Learning the plural from variable input:
An eye-tracking study of Chilean children's plural comprehension

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Abstract

Natural languages frequently display both consistent and variable morphological patterns. Previous studies have indicated that variable morphological patterns are mastered more slowly than consistent ones. In particular, it has been argued that Chilean children, who are exposed to variable plural-marking, take longer to consistently associate the plural marker to a more-than-one interpretation than children who are exposed to non-variable plural-marking (e.g., children from Mexico City). Building on this previous work, the present study assesses Chilean children's ability to associate the plural marker to a more-than-one interpretation in both an act-out task and an eye-tracking task, in order to compare performance across different contexts and between offline and real-time comprehension, and to enrich our understanding of the acquisition of variable morphology.

120 words

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Introduction

Theoretical accounts of how children learn the morphology of their native language often assume that form-meaning pairs (e.g., Spanish nominal suffix /-s/ = plural) are consistent in the input (e.g., Pinker, 1984; Ramscar, Dye, & McCauley, 2013). This assumption allows the theoretical learner to approach the adult grammar by changing their system anytime they observe an unexpected form (Chang, Dell, & Bock, 2006; Pinker, 1984; Yang, 2002). However, natural languages are not always so well-behaved: Most display both consistent patterns (e.g., Spanish verbal suffix +r indicates an infinitival verb) and variable patterns (e.g., Spanish nominal suffix +s indicates plurality, but is variably omitted).

The majority of language acquisition research focuses on the acquisition of properties that are non-variable (e.g., Berko, 1958; R. Brown, 1973; Davies, Xu Rattanasone, & Demuth, 2017), or on how children's use of sociolinguistic variability becomes adultlike (e.g., Author, 2013; Roberts, 1997; Roberts & Labov, 1995; Smith, Durham, & Fortune, 2007, 2009). Some have examined how children learn rules from input with structured versus unstructured variability (e.g., Hudson Kam & Newport, 2005, 2009; Singleton & Newport, 2004). Only a few have explored the acquisition of categorical components associated with conditioned variability (Author, 2012, 2013; Author & Author, 2012; Samara, Smith, Brown, & Wonnacott, 2017).

One series of studies has examined the impact of phonological variability on the acquisition of grammatical morphology (e.g., Author, 2007, 2013; Author & Author, 2010), using plural marking in varieties of Spanish with and without variable syllable-final /s/ lenition as a test case. Because this process affects the production of the plural /-s/, children learning these varieties are exposed to input in which the plural morpheme /-s/ is sometimes saliently present on plural nouns, determiners and adjectives, and sometimes subtle or absent (Lipski, 1984; Author, 2007; Poplack, 1980). When paired with a plural referent, the presence of /-s/ in the determiner phrase provides evidence for mapping the affix to plurality, and its absence provides evidence against such a mapping.

Studies comparing plural acquisition in children learning Mexican Spanish (Mexico City), which has no /s/ lenition, and children learning Chilean and Dominican Spanish, which have /s/ lenition, have consistently reported that children with variable input are less likely to interpret overtly marked plural forms as indicating plural meaning than adult speakers of the same varieties or children with consistent input (Author, 2007; Author & Author, 2010, 2012). Various offline tasks (act-out, picture matching, elicitation) showed substantial differences between 3- to 5-year-old Mexican children and Chilean and Dominican children of the same age. Children's performance typically differed until about 5-6 years of age. Author (2007) and Author and Author (2012) interpret these and related findings (e.g., Johnson, de Villiers, & Seymour, 2005; Moore, 1979) as indicating that variable input slows the time course of acquisition, but not its ultimate outcome.

Up to this point, research has primarily focused on whether children have or have not *fully* acquired a variable form at a particular age, but it is likely that the pattern of acquisition is more complex than such an approach can capture. Children might produce or comprehend the variable form in some contexts but not others, they might produce it but not use it in comprehension or vice versa, or they might use it in implicit but not explicit tasks. A finer-grained approach to studying the acquisition of variable forms is necessary to characterize the process.

The current study begins to address this issue by using two different tests of plural comprehension with the same children: an act-out task and a visual-world eye-tracking task. Both have previously been used to assess plural and quantifier comprehension (Arias-Trejo, Cantrell, Smith, & Alva Canto, 2014; Barner, Chow, & Yang, 2009; Kouider, Halberda, Wood, & Carey, 2006), and their differing task demands have been argued to interact with the time course of learning (Chang et al., 2006), with sensitivity appearing earlier in implicit tasks like eye-tracking. Previous studies have shown that around 5-6 years of age, Chilean children begin to consistently associate the plural marker to a plural interpretation, but that earlier many children do not (e.g., Author & Author, 2012). We test Chilean 4- to 6-year-olds' knowledge of the variable plural marker in both types of tasks with the goal of obtaining a finer-grained understanding of their knowledge, its development across this age range, and the relationship between the two tasks.

Linguistic Background

Plural Morphology in Spanish

In Spanish, number is reflected on all elements of the Determiner Phrase (DP, i.e., determiners, quantifiers, nouns, adjectives), and in verbal agreement, as shown in (1). In the DP, plurality is indicated by the addition of an /-s/ or, in the case of a consonant-final root, /-es/, see (1b).

(1) a. La niña feliz está en el patio.
the.F.SG girl.F.SG happy.SG BE.3SG in the.M.SG backyard.M.SG
"The happy girl is in the backyard"

b. Las niñas felices están en el patio.
the.F.PL girl.F.PL happy.PL BE.3PL in the.M.SG backyard.M.SG
"The happy girls are in the backyard"

/s/ Lenition and Plural Marking

In some varieties of Spanish (e.g., those spoken in Mexico City and Madrid) the plural morpheme is consistently realized as the alveolar fricative [s], but in many varieties, including Chilean Spanish, a phonological process frequently results in the deletion [∅] or aspiration [h] of syllable-final /s/ (e.g., Brown & Torres Cacoullos, 2003; Cepeda, 1995; Erker, 2010; File-Muriel & Brown, 2011; Lipski, 1984; Author, 2013; Poplack, 1980). This process, known as /s/-lenition, affects both morphological /-s/ (e.g., gato-s /gatos/ 'cat-pl') and non-morphological /s/ (e.g., lapiz /lapis/ 'pencil', están /estan/ 'are').

The examples in (2) show possible pronunciations of (1b). Children learning non-leniting varieties of Spanish hear only (2a), in which each /s/ is realized as the alveolar fricative, while children learning Chilean Spanish and other leniting varieties may hear any of the alternatives in (2), among others. This means that children learning leniting varieties of Spanish hear both overtly plural-marked and unmarked elements in DPs with plural referents.

(2) a. La-[s] niña-[s] felic-[es] e[s]tán en el patio.

b. La-[∅] niña-[∅] felic-[e∅] e[h]tán en el patio.
c. La-[h] niña-[∅] felic-[e∅] e[h]tán en el patio.
d. La-[s] niña-[h] felic-[e∅] e[h]tán en el patio.

The frequency of the lenited and omitted variants is conditioned on both sociolinguistic (e.g., register, speaker socio-economic status (SES)) and linguistic factors (e.g., morphological status, phonological context; Cepeda, 1995; Author, 2007). For instance, speakers omit more in informal contexts than in formal ones, lower-SES speakers omit final /s/ more than higher-SES speakers do, and omission is most common when the following segment is a continuant consonant (Cepeda, 1995; Author, 2007, 2013).

Several patterns of /s/ omission in Chilean Spanish are particularly relevant for acquisition of plural morphology. First, lenition is common in both adult and child-directed speech: Author (2013) found an overall omission rate of 44% in lower-SES caregivers' speech to their children, only slightly lower than the rate she found in a study of adult-directed free speech in the same community several years prior (50%; Author, 2007). Second, the plural /-s/ is more likely to be omitted than lexical /s/ is (approximately 57% vs. 38% omission; Author, 2013). Third, as shown in Table 1, even within child-directed speech, the rates of omission, lenition and use of the alveolar [s] vary substantially across contexts and elements of the DP: Omission is more common in play contexts than in teaching, and omission is more common on nouns, adjectives and quantifiers than on determiners.

