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

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Abstract

How does variable input affect children's acquisition of morphology? We tested plural comprehension in children learning a variety of Spanish with variable syllable-final /s/-lenition, which results in the frequent weakening or aspiration of the plural affix. Chilean 4- to 6-year-olds' completed two comprehension tasks: an act-out task and a visual-world eye-tracking task. As a group, children showed sensitivity to plural morphology in both tasks: they gave more plural responses to plural than to singular requests in the act out task and they looked longer at a plural picture while hearing a sentence with plural morphology than while hearing one with singular morphology. At the individual level, results were more complex. As in previous studies, participants frequently gave non-adult-like singular responses to indefinite plural requests in the act-out task (*pon unas botellas en la caja*, "put some bottles in the box"), and their performance on the tasks was not correlated.

Abstract word count: 149 (target 150)

Introduction

How children learn the morphology of their native language has been at the center of long-running debates in language acquisition (e.g., Pinker & Ullman, 2002). Proposals about how children arrive at the appropriate generalizations vary, but often rely on the assumption that the pairings of particular forms and meanings are consistent (Pinker, 1984; Ramscar, Dye, & McCauley, 2013). However, language consists both of regular patterns (e.g., Spanish plural +s) and of variability (e.g., variable lenition of syllable-final /s/ in many Spanish varieties). Research on acquisition from variable input remains sparse relative to research on consistent input.

The current study examines children's comprehension of plural morphology in Chilean Spanish. In Chilean Spanish a phonological process frequently but variably results in the deletion or aspiration of syllable-final /s/. Chilean children therefore hear both production and omission of the plural-marker in descriptions of plural referents: in Chile (1) may be pronounced in any of the ways shown in (2a-d). In contrast, children learning non-leniting varieties of Spanish (e.g., in Mexico City or Madrid) hear only (2a), in which /s/ is always pronounced. How does the variable marking of plurality in their input affect Chilean children's acquisition of number-marking?

(1) Todas las niñas están en el patio.
all.PL the.PL girl.PL BE.3PL in the.SG backyard.SG
"All the girls are in the backyard"

(2) a. Toda-[s] la-[s] niña-[s] e[s]tán en el patio
b. Toda-[Ø] la-[Ø] niña-[Ø] e[h]tán en el patio
c. Toda-[Ø] la-[s] niña-[Ø] e[h]tán en el patio
d. Toda-[Ø] la-[h] niña-[s] e[h]tán en el patio

Acquisition of Number-Marking from Consistent and Variable Input

Children learning languages in which plurality is consistently marked begin producing their first plural forms around age 2 (Brown, 1973; Clark & Nikitina, 2009; de Villiers & de Villiers, 1973), and begin using number morphology in comprehension between 2 and 2.5 years of age (Mexican Spanish: Arias-Trejo, Cantrell, Smith, & Alva Canto, 2014; English: Jolly & Plunkett, 2008; Kouider, Halberda, Wood, & Carey, 2006; Zapf & Smith, 2009). Mexican Spanish learning 2-year-olds, for instance, increase their looking to a picture of multiple novel objects after hearing a plural-marked novel noun (e.g., *¡Mira, pamos!*, "Look, pamos!"; Arias-Trejo, et al., 2014).

When children receive variable input, they take longer to reach adult-like patterns of plural comprehension: many Chilean 4- to 6-year-olds appear to ignore the plural –s in act-out tasks, responding to indefinite plural requests (e.g., *pon unas bollitas en la caja* "put some marbles in the box") with a single item, while children learning Mexican Spanish do not (Miller & Schmitt, 2010, 2012). Miller and Schmitt (2010) found that a full 67% of lower-SES Chilean children gave 1 or 0 plural responses (of 4 possible), while only 14% of lower-SES Mexican children and no adults tested in either community did so.

Children's performance in these act-out tasks tends to be bimodal: some children consistently associate plural morphology with more-than-one (3 or 4 plural responses out of 4 indefinite plural trials), others rarely do (0 or 1 plural response), and very few give two responses of each type. This suggests a delay in children's acquisition of the variably produced morpheme, and has been taken as evidence that some children have and some have not learned the significance of the plural affix.

