's comprehension and production of grammatical morphemes, across different allomorphs.

Another limitation of this thesis is that children's acquisition of the voiced plural allomorph /-z/ was not completely explored. IPL tasks looked at children's acquisition of /-s/ and /-əz/, but did not determine an age at which children develop an understanding of /-z/. In chapter three children's online comprehension of novel words inflected with syllabic plural /-əz/ was explored, yet it is unclear if there would be online processing differences between the plural allomorphs.

FUTURE DIRECTIONS

There is no shortage of questions raised by the studies in this thesis. Further investigation into children's different representations of singular and plural is certainly called for. Chapter four suggested that children struggle to improve their comprehension of the English singular. This may point to difficulty with null morphemes, or it may point to semantic difficulties with *a set of one*. Further studies looking at languages such as Sesotho, which marks both singular and plural form may help answer these questions.

The results in chapter three suggested that children are slower to comprehend inflected plural forms than uninflected singular forms. However, this was only tested on novel nouns inflected with the syllabic plural /-əz/ allomorph, and on /s/- and /z/-final novel singular nouns. Therefore there are opportunities for more research into the other plural allomorphs, other grammatical morphemes, (e.g., past tense or 3SG), and indeed other languages.

Finally, much more research is needed into the morphological representations of children with hearing loss. As a group, the participants tested in chapter five did not demonstrate comprehension of plural morphology. However, this might be because the children tested were too young. A follow up study needs to be conducted on primary school aged children, in order to determine if, and when children with hearing loss develop representations of morphological structure similar to their normal hearing peers. Furthermore, testing young children with hearing loss using an IPL task, rather than a forced choice paradigm might provide a more sensitive measure of their understanding of morphological structure.

IMPLICATIONS AND CONCLUDING REMARKS

This thesis goes some way to paint a picture of how children gradually develop an understanding of the singular and the plural in English, and provides some insight as to how children acquire representations of morphological structure. With a better understanding of how perceptual salience and input frequency, in the form of allomorphic variation, affects children's acquisition, we can better develop therapies and interventions for children who have language delays. Furthermore, we are starting to develop an understanding that the singular and the plural may develop somewhat separately. Typically, language therapies have focused on developing children's skills with plurals, however, results from this thesis suggest that the singular may present its own unique difficulties for the young learner. The importance of this research is best demonstrated in chapter five; by gaining a better understanding of what children’s acquisition looks like for typically developing populations, we can better devise diagnostic and intervention strategies for children who are at risk of language delay, such as those with hearing loss. Overall, this thesis contributes to the growing body of research revealing the remarkable word-learning abilities of young children, and the factors that contribute to this learning path.

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MACQUARIE University

BENJAMIN DAVIES <benjamin.davies1@students.mq.edu.au>

RE: HS Ethics Application - Approved (5201401065)(Con/Met)

1 message

Fhs Ethics <fhs.ethics@mq.edu.au> Fri, Nov 28, 2014 at 2:10 PM
To: Professor Katherine Demuth <katherine.demuth@mq.edu.au>
Cc: Dr Nan Xu <nan.xu@mq.edu.au>, Mr Benjamin Luke Davies <benjamin.davies1@students.mq.edu.au>, Mrs Katherine Revius <katherine.revius@mq.edu.au>, Miss Hui Chen <hui.chen15@students.mq.edu.au>

Dear Professor Demuth,

Re: "The Acquisition of English Plural Morphology and Allomorphy"(5201401065)

Thank you very much for your response. Your response has addressed the issues raised by the Faculty of Human Sciences Human Research Ethics Sub-Committee and approval has been granted, effective 28th November 2014. This email constitutes ethical approval only.

This research meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). The National Statement is available at the following web site:

http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf.

The following personnel are authorised to conduct this research:

Dr Nan Xu
Miss Hui Chen
Mr Benjamin Luke Davies
Mrs Katherine Revius
Professor Katherine Demuth

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research (2007).

2. Approval will be for a period of five (5) years subject to the provision of annual reports.

Progress Report 1 Due: 28th November 2015
Progress Report 2 Due: 28th November 2016
Progress Report 3 Due: 28th November 2017
Progress Report 4 Due: 28th November 2018
Final Report Due: 28th November 2019

NB. If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/

human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Sub-Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

4. All amendments to the project must be reviewed and approved by the Sub-Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

5. Please notify the Sub-Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.

6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:

http://www.mq.edu.au/policy

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy

If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.

If you need to provide a hard copy letter of approval to an external organisation as evidence that you have approval, please do not hesitate to contact the Ethics Secretariat at the address below.

Please retain a copy of this email as this is your official notification of ethics approval.

Yours sincerely,

Dr Anthony Miller
Chair
Faculty of Human Sciences
Human Research Ethics Sub-Committee

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