Table 1. Percent use of /s/ variants according to syntactic category and speech style. (Author, 2013).

	Syntactic Category				**Speech Style**	
	Determiner	*Quantifier*	*Noun*	*Adjective*	*Teaching*	*Playing*
[s]	5%	18%	23%	19%	35%	8%
[h]	**66%**	12%	11%	7%	**64%**	41%
Omission	29%	**70%**	**66%**	**74%**	29%	**51%**

Thus, children learning Chilean Spanish hear substantial variation in plural marking: Plural nouns, determiners, adjectives and quantifiers may be marked or unmarked, and when marked may appear with final [s] or final [h]. This stands in sharp contrast to the Spanish of Mexico City, in which adults produce the plural marker as [s] 98% of the time, and omit the plural marker less than 1% of the time (Author, 2007; Author & Author, 2012).

Acquisition Background

Acquisition of Plural Morphology

Across a wide variety of plural-marking languages, studies of children's naturalistic speech show that they begin producing their first productive plural forms around their second birthday (English: R. Brown, 1973; Cazden, 1968; de Villiers & de Villiers, 1973; Madrid Spanish: Marrero & Aguirre, 2003; Palestinian Arabic: Ravid & Farah, 2009; Finnish: Laalo, 2009; German: Szagun, 2001; Latvian: Rūķe-Draviņa, 1973; Russian: Slobin, 1966). The earliest evidence of plural comprehension in experimental studies also appears around age 2: English- and Mexico City Spanish-learners successfully use the plural marker on a novel noun to infer

multiple referents between 2;0 and 2;6 (Mexico City Spanish: Arias-Trejo et al., 2014; English: Davies et al., 2017; Jolly & Plunkett, 2008). Twenty-four-month-olds learning English, for instance, look more at a picture of multiple identical creatures than at a picture of a single different creature after hearing a plural-marked novel noun (e.g., "Look at the mips", Davies et al., 2017).

Evidence suggests that factors such as the complexity and consistency of plural marking in a child's input influence the pattern and rate of acquisition. First, it takes children who are learning languages with complex plural paradigms (e.g., German: Park, 1978; Szagun, 2001; Palestinian Arabic: Ravid & Farah, 2009; Welsh: Thomas, Williams, Jones, Davies, & Binks, 2014) longer to reach adult-like productive mastery of the plural than it does children learning languages with simpler plural paradigms. Unlike English, which has a relatively straightforward regular plural rule ([ez] following sibilants, [z] following voiced segments, and [s] following voiceless consonants) and a handful of irregular plurals (e.g., feet, mice), the German plural system is characterized by numerous sub-patterns, none of which covers the majority of the lexicon. Children show a wide variety of errors as they acquire the German system, and continue to make frequent errors with familiar nouns in kindergarten (e.g., age 4;0-5;0 26% errors; age 5;0-6;0 15% errors, Kauschke, Kurth, & Domahs, 2011; age 5;7-6;0, 43% errors, Laaha, Ravid, Korecky-Kröll, Laaha, & Dressler, 2006). Even in English, features of a particular allomorph appear to influence the order of acquisition: Children use the high-salience [s] allomorph in comprehension before the higher frequency but lower-salience [z] allomorph or the low-frequency but high-salience [əz] allomorph (Berko, 1958; Davies et al., 2017; Kouider et al., 2006).

Acquisition of Variable Morphology

Because research on the acquisition of variability and variable morphology is sparse, relevant information comes from several literatures.

Artificial Language Learning Studies

Conditioned variability, like the sociolinguistic variability of /s/ lenition in Spanish, is common across natural languages, but is under-researched in the acquisition literature. A number of artificial language learning studies have examined the effect of *unconditioned* variability on acquisition, and have found that young school-aged children tend to regularize (e.g., Hudson Kam & Newport, 2005, 2009; Singleton & Newport, 2004), displaying a systematicity in later production tasks that was not present in the input.

To our knowledge, only three artificial language learning studies have examined the effect of *conditioned* variability in the input. Hudson Kam (2015) found that 5- to 7-year-olds who heard variable production of a determiner conditioned on syntactic position (e.g., 80% determiner presence on subjects vs. 20% on objects) were less likely to regularize their input than their peers who heard unconditioned variability. This would be expected if children were accurately acquiring the patterns in the input, but their production was variable in a way that did not reproduce those patterns. Two other studies compared children's performance in both follow-up production and forced choice tasks (Samara et al., 2017; Schwab, Lew-Williams, & Goldberg, 2018). In both cases, children showed sensitivity to the conditioning factors in the forced choice task but failed to do so in their production, suggesting that task demands may influence

children's ability to show emerging sensitivity. Furthermore, Samara et al. (2017) found that children's regularization declined as exposure increased, suggesting that children's patterns in naturalistic settings, where the amount of input dwarfs the amount available even the most extensive artificial language study, may be quite different.

Natural Language Acquisition

A small amount of natural language evidence on the acquisition of variable morphology is available. In naturalistic production, a study of Yucatec Maya, in which roots are unmarked for number and plural marking is grammatically optional, found that young children produced their first productive plurals before age 2;0 (Pfeiler, 2009), suggesting that despite their optionality they are readily produced early in development. In contrast, Marrero and Aguirre (2003) studied the naturalistic production of a child learning a leniting variety of Spanish in the Canary Islands and two children learning the non-leniting Spanish of Madrid. They found that the child learning the variable variety did not begin producing overt markers of plurality until age 3;0, over a year later than two children learning the consistent variety, suggesting that the variability slowed acquisition.

Other studies support the claim that variability impacts the time course of acquisition. African American English (AAE) and Mainstream American English (MAE) differ in the consistency with which they produce final consonants, which include a number of English morphemes such as the noun plural /-s/ and the past tense marker /-d/. Children learning MAE hear these markers consistently, while children learning AAE hear variable omission of these markers. Comparing across studies, AAE-learning children produce these markers less frequently than MAE-learning children do (Berko, 1958; Ramer & Rees, 1973), and rely less heavily on the plural and 3rd person singular present tense markers in comprehension than their MAE-learning peers (Anisfeld & Tucker, 1967; de Villiers & Johnson, 2007; Moore, 1979).

Prior Evidence from Chilean Spanish

A handful of studies make more direct comparisons of natural language input types by testing children learning Chilean and Mexico City Spanish with the same tasks and materials. These comparisons have found that children acquiring Chilean Spanish take longer to associate the plural marker to a more-than-one interpretation than children acquiring Mexico City Spanish (Author, 2007; Author & Author, 2010, 2012). In one set of studies, Chilean 4- to 6-year-olds frequently responded to indefinite plural requests (e.g., *pon unas bolitas en la caja* 'put some marbles in the box') with a single item, while children learning Mexican Spanish consistently provided plural responses to the same request (Author & Author, 2010). Children's performance in these act-out tasks tends to be bimodal: some children consistently associate plural indefinite noun phrases with more-than-one, others rarely do.

On the whole, these findings suggest that children take longer to master variably produced morphology than consistently produced morphology in both naturalistic and artificial language learning contexts, but the results are complex and this pattern is not without exception (e.g., Pfeiler, 2009).

Research Goals

The current study seeks to further explore these issues by assessing plural comprehension in 4- to 6-year-old Chilean children in both an act-out task, following Author (2007; Author & Author, 2010), and a visual-world eye-tracking task, following Kouider et al. (2006) and Arias-Trejo et al. (2014). Previous studies have tested Chilean children in this age range on act-out tasks, and younger children learning other varieties in visual-world tasks (e.g., Arias-Trejo et al., 2014; Kouider et al., 2006). By running both tasks with the same Chilean children across a relatively wide age range, we will (a) further explore Chilean children's plural knowledge, (b) examine the development of their knowledge across this age range, and (c) consider the relationship between real-time ("online") comprehension and performance in offline comprehension tasks.