Studies of plural comprehension in languages with variable and consistent input differ both in observed patterns and in methodology. To better understand what Chilean 4- to 6-year-olds know about plural morphology and to facilitate comparison with previous studies, the current study examines comprehension in both an act-out task and an eye-tracking task. This provides two measurements of plural comprehension for each participant and allows us to explore how children's interpretation unfolds over time, in addition to their ultimate interpretation.

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 quantified noun phrases with familiar nouns. Quantifiers included *un/una* ("a") and *unos/unas* ("some"), which differ only in the presence of plural morphology, among others. In previous studies, Chilean children frequently gave singular responses to *unos/unas* trials, in contrast to the consistently plural responses of children learning Mexican Spanish, and of adult speakers of both varieties (Miller & Schmitt, 2010, 2012). The act-out task provided a measure of plural comprehension, permitted comparison among quantifiers, and allowed us to characterize participants for comparison to previous studies.

The eye-tracking task examined children's use of linguistic cues to plurality in online comprehension using a novel-noun design (Kouider, Halberda, Wood & Carey, 2006; Arias-Trejo, et al., 2014). Participants saw pairs of pictures, one showing a single novel item and another showing four instances of a second novel item (Figure 1), and heard sentences labeling either the singular or the plural picture. Sentences were of two types: half the participants heard *hay* sentences, in which plurality was marked in the NP, and half heard *ser* sentences, in which

plurality was marked both in the NP and on the verb. Plurals were either bare or indefinite. All singulars were indefinite, as the distribution of bare singulars in Spanish is tightly restricted.

If participants use the available cues to plurality in comprehension, they should look longer to the picture showing multiple instances of a novel item when they hear a plural-marked sentence than when they hear a singular one. This provides a measure of plural comprehension for comparison to the act-out results, and allows us to see how children's comprehension of unfolds over the course of a sentence. Though the children we test are older than those in previous eye-tracking studies, this task also allows us to begin comparing Chilean learners to them (e.g., Arias-Trejo et al. 2014; Kouider, Halberda, Wood & Carey, 2006).

Participants

Fifty-six children (ages 3;11-6;10, M = 5;3, 34 girls) participated. One additional child completed the act-out task, but was excluded from the sample because her inattentiveness prevented calibration of the eye-tracker. Nine adults completed the act-out task as a comparison group. All participants were native speakers of Chilean Spanish, recruited in Punta Arenas, Chile. Children attended parochial tuition-based schools and were predominantly from middle-class Chilean families.

Act-out Comprehension Task

Stimuli and Procedure. Participants completed 20 test trials in which they were asked to place a certain quantity of toys into a box (e.g., *pon unas botellas en la caja*, "put some bottles in the box"). All nouns were familiar. On each trial, there were two sets of 6 miniature items on the table along with a box. Participants heard 4 requests with each of the quantifiers *un/una* ("a"), *unos/unas* ("some"), *algunos/algunas* ("some"), and *muchos/muchas* ("many"), and 2 each with the quantifiers *pocos/pocas* ("few") and *todos/todas* ("all"). These test trials were preceded by

three practice trials using the quantifier *un solo* ("a single"), and numerals *dos* ("two") and *tres* ("three"), and were presented in a pseudorandom order such that the same quantifier never occurred on adjacent trials. The number of items children placed in the box was recorded and classified as singular or plural.

Results and Discussion. Figure 2 shows the mean proportion of plural responses for children and adults. As in previous studies, children nearly always provided one item in response to *un/una* ("a") trials, but sometimes responded with one item and sometimes with multiple items on *unos/unas* ("some") trials.

Chilean children gave reliably fewer 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), but reliably more plural responses than in *un/una* ("a") trials (*un/una* Mdn = 0, *unos/unas* Mdn = 0.5; $V = 0$; $p < .0001$; Wilcoxon signed-rank). Children also provided fewer plural responses than adults in *algunos/algunas* ("some") trials (adult Mdn = 1, child Mdn = 1; $W = 369$; $p = .012$). This suggests that while Chilean 4- to 6-year-olds have not yet reached adult-like performance with plural comprehension, they are, as a group, sensitive to plural morphology: though they only sometimes provide plural responses to plural requests, they essentially never do so for singular requests.