The Current Study

Children in the current study completed two tasks: an act-out task and a visual-world eye-tracking task. The act-out task explored comprehension of plural morphology using familiar nouns in quantified phrases (Author & Author, 2010, 2012), while the eye-tracking task examined children's use of linguistic cues to plurality during online comprehension using a novel-noun design (Arias-Trejo et al., 2014; Davies et al., 2017; Kouider et al., 2006). Running both tasks with the same set of Chilean Spanish-learning participants allows us to compare results of the two methodologies and begin to bridge two segments of the previous literature, and to better understand Chilean' children's acquisition of plural morphology in comprehension. If children associate the plural marker to a more-than-one interpretation in the eye-tracking task, despite inconsistent performance in the act-out task, then this would indicate that they have sensitivity to plural marking, though they may not be using it in the same way as Mexican children in past studies.

Participants

Fifty-six monolingual Chilean children (ages 3;11-6;10, M = 5;3, 34 girls, 22 boys) participated. One additional child completed the act-out task, but was excluded from the sample because her inattentiveness prevented eye-tracker calibration. Nine monolingual Chilean adults completed the act-out task as a comparison group. Children attended parochial tuition-based schools and were predominantly from middle-class Chilean families. Adults were undergraduate students at a local university.

Act-out Comprehension Task

The act-out comprehension task was designed to be parallel to the tasks used by Author and Author (2010, 2012). In this task, participants heard a series of requests that included quantified noun phrases with familiar nouns (as in (3), below). Quantifiers included *un/una* 'a', and *unos/unas* 'some', which differ only in the presence of plural morphology and have therefore been taken as a good measure of plural comprehension, among others (see Stimuli and Procedure, below). Using the same task allows us to characterize participants for comparison to previous studies, in addition to providing a measure of plural comprehension and permitting comparison among quantifiers.

Stimuli and Procedure

Participants completed 23 trials, 3 practice trials and 20 test trials. On each trial, a native speaker of Chilean Spanish asked the participant to place a certain quantity of toys into a box, using sentences like (3), below.

(3)	*Pon*	*unas*	*botellas*	*en*	*la*	*caja.*
	put.IMP	one.F.PL	bottle.F.PL	in	the.F.SG	box.F.SG
	'put some bottles in the box'					

The speaker, a trained research assistant, produced all instances of the plural marker as [s], which is the most frequent variant used by Chilean adults in naming tasks (Author, 2007). All nouns were familiar.

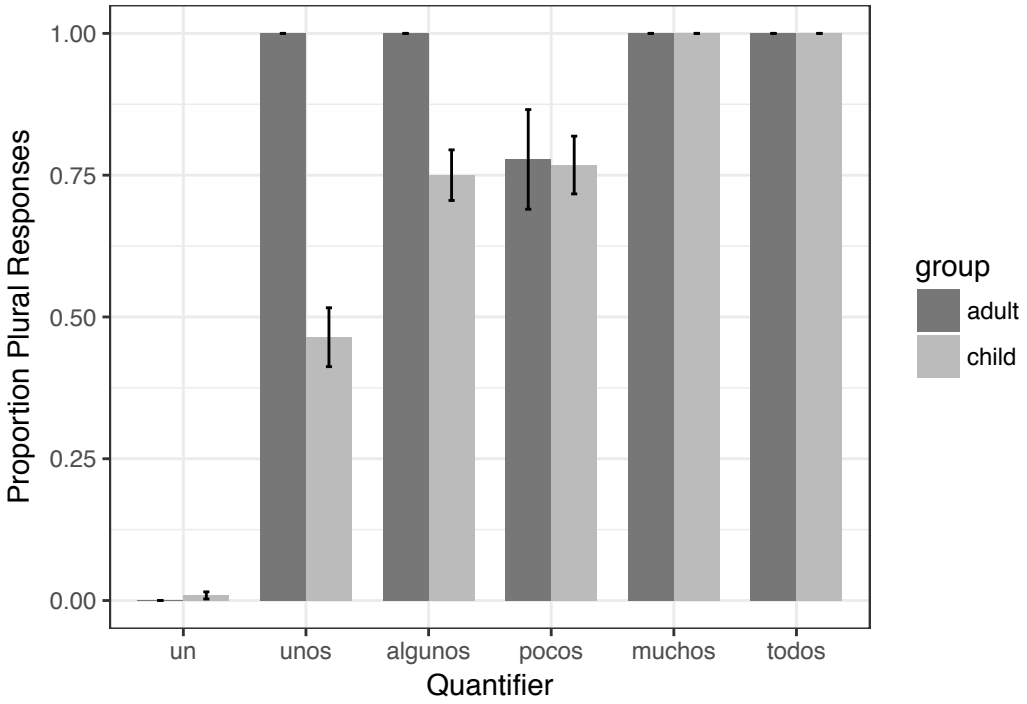
On each trial there were two sets of 6 miniature items (e.g., 6 bottles, 6 cows) on the table along with a shallow box. Items' names always matched in gender. Participants heard 4 requests with each of the quantifiers *un/una* 'a', *unos/unas* 'some', *algunos/algunas* 'some', and *muchos/muchas* 'many', and 2 requests each with the quantifiers *pocos/pocas* 'few', and *todos/todas* 'all' (see Appendix A for a full list of stimulus sentences), for a total of 20 test trials. These test trials were presented in a pseudorandom order, such that the same quantifier never occurred on adjacent trials. The test trials were preceded by three practice trials with the quantifier *un solo* 'a single', and the numerals *dos* 'two', and *tres* 'three'. The number of items children placed in the box in response to each request was recorded, and was classified as singular (1) or plural (>1).

For evaluating children's plural comprehension, the crucial comparison is between responses to *unos/unas* 'some', and *un/una* 'a' trials, as these differ only in plural morphology. For comparison to adults and previously tested groups, *unos/unas* 'some' and *algunos/algunas* 'some' trials are key. These are the loci of the largest differences between Chilean child and adult performance and between Mexican and Chilean child performance in previous studies (Author, 2007). In contrast, based on previous findings, we expected Chilean children to provide consistent, adult-like plural responses to the plural quantifiers *muchos/muchas* 'many' and *todos/todas* 'all', and an adult-like variety of singular and plural responses to *pocos/pocas* 'few' (approximately 70% plural responses; Author & Author, 2010). These trials create some variety in the task and act as controls. If children provide consistent plural responses to *muchos/muchas* 'many' and *todos/todas* 'all', then reduced plural responses in *unos/unas* trials are not due to an overall dispreference for plural responses, such as might be caused by children having physical difficulty picking up several toys at once.

Results

Figure 1 shows the mean proportion of plural responses for children and adults for each quantifier. As in previous studies, children nearly always provided one item in response to *un/una* 'a' trials, and always responded with more than one item on *muchos/muchas* 'many' and *todos/todas* 'all' trials, but provided a non-adult-like variety of singular and plural responses on *unos/unas* 'some' and *algunos/algunas* 'some' trials. Both children and adults provided a mix of singular and plural responses to *pocos/pocas* 'few'.

Figure 1. Act-out task results. Mean (se) proportion of plural responses to prompts with each quantifier. The x-axis shows the masculine version of each quantifier, but across the experiment, each quantifier appeared in both its masculine and feminine forms.



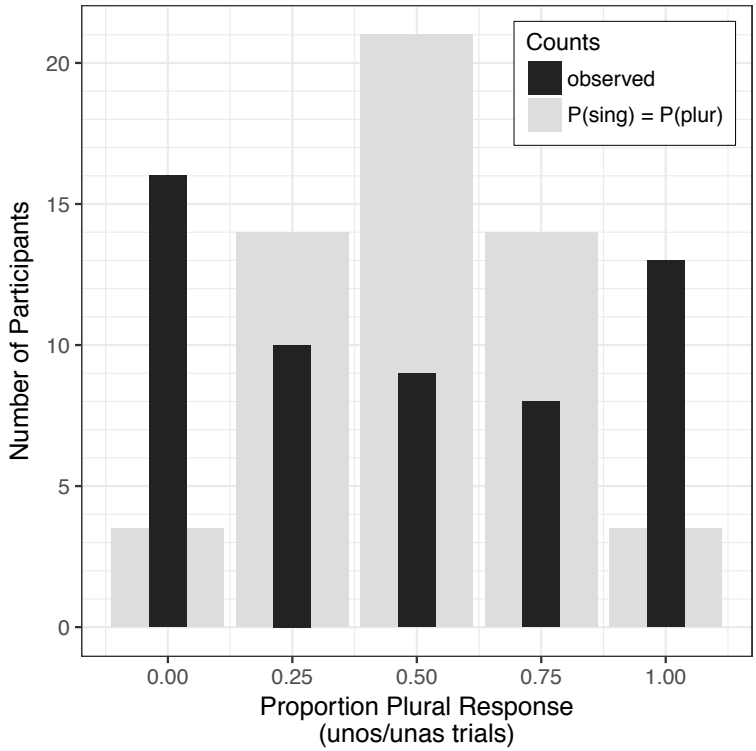
To test these patterns, we first compared children's and adults' responses for each quantifier. Chilean children displayed non-adult-like behavior, in that they gave a reliably lower proportion of plural responses in *unos/unas* 'some' trials than adults did (adult Mdn = 1, child Mdn = 0.5; $W = 445.5$; $p = .0002$; Wilcoxon rank sum), as well as in *algunos/algunas* 'some' trials (adult Mdn = 1, child Mdn = 1; $W = 369$; $p = .012$). Children's performance on other quantifiers was not reliably different from adults' (*un/una* 'a', adult Mdn = 0, child Mdn = 0, W = 243, $p = .59$; *pocos/pocas* 'few', adult Mdn = 1, child Mdn = 1, W = 234.5, $p = .70$; *todos/todas* 'all' and *muchos/muchas* 'many', all plural responses in both groups).

Note that as a group, children gave a reliably higher proportion of plural responses to *unos/unas* 'some' trials than to *un/una* 'a' (*un/una* Mdn = 0, *unos/unas* Mdn = 0.5; $V = 0$; $p < .0001$; Wilcoxon signed-rank), indicating some, group-level sensitivity to plural-marking, despite their strongly non-adult-like performance.

Individual Child Patterns

Figure 2 shows that, as in previous studies, responses to *unos/unas* 'some' trials (black bars) were markedly more bimodal than would be expected by chance (pale grey bars). Children's overall mean proportion of plural responses to *unos/unas* ("some") trials was .46. That is, plural and singular responses were almost equally likely. If each child had an equal probability of providing a plural or singular response on each trial, we would predict the light gray distribution of participants across response patterns. Instead, we observed the substantially more bimodal distribution shown by the black bars, which differs reliably from the distribution predicted by chance ($p < .0001$, multinomial test).

Figure 2. Histogram showing the number of children with each proportion of plural responses in our data (narrow black bars) and the expected counts if singular and plural responses were equally likely on each trial for each child (wide gray bars).



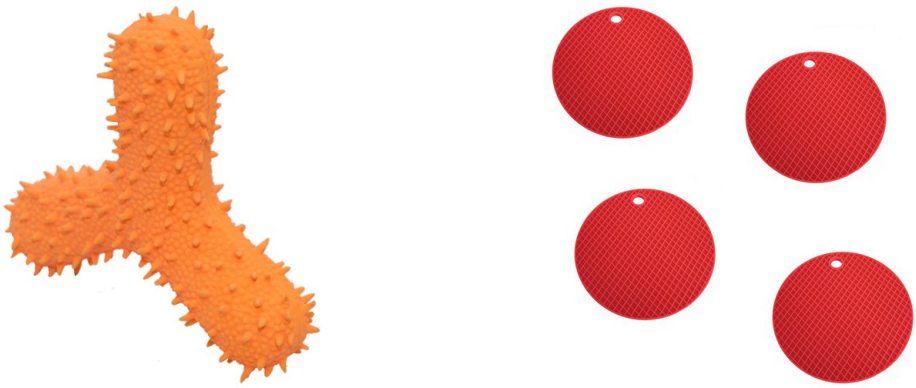
Children's performance on *unos/unas* 'some' trials is also marginally positively correlated with their age (r = .23, p = .09). This suggests that children's performance on this task becomes slightly more adult-like over time, and is compatible with an interpretation in which variable input prolongs the process of learning the association between the plural morpheme and plural meaning.

Eye-tracking Comprehension Task

The eye-tracking task was designed to test plural comprehension using a very different approach. In contrast to the act-out task, the eye-tracking task required no explicit response from participants, and tested children's ability to use plural morphology to disambiguate the referent of a novel noun. On each trial, participants saw a pair of pictures, one showing a single novel item and another showing four instances of a different novel item, and heard a sentence with either singular or plural morphology (Figure 3, see Appendix B for a full list of stimuli). Because participants do not know which type of novel item the novel noun refers to, they must use morphology to determine its referent (Jolly & Plunkett, 2008; Kouider et al., 2006). Following previous studies, we used these novel words and distinct novel items to avoid the superset ambiguity inherent in labeling single- and multiple-item images of familiar items with a plural familiar word (e.g., pictured: 1 cat, 4 cats; "Look at the cats!"; for discussion see Davies et al., 2017; Kouider et al., 2006).

Figure 3. Sample materials for the eye-tracking task.

Video:



Audio:

		hay	**ser**	trials
singular		*¡Mira! Hay una teka.* "Look! There('s) a teka."	*¡Mira! Es una teka.* "Look! (It) is a teka."	8
plural	*indefinite*	*¡Mira! Hay unas petas.* "Look! There (are) some petas"	*¡Mira! Son unas petas* "Look! (They) are some petas."	4
	bare	*¡Mira! Hay petas.* "Look! There (are) petas."	*¡Mira! Son petas* "Look! (They) are petas."	4

Novel words were presented in sentence frames of two types: half the participants heard *hay* (existential verb) sentences, in which the verb does not agree with the subject and plurality was marked in the DP only, and half heard *ser* (to be) sentences in which plurality was marked on both the DP and the verb (Figure 3)[i]. The goal of including both verb types was to explore whether the addition of verbal agreement marking would increase children's ability to infer number from the subject noun phrase. As shown in Figure 3, plurals were either bare or indefinite, and all singulars were indefinite[ii]. If participants are sensitive to the presence and absence of plural morphology as a cue to number meaning, they should look more at the plural image in plural trials than in singular trials.

Methods

Stimuli

Stimuli were sentences containing 16 novel object-names (e.g., *teka, kipo*), accompanied by photographs of novel objects, as shown in Figure 3 (see Appendix B for full stimulus list). All target nouns began with voiceless stops ([p], [t] or [k]) and were two syllables. Half were transparently feminine (i.e., ended in [-a]) and half were transparently masculine (ended in[-o]). Sentences were recorded by a male native speaker of Chilean Spanish, who used child directed intonation and produced all plural markers as [-s].

Participants were assigned to one of two conditions: half to the *hay* condition (n = 28, range = 3;11-6;3, 16 girls, 12 boys), and half to the *ser* condition (n = 28, range = 4;1-6;10, 18 girls, 10 boys). In the *hay* condition, the only number cues appeared in the noun phrase. In the *ser* condition, the sentence-initial verb also provided a number cue. Each participant heard 8

singular and 8 plural test trials. Half of the plurals were bare and half were indefinite. Within-participants, the left-right position of the target and of the four-object image were counterbalanced with target plurality and gender, and each item appeared once as the target and once as the distractor.