As in previous studies, responses to *unos/unas* ("some") trials were bimodal: children were more likely to provide singular or plural responses consistently than to provide some of each (Figure 3). The current sample is roughly equivalent to the younger Chilean middle-class group (mean age 5;2) tested by Miller and Schmitt (2010). Using their classification system, 26 of the current participants (46%) were singular responders (0 or 1 plural response out of 4), 21 (38%) were plural responders (3 or 4 plural responses), and 9 (16%) were variable responders (2

plural responses). For comparison, their group had 33% singular responders, 53% plural responders, and 13% variable responders.

Eye-tracking Comprehension Task

Stimuli. Stimuli were sentences containing 16 novel object-names (e.g., *teka, kipo*) accompanied by photographs, as shown in Figure 1. There were two images in each trial, one showing a single novel item, and the other showing four instances of another novel item. All target nouns began with voiceless stops (p/t/k), and were two syllables. Half were transparently feminine (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]. Though including every /s/ was unusual, no instance of /s/ was ungrammatical in the target dialect.

Participants were assigned to one of two conditions: half to the *hay* condition (n = 28, range = 3;11-6;3, 16 girls) and half to the *ser* condition (n = 28, range = 4;1-6;10; 18 girls). In the *hay* condition, the only cues to number appeared in the noun phrase. In the *ser* condition, the verb also provided a cue to number. Each participant heard 8 singular and 8 plural test trials, evenly divided between masculine and feminine target nouns. Half of the plurals were bare and half were indefinite. Within participants, the left-right position of the target and 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 as breaks. Across participants, sequences were counterbalanced for order (the chosen pseudorandom order or its reverse), which image was the target, and left-right position of the images.

Apparatus and Procedure. Participants sat about 2.5 feet from a 24-inch monitor, with an EyeLink 1000+ eye-tracking camera between the participant and monitor, in a quiet lab space. 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, and were separated by a central fixation image.

Measures. We considered participants' fixations to the plural (4-object) picture in three windows. The *sentence window* was 1500 ms long, and encompassed the full sentence (sentence duration: range 807–1322 ms, M = 973 ms). The window was offset by 300 ms, as is typical in analyses of children's eye-movements (Fernald, Zangl, Portillo, & Marchman, 2008), and 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.

To investigate children's use of a subset of the available cues, we also considered fixations to the plural image in two shorter windows. 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 /s/ or /∅/: una|s tekas, teka|s, una| teka). This encompassed the frame verb (*hay*, *es/son*), but ended before determiner or noun morphology could have influenced looking. The *determiner window* was 398 ms long and extended from 300 ms after the beginning of the NP until 300 ms after the earliest noun affix (i.e., teka|s, unas teka|s, una teka|). Participants' behavior during this window should reflect their processing of determiner number morphology (or the determiner's absence), but not the nominal morphology itself.

Exclusions. Trials were excluded if the sound signaling trackloss occurred during or immediately after the test sentence (90 trials of 896 total, 10%). For each window, trials were excluded if the participant looked away from the target and distractor for more than 50% of the time-period of interest (sentence window: 51of 806 trials excluded, 6%; verb window: 90 of 806, 11%; determiner window: 52 of 806, 6%)[1].

Results and Discussion. Figure 4 shows looks to the plural image as a proportion of looks to either image in 2-ms intervals from sentence onset, plotted by target plurality (singular/plural), and by condition (*hay/ser*). Participants in both conditions looked about equally at the two pictures before sentence onset, then more to the plural picture during sentences with plural morphology than during sentences with singular morphology. The *hay* condition shows a distinct peak, while the *ser* condition has a less drastic differentiation between singular and plural trials.

Sentence window. Figure 5a shows that in both the *hay* and *ser* conditions the proportion looking to the plural image was greater in plural trials than in singular trials and did not differ by plural type. Figure 5b shows the same data as by-participant difference scores: average looking to the plural image in plural trials minus average looking to the plural image in singular trials. Difference scores above zero indicate that the participant looked more at plural images in plural than in singular trials.