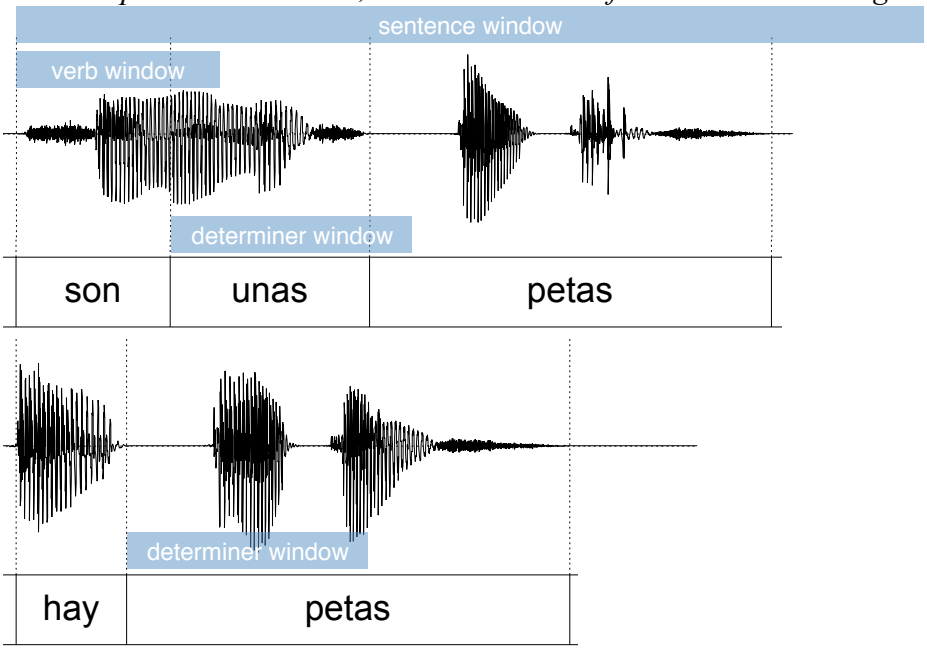
Test trials were preceded by four familiar-noun practice trials. Test trial order was pseudo-randomized: The same pictured items neither appeared in consecutive trials nor with only one intervening trial, there were no more than two trials with the same target plurality or target location in a row, and no more than three trials in a row with the same location for the 4-object picture. Three filler trials with an animal photo (duck, lion, rooster) were interspersed to provide brief breaks. Across participants, sequences were counterbalanced for order (the chosen pseudorandom order or its reverse), which image was the target, and the left-right position of the images.

Apparatus and procedure

Participants sat about 2.5 feet from a 24-inch monitor in a quiet home that had been converted into a lab space. An EyeLink 1000+ remote eye-tracking camera sat between the participant and the monitor, and recorded gaze position once every 2 ms (500 Hz). Participants completed a 9-point calibration before the study began. An automatically generated warning tone signaled track loss longer than 500 ms. Trials in which the tone occurred during or immediately after the test sentence were excluded from analysis (90 trials of 896 total, 10%).

On each trial, two pictures, each about 5.5 inches square, appeared approximately 10 inches apart and a recorded sentence played. The auditory stimulus began 2 s after the pictures appeared. Trials lasted 6.5 s each, and were separated by a central fixation image.

Figure 4. Analysis Windows. Portions of the trial targeted by each analysis are shown in blue. All analysis windows were offset from the illustrated target time periods by 300 ms to allow time for children to plan a saccade. Note that the sentence and verb windows begin at the start of the utterance and were the same in all trials. The determiner window was aligned with the onset of the noun phrase in all trials, and its onset therefore varied according to verb length.



Measures and predictions

We defined two interest areas of equal size around the plural (4-object) and the singular (1-object) image. We considered the proportion of time participants' gaze was in the plural interest area, out of the time their gaze was in either interest area in three analysis windows (Figure 4).

Our primary interest was in children's responses during the 1500-ms *sentence window*. This window encompassed the full sentence (sentence duration: range 807-1322 ms, $M = 973$ ms), and was offset by 300 ms to allow time for saccade planning, as is typical in analyses of children's eye-movements (Fernald, Zangl, Portillo, & Marchman, 2008). The sentence window therefore extended from 300 to 1800 ms after sentence onset. Participants' looking behavior in this window should reflect their processing of all available number cues (i.e., verb agreement (*ser* condition), bare vs. indefinite DP, number-marking in DP).

We also explored looking behavior in two brief, early windows to help us understand the time course of children's comprehension. Several studies have found that young children make incremental, even predictive use of function words (Lew-Williams & Fernald, 2007; Author & Author, 2016; Melançon & Shi, 2015), and we were curious whether we would find similar effects in our data. Because Spanish does not readily permit the prenominal adjectives that have allowed other studies to successfully observe early effects of function words, we do not treat these analyses as a strong test of children's predictive use of verbal morphology.

The *verb window* was 338 ms long, extending from 300 ms after sentence onset to 300 ms after the earliest affix onset (i.e., the first plural [-s] or singular [-∅], see Figure 4). This included the verb (*hay*, *es/son*), but ended before the determiner- or noun-final morphology could have influenced looking. In this window, the only available cue to number was the verb form in the *ser* condition. If children rapidly use an agreeing verb to anticipate the number of the upcoming noun, we predict a difference between singular and plural trials in the *ser* condition, and not in the *hay* condition.

The *determiner window* was 398 ms long, extending from 300 ms after the beginning of the noun phrase until 300 ms after the earliest noun affix (see Figure 4). Participants' behavior during this window should reflect their processing of determiner number morphology or, in bare plural trials, of the determiner's absence, and the integration of that information with the preceding verb, but not of the nominal morphology itself. If participants use the number-marking on the determiner, we expect a main effect of target number. Any effect of the preceding verb in this window should appear as an interaction between target number and condition.

For each analysis, trials were excluded[iii] if the participant looked away from the images on the screen for more than 50% of the time period of interest. This led to the exclusion of 51 of 806 trials (6%) in the sentence window, 90 of 806 trials (11%) in the verb window, and 52 of 806 trials (6%) in the determiner window.

Results

Figure 5 shows looks to the multiple-object image as a proportion of looks to either image in 2-ms intervals from sentence onset, plotted by target plurality (singular/plural) and condition (*hay/ser*). Before sentence onset, both groups looked about equally at the two pictures, though the participants in the *ser* condition showed a strong tendency to look first at the plural and then at the singular image. After sentence onset, participants in both conditions looked more

to the plural picture during sentences with plural morphology than during sentences with singular morphology. Participants in the *hay* condition showed a distinct peak in looking at the matching image about 1300 ms after sentence onset, while the participants in the *ser* condition showed less drastic differentiation between singular and plural trials.

Figure 5. Mean (se) proportion looking to the plural image as a function of trial time. The vertical lines indicate key timepoints in the trial. The dashed line marks the onset of the introductory ¡Mira! ("Look!"), the solid line marks the sentence onset, and the two dotted lines indicate average noun onset and average sentence offset, in that order.

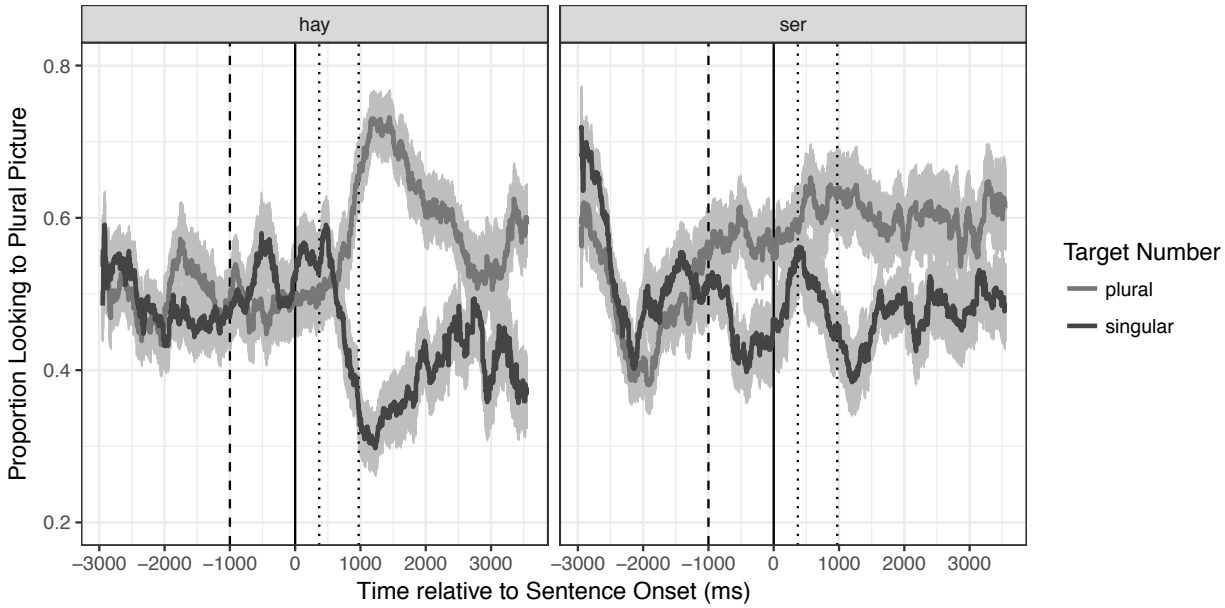


Figure 6a. Proportion looking to the plural image in the sentence window. Each dot represents a participant mean, with left-right position of each dot in the box representing participant age.

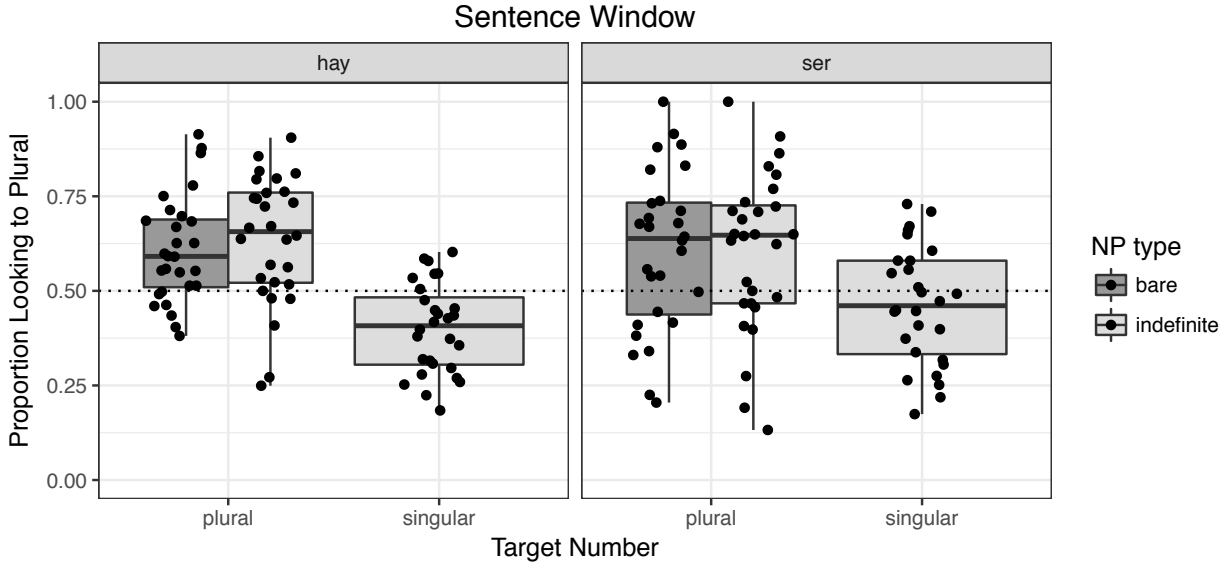
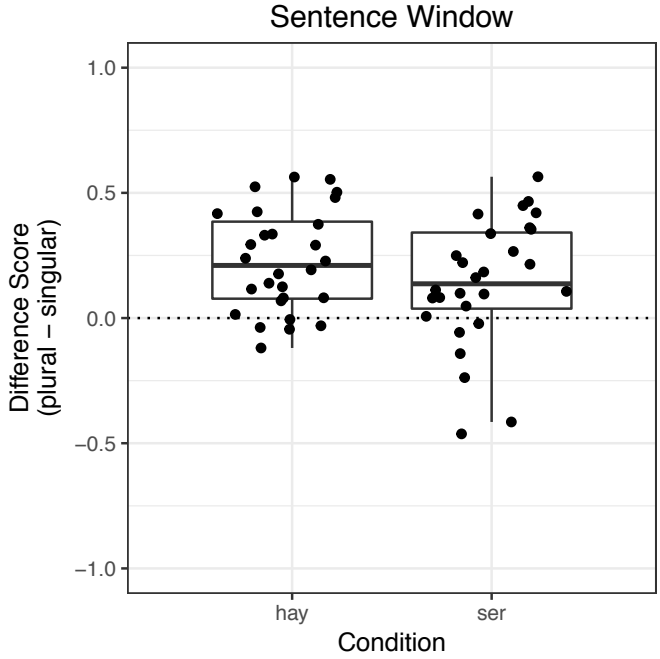


Figure 6b. Proportion looking to the plural image in plural trials minus proportion looking to the plural in singular trials in the sentence window. Each dot represents a participant, with left-right position in the box representing age.



Sentence window

Figure 6a shows that in the sentence window, in both conditions, the proportion of looks at the plural image was greater in plural trials than in singular trials, and that it did not differ according to plural DP type (i.e., bare vs. indefinite). Figure 6b shows the same data, plotted as by-participant difference scores: each child's average looks to the plural image in plural trials minus their average looks to the plural image in singular trials. Difference scores above zero indicate that the participant looked more at the plural image when they heard sentences with plural morphology than when they heard sentences with singular morphology, and difference scores at or below zero indicate the reverse. In both graphs, each group of data points is arranged along the x-axis according to participant age, with the x-axis midpoint of each box corresponding to the mean age (5;3). The majority of participants in each group had positive difference scores (*hay*: 23/28 participants, 82%; *ser*: 22/28 participants, 79%), and there was a reliable, moderate positive correlation of difference score with age ($r = .33$, $p = .01$).

We fit a linear mixed effects model of proportion looking to the plural image. Predictor variables, entered into the model using mean-centered effects coding, were the within-participant factor, target number (contrast codes: singular, -.50 vs. plural, .50), and the between participants factor, condition (*hay*, -.49 vs. *ser*, .51). The model included the maximal random effects structure justified by the design (Barr, Levy, Scheepers, & Tily, 2013). Including the interaction of z-scored age with target number significantly improved model fit ($\chi^2(1) = 7.19$, $p = .007$), so both age and this interaction were retained in the final model. This analysis revealed a significant main effect of target number ($N_{trials} = 755$, $b = 0.19$, $se = 0.03$, $\chi^2(1) = 25.83$, $p < .0001$)[iv], such that the proportion looking at plural images was higher in plural than in singular trials. Neither the main effect of condition nor its interaction with target number were statistically reliable

(condition: $\chi^2(1) = 0.65$, $p = .42$; interaction: $\chi^2(1) = 1.91$, $p = .17$). Planned comparisons indicated that the simple main effect of target number was significant in both conditions (*hay*: $\chi^2(1) = 21.38$, $p < 0.001$; *ser*: $\chi^2(1) = 9.05$, $p = 0.003$). A secondary analysis within the plural trials revealed no effect of plural type (bare/indefinite), or the interaction between plural type and condition (all $\chi^2(1) < 1$, $p > 0.5$).

These results indicate that participants used plural morphology to infer subject number. The lack of an interaction between target number and condition suggests that, across the full sentence, the additional cue provided by the number-marked verb in the *ser* condition did not contribute substantially to children's successful inference. The lack of effect of plural type suggests that bare and indefinite plurals were both effective cues to number.

For comparison to previous studies (Arias-Trejo et al., 2014; Kouider et al., 2006), we also calculated a pre-sentence/post-sentence difference score by subtracting participants' proportion looking to the plural picture in a 1.5-s pre-sentence baseline window from their proportion looking to the plural picture in the 1.5-s test sentence window. In the *hay* condition, looking to the plural reliably increased in plural trials ($t(27) = 4.04$, $p = .0004$) and decreased in singular trials ($t(27) = -3.22$, $p = .003$; all tests two-tailed). In the *ser* condition pre-post difference scores revealed no reliable changes ($t(27) < 1$, $p > .4$).

Other windows

For the 338-ms *verb window*, analysis parallel to those for the sentence window revealed no reliable effects of target number, condition or their interaction (all $\chi^2(1) < 1.5$, $p > .25$, $N_{trials} = 716$). The simple effect of target plurality was not reliable in either condition (both $\chi^2(1) < 1$, $p > .3$).

For the 398 ms *determiner window*, Figure 7a shows that participants spent more time looking at the plural image in plural than in singular trials in the *ser* condition, and Figure 7b shows the corresponding by-participant difference scores. The majority of the participants in the *ser* condition showed positive difference scores (21/28 participants, 79%), while in the *hay* condition only half of the children showed positive difference scores (14/28 participants, 50%).