To test this group-level pattern, we fit a linear mixed-effects model of proportion looking to the plural image[2]. Predictor variables, entered into the model using mean-centered effects

[1] Window proportions and exclusions were calculated using R 3.3.1 (R Core Team, 2016) and the *eyetrackingR* package (Dink & Ferguson, 2015).
[2] For comparison to previous studies (Kouider, et al., 2006; Arias-Trejo et al., 2014), we also calculated a pre-post difference score by subtracting participants' proportion looking to the plural

coding, were the within-participants factor target number (singular/plural), and the between-participants factor condition (*hay/ser*). The model included the maximal random effects structure justified by the design. Including the interaction of z-scored age with target number significantly improved model fit ($\chi^2(1) = 7.19$, $p = .007$). Age and its interaction with target number were retained. This analysis revealed a significant main effect of target number ($N_{trials} = 755$, $\beta = 0.19$, $se = 0.03$, $\chi^2(1) = 25.83$, $p < .0001$) [3], but neither the main effect of condition nor its interaction with target number were statistically reliable (condition: $\chi^2(1) = 0.66$, $p = .42$; interaction: : $\chi^2(1) = 1.89$, $p = .17$). Planned comparisons revealed a significant simple main effect of target number in both conditions (*hay*: $\chi^2(1) = 22.89$, $p < 0.001$; *ser*: $\chi^2(1) = 9.05$, $p = 0.003$). A secondary analysis within the plural trials revealed no effect of plural type (bare/indefinite), condition, or their interaction (all $\chi^2(1) < 1$, $p > 0.5$).

The main effect of target number in the sentence window indicates that participants used plural morphology to infer number meaning, and looked longer to the plural picture in plural than in singular trials. 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 interpretation of the sentence. The lack of an effect of plural type suggests that bare and indefinite plurals were similarly good cues to plurality. These analyses, however, offer only a coarse-grained look at the time-course of

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picture in a 1.5-s pre-sentence window from their proportion looking to the plural picture in the 1.5-s 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 ($t(27) < 1$, $p > .4$).

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

processing. To further investigate children's processing of subsets of the available cues, we examined the verb and determiner windows.

Verb window. In the verb 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 expect a difference between singular and plural trials in the *ser* condition, and not in the *hay* condition. Analyses parallel to those described above 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 $\chi^2(1) < 1.5$, $p > .2$).

Thus, in contrast with recent studies showing that 2.5- and 3-year-old English-learning children use an agreeing verb to anticipate features of an upcoming familiar noun (Lukyanenko & Fisher, 2016), in the current study a number-marked verb did not drive anticipatory changes in looks to the target image. This discrepancy may be due slower processing of novel nouns, the brevity of the measurement window, or the different measures used. Spanish does not readily permit the prenominal adjectives that previous studies have used to lengthen the window and observe predictive effects of function words (Lukyanenko & Fisher, 2016; Melançon & Shi, 2015), and the current between-participants design renders comparisons of dynamic measures (e.g., reaction time, shift proportion) impractical.

Determiner window. During the determiner window, participants are processing the linguistic information carried by the determiner (or its absence), and integrating it with the previously-heard verb (*hay, es* or *son*). 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 in an interaction between target number and condition.

Figure 6a shows that proportion looking to the plural image was greater in plural than in singular trials in the *ser* condition, and Figure 6b shows by-participant difference scores. We fit a mixed-effects model as described above. 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 revealed a significant main effect of target number ($N_{trials} = 754$, $\beta = 0.09$, $se = 0.04$, $\chi^2(1) = 7.98$, $p = .005$), but not of condition ($\chi^2(1) = 1.83$, $p = .18$) or their interaction ($\chi^2(1) = 0.62$, $p = .43$). 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 indicates that participants used the form of the determiner, or its absence, to infer the number of items under discussion. 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.

Overall, Chilean children's performance in the eye-tracking task reveals sensitivity to plural morphology, despite its variability in their input. Children looked longer to a matching picture overall and in an early window in which the nominal affix itself was not yet available.

Correlation Between Tasks. We also asked whether performance in the two tasks was correlated. If some children ignore markers of plurality, their responses in both tasks should be less accurate. Figure 7 shows each participant's number of plural responses in the *unos/unas* ("some") trials in the act-out task plotted against their sentence window difference score in the eye-tracking task. Though the difference score showed a reliable, moderate correlation with age

(r = .33, p = .01), and the proportion of plural responses to *unos/unas* trials was marginally correlated with age (r = .23, p = .09), the measures themselves were not correlated: children who provided more plural responses in *unos/unas* trials did not consistently show larger differences between their plural looking in plural and singular trials (r = .07, p = .60). This suggests that there is no clear group of children who consistently ignore plural morphology.