Figure 7a. Proportion looking to the plural image in the determiner window. Each dot represents a participant mean, with left-right position in the box representing age.

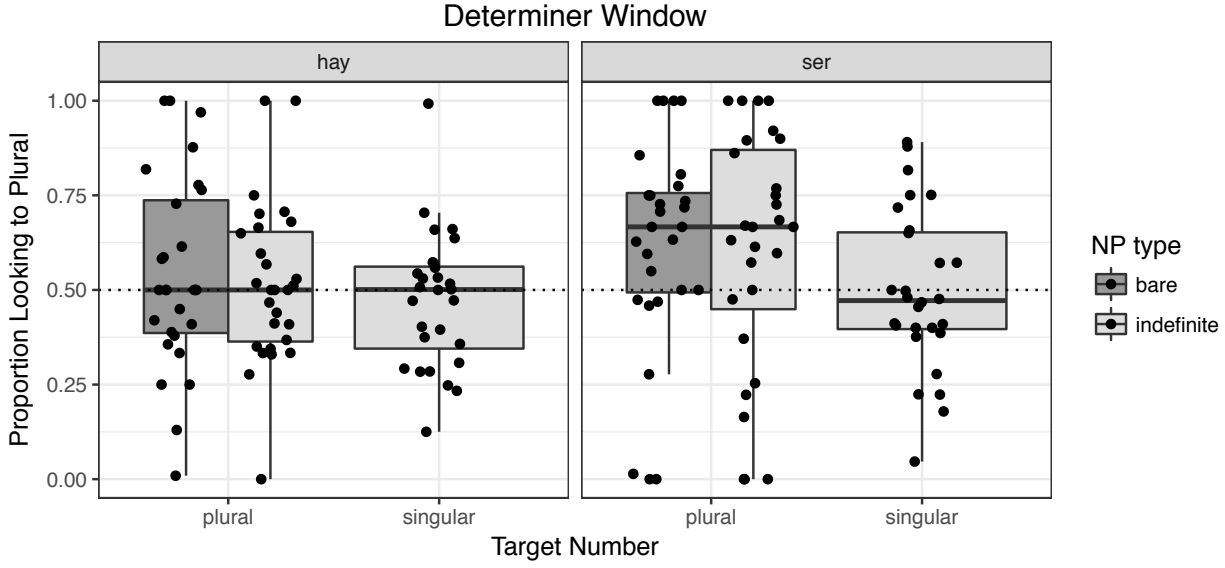
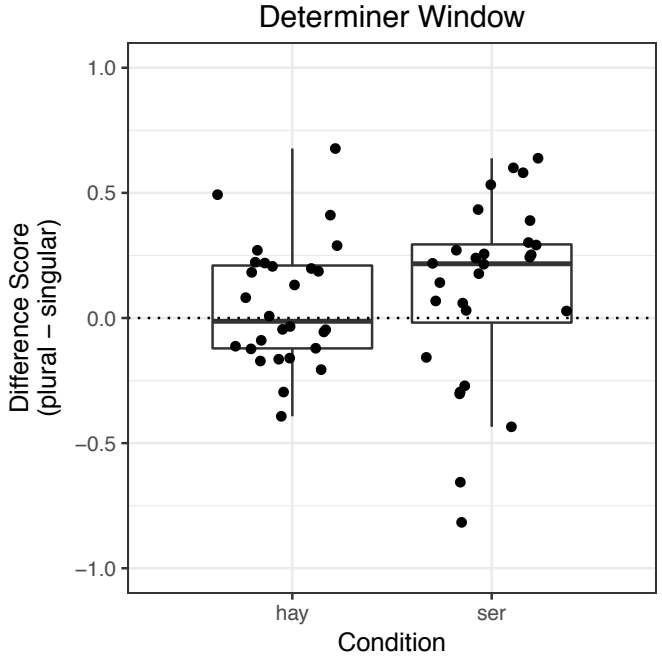


Figure 7b. Determiner window difference scores. Proportion looking to the plural image in plural trials minus proportion looking to the plural in singular trials. Each dot represents a participant, with left-right position in the box representing participant age.



We fit a linear mixed effects model of proportion looking to plural with the mean-centered effects-coded predictors target number (singular, -.50 vs. plural, .50) and condition (*hay*, -.48 vs. *ser*, .52) and the maximal random effects structure justified by the design. It included z-scored age and its interaction with target number, as adding the interaction improved fit ($\chi^2(1) = 5.86$, $p = .02$). This model revealed a significant main effect of target number (N_{trials} = 754, $b = 0.09$, $se = 0.04$, $\chi^2(1) = 4.84$, $p = .03$), such that participants looked more to the plural image in plural than in singular trials. Neither the main effect of condition ($\chi^2(1) = 1.83$, $p = .18$) nor the interaction ($\chi^2(1) = 0.62$, $p = .43$) were statistically reliable. The simple main effect of target number was reliable in the *ser* condition ($\chi^2(1) = 4.86$, $p = .03$), but not in the *hay* condition ($\chi^2(1) = 0.09$, $p = .76$). An analysis within plural trials revealed no effect of condition ($\chi^2(1) = 2.12$, $p = .15$), plural type, or their interaction (both $\chi^2(1) < 1$, $p > 0.5$).

The main effect of target number in the determiner window suggests that participants used the form of the determiner or the determiner's absence to infer subject number. This led to an emerging difference between singular and plural trials, even before information from the morphological marking on the novel noun became available. The lack of an effect of plural type suggests that both the indefinite plural determiner and the absence of a determiner serve as cues to plurality for Chilean children. Though the numerically larger effect of target number in the *ser* than the *hay* condition hints at an emerging effect of the preceding informative verb, the lack of a reliable interaction between condition and target number and the pre-sentence differences present in the *ser* condition do not permit us to draw strong conclusions about the effects of the agreeing verb. This may be due to the between-participants nature of the comparison, or the brevity of the measurement window relative to studies that have found reliable differences, among other differences. Future work with different designs will be required to more thoroughly investigate these questions.

General Discussion

The goal of this study was to explore children's acquisition of plural morphology when the input for plural morphology is variable. Previous studies have shown that variable input for grammatical morphology impacts the time course of acquisition of that morphology. In particular, it has been argued that Chilean children, who are exposed to variable plural marking, take longer to associate the marker to a more-than-one interpretation than do children who are exposed to non-variable input (e.g. children from Mexico City). Building on this previous work, the present study set out to determine whether Chilean children, who frequently provide singular interpretations of the plural marker in act-out tasks, would show sensitivity in an eye-tracking task, a more implicit, online measure.

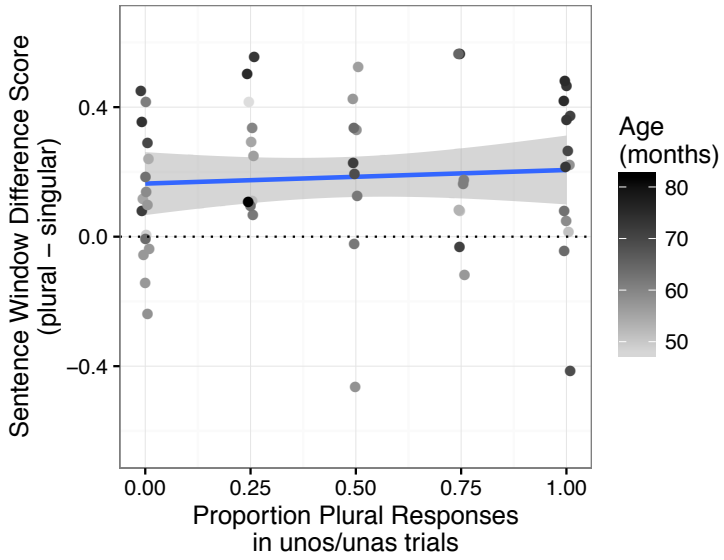
In the act-out task, the results were similar to previous studies (Author 2007, Author & Author 2012): children provided plural responses to only about half of the indefinite plural (*unos/unas* 'some') trials. In the eye-tracking task, the results showed that children in both the existential *hay* condition and the labeling *ser* condition looked reliably longer at a plural image in plural trials than in singular trials. Performance on both tasks was positively correlated with age, marginally for the act-out task and reliably for the eye-tracking task.