Discussion

In two tasks, Chilean 4- to 6-year-olds, as a group, distinguished between singular and plural morphology: in an act-out task they gave reliably more plural responses to indefinite plural than to indefinite singular requests, and in an eye-tracking task they looked reliably longer to a picture of multiple items in plural than in singular trials.

At the individual level, results are more complex. Replicating previous findings, many children provided no plural responses to indefinite plural trials in the act-out task (16/56 participants, 29%), and in the eye-tracking task, 12 of 56 participants (21%) had sentence window difference scores of 0 or less. Only 5 participants fell into both groups, which is not reliably different than would be expected by chance given participant distributions on each task (p = .29, Fisher's Exact). This and the lack of correlation between the act-out and eye-tracking measures, suggest that poor performance on either task is not, alone, a reliable indicator of lack of plural knowledge. However, the observed correlations of age and performance on each task are consistent with previous findings (Miller & Schmitt, 2010; 2012) and suggest that Chilean children's performance in these tasks becomes more adult-like over time.

These results raise two main questions: First, what accounts for the lack of correlation between performance in the two tasks? Second, how do we account for Chilean children's non-

adult-like behavior and the differences between their performance and Mexican children's in previous studies?

There are a number of potential explanations for the lack of correlation between tasks. The first, and perhaps least interesting, is that these measures may not be highly reliable at the individual level. Establishing test-retest reliability will be an important step as we move forward. Second, the two tasks may tap different aspects of plural knowledge. The eye-tracking task asks children to use plural morphology to disambiguate a novel noun, and feels like word-learning. In contrast, the act-out task uses familiar nouns and is clearly about quantities. The pragmatics of using *unos* in each situation may differ in subtle ways.

Previously observed asymmetries between Mexican and Chilean children's plural comprehension clearly indicate that the variability in Chilean Spanish influences acquisition. The current results raise questions about precisely how acquisition is affected. One intriguing possibility is that the variability affects children's acquisition of quantifier meaning in a way that differentially affects the act-out task. While children acquire the denotational meaning of *some* early, it takes time before they rapidly calculate the implicature that *some* is *not all* (e.g., Papafragou & Musolino, 2003). Lenition is especially common in NPs with plural quantifiers (e.g., *todos, muchos*), reducing the probability of getting redundant evidence of quantifier plurality from local affixes. This may make it more difficult for Chilean children to discover that *some* is a poor description of *one* (Degen & Tanenhaus, 2015), and lead them to provide singular responses despite familiarity with plural morphology.

To begin to answer these remaining questions, future studies will use eye-tracking to (a) explore Chilean children's processing of sentences with familiar nouns, (b) test younger Chilean children's comprehension of the plural and (c) provide direct comparisons between child and

adult Chilean and Mexican Spanish speakers' online processing. This will allow us to better understand the role of the agreeing verb in Chilean children's comprehension, changes in their sentence processing over time, and cross-dialectal differences in processing and comprehension.

word count: 4021 (target 4000)

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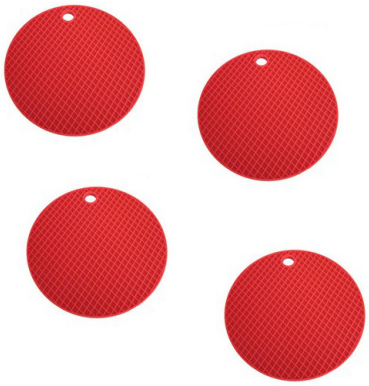
Figure 1. Sample materials for the eye-tracking task.



		hay	**ser**	trials
singular		*¡Mira! Hay una teka.* "Look! There's a teka."	*¡Mira! Es una teka.* "Look! It's 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

Figure 2. Act-out task results. Mean (se) proportion of plural responses in response to prompts with each quantifier.