Comparison Between Tasks

What does this mean for Chilean children's knowledge of plural? To the extent that each task reliably measures an individual child's ability to use plural morphology to infer plural meaning, we would expect performance on the two tasks to be positively correlated. Adult-like knowledge of plural morphology should lead to more plural responses to *unos/unas* 'some' trials in the act-out task and more looks to the plural image in plural trials in the eye-tracking task. If children do not have adult-like knowledge, Author & Author (2012) suggest that they might look to the determiner root for number information. In this case, we would expect them to treat both *unos/unas* 'some' and *un/una* 'a' trials as singular, since their root is homophonous with the Spanish word for 'one'. This predicts an overall singular preference for both singular and plural indefinites, and therefore singular act-out responses and small eye-tracking difference scores. Thus, we predicted that higher proportions of plural responses in *unos/unas* 'some' trials in the act-out task would be associated with larger positive difference scores in the eye-tracking task.

To determine whether the predicted correlation was present, we examined the relationship between the proportion of plural responses participants gave in the *unos/unas* 'some' trials in the act-out task and three measures in the eye-tracking task. Figure 8 plots one of these correlations: Participants' proportion plural responses to *unos/unas* 'some' trials and their sentence window difference score in the eye-tracking study. These measures were not correlated ($df = 54$, $r = .08$, $t = 0.6$, $p = .56$). We also examined the correlation between proportion plural responses in *unos/unas* 'some' trials and the time children spent looking to the plural picture in plural trials in the eye-tracking task, both for plural trials overall, and for indefinite plural trials specifically. We reasoned that noise in the singular trials might be clouding any true correlation between performance in plural trials in both tasks. However, these measures were also not correlated (all plural trials: $df = 54$, $r = .08$, $t = 0.57$, $p = .57$; indefinite plural trials: $df = 54$, $r = -.001$, $t = -0.01$, $p = .99$).

Figure 8. Proportion plural responses in unos/unas ("some") trials in the act-out task plotted against mean difference in proportion looking to the plural picture during the sentence window in plural and singular trials in the eye-tracking task. Darker points represent older participants.



One thing to keep in mind for interpreting this lack of correlation is that the gradience in these measures is not strongly interpretable. For example, in the eye-tracking task, a higher positive difference score (e.g. a score of .40) does not necessarily indicate that the child knows more about the plural than a child with a lower positive difference score (e.g. a score of .25). For instance, a particularly quick child with strong knowledge of the plural might look at the correct picture and then quickly look for other interesting things, resulting in a consistent, but small difference between trial types. Similarly, while it seems likely that a child who gives 4 plural responses to *unos/unas* 'some' trials in the act-out task knows more about the plural than the child who gives 0 plural responses, it is not entirely clear whether a child who gives 2 plural responses knows more than a child who gives 1 plural response.

While we did not find a correlation between the tasks, other comparisons of children's performance may provide some insight on the results. To the extent that implicit, online tasks are more sensitive than explicit, offline ones, we might expect performance on the eye-tracking task to be better than on the act-out task. Note that this is a tricky comparison, as performance is measured quite differently in the two tasks. However, as shown in Figure 8, even among the children who provided few plural responses in the indefinite plural act-out trials, the majority showed positive difference scores in the eye-tracking task (left side of Figure 8). It is also interesting that children who performed well in both tasks (upper right-hand corner of Figure 8) were among the oldest children and those who performed poorly in both tasks (lower left-hand corner of Figure 8) were among the youngest children.

One possibility is that the eye-tracking task, an implicit measure, may represent earlier knowledge of the plural marker and the act-out task, an explicit measure, may represent later, more entrenched knowledge. This explanation is consistent with the age effects found in these tasks and previous investigations indicating that variable input for plural morphology impacts the time course of acquisition.

Further research is needed to explore the effect of variable input on acquisition of the plural in three ways: by taking the current pair of tasks to younger children to explore earlier

stages of plural acquisition than has previously been possible in Chilean Spanish, by further exploring adult Chilean Spanish speakers' use of the plural in online comprehension, and by exploring the development of online comprehension processes. This requires cross-dialectal comparison, exploring the similarities and differences between, for instance, Mexican and Chilean children in early sensitivity to the plural and use of different cues to number in online comprehension. Such studies will build on the current work to inform our understanding of adults' representation and processing of variable morphology and morphological dependencies, and the learning mechanisms that children use to approach the adult grammar.

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[i] Designing the study so that the *hay/ser* manipulation was within-participants would have made the comparison stronger, but the 32 distinct novel word trials that would have required was deemed too overwhelming for children in this age range.

[ii] Bare singulars are possible in Spanish, but their distribution is much more tightly restricted than that of bare plurals. They are also underspecified for number, not semantically singular. In Chilean Spanish, bare singulars occur primarily in contexts related to possession (Bosque, 1996; Author & Author, 2004).

[iii] Window proportions and exclusions were calculated using R 3.3.1 (R Core Team, 2016) and the *eyetrackingR* package (Dink & Ferguson, 2015).

[iv] All mixed-effects models were also run on empirical logit transformed proportions (log odds). The statistical outcomes did not differ.

Appendix A. Act-out task stimuli.

All NPs were presented in the following frame:

(#) Pon NP en la caja

Put.IMP NP in the box

"Put NP in the box"

	Spanish	English translation
Practice trials	dos gato-s two cat-PL	"two cats"
	un solo gato a single cat	"a single/one cat"
	tres gato-s three cat-PL	"three cats"
Block 1	una vaca a cow	"a cow"
	una-s botella-s a-PL bottle-PL	"some bottles"
	mucha-s vaca-s many-PL cow-PL	"many cows"
	alguna-s botella-s some-PL bottle-PL	"some bottles"
	poca-s vaca-s few-PL cow-PL	"a few bottles"
	toda-s la-s botella-s all-PL the-PL bottle-PL	"all the bottles"
	una-s vaca-s a-PL cow-PL	"some cows"
	una botella a bottle	"a bottle"
	alguna-s vaca-s	"some cows"

	some-PL cow-PL	
	mucha-s botella-s many-PL bottle-PL	“many bottles”
	toda-s la-s vaca-s all-PL the-PL cow-PL	“all the cows”
	poca-s botella-s few-PL bottle-PL	“a few bottles”
Block 2	un anillo a ring	“a ring”
	un-os pato-s a-PL duck-PL	“some ducks”
	mucho-s anillo-s many-PL ring-PL	“many rings”
	alguno-s pato-s some-PL duck-PL	“some ducks”
	uno-s anillo-s a-PL ring-PL	“some rings”
	un pato a duck	“a duck”
	alguno-s anillo-s some-PL ring-PL	“some rings”
	mucho-s pato-s many-PL duck-PL	“many ducks”

Appendix B. Eye-tracking stimuli.

Twelve of the 16 novel objects were drawn from the NOUN database (Horst & Hout, 2016). The remaining four were drawn from the novel items used by Lukyanenko and Fisher (2014). Each item appeared once as a target and once as a distractor. To avoid making the target obvious on the second presentation, items were grouped in sets of four rather than yoked in pairs. Each item in the set received a novel name of the same gender, and was paired with a different item in the group each time it appeared. Several objects have noticeable spikes or dots that could conceivably be appropriate referents for a plural noun, but there is a strong whole-item bias in novel-word learning (Hollich, Golinkoff, & Hirsh-Pasek, 2007; Markman & Wachtel, 1988). Previous findings thus suggest that children will be extremely unlikely to entertain such a hypothesis.

Novel words began with a voiceless stop and had a CVCV structure. They all took the segmental /s/ plural ending, rather than the syllabic /es/ ending.

Table B.1. Novel objects

Set A				
Set B				

Set C				
Set D				

Table B.2. Novel words

Feminine	Masculine
taga	pulo
pola	kipo
kupa	pilo
teka	peko
pona	toko
kota	pamo
tepa	piro
peta	kebo