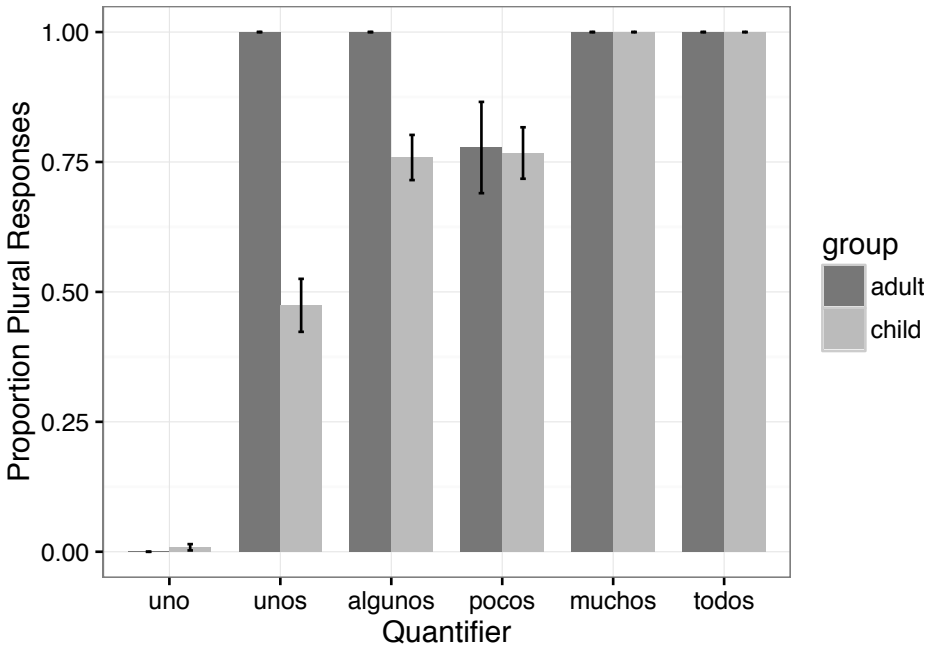


Figure 3. Histogram children's plural responses in *unos/unas* trials in the act-out task.

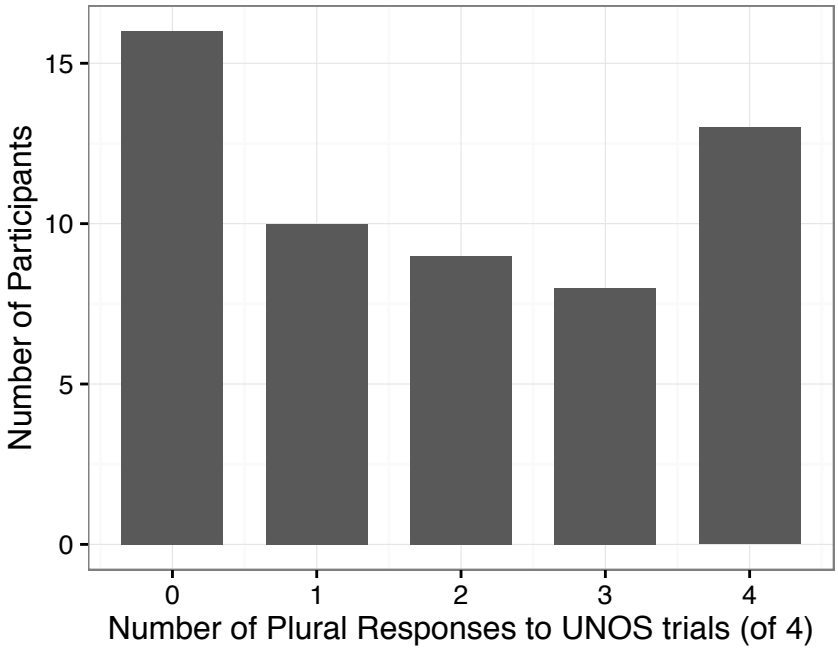


Figure 4. Mean (se) proportion looking to the plural image as a function of trial time. Solid vertical line indicates sentence onset. Dotted lines indicate average noun onset and average sentence offset.

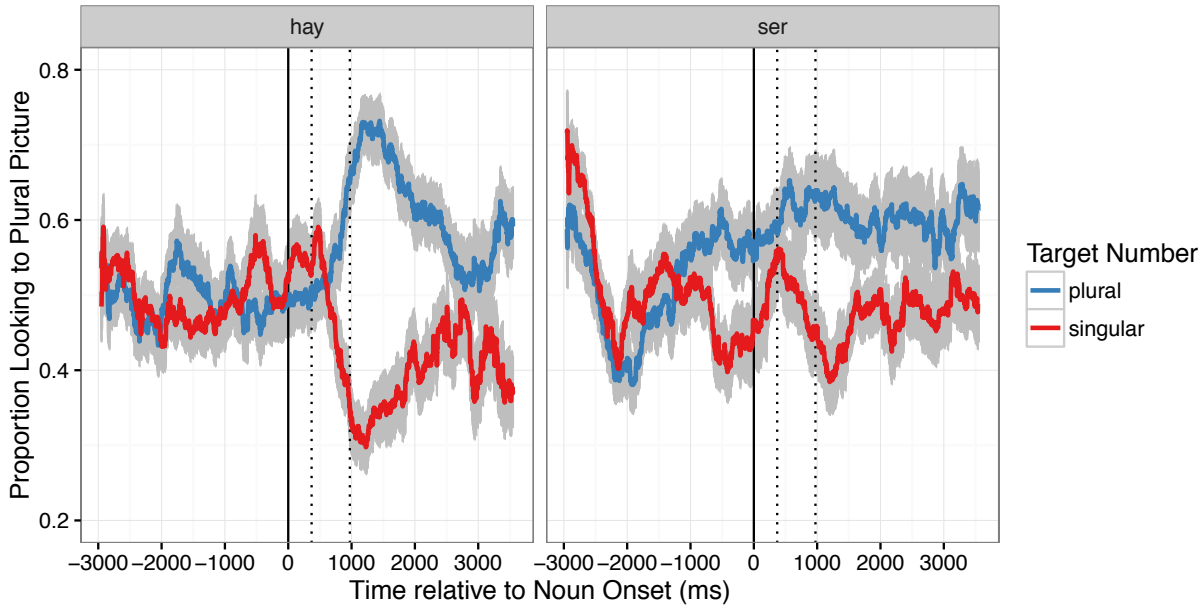


Figure 5a. Proportion looking to the plural image in the sentence window. Each dot represents a participant mean.

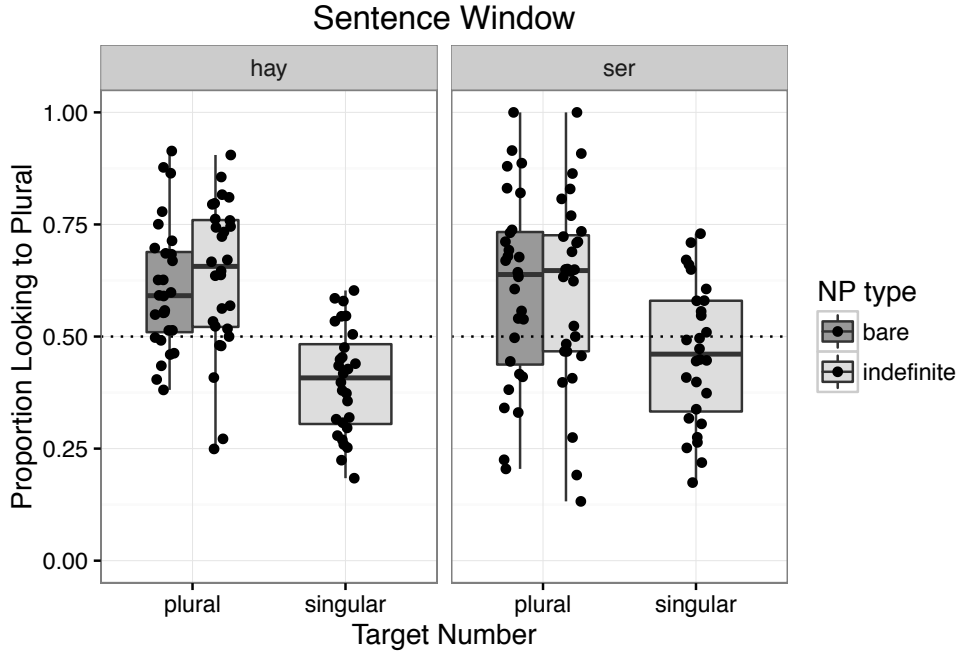


Figure 5b. Proportion looking to the plural image in plural trials minus proportion looking to the plural in singular trials. Each dot represents a participant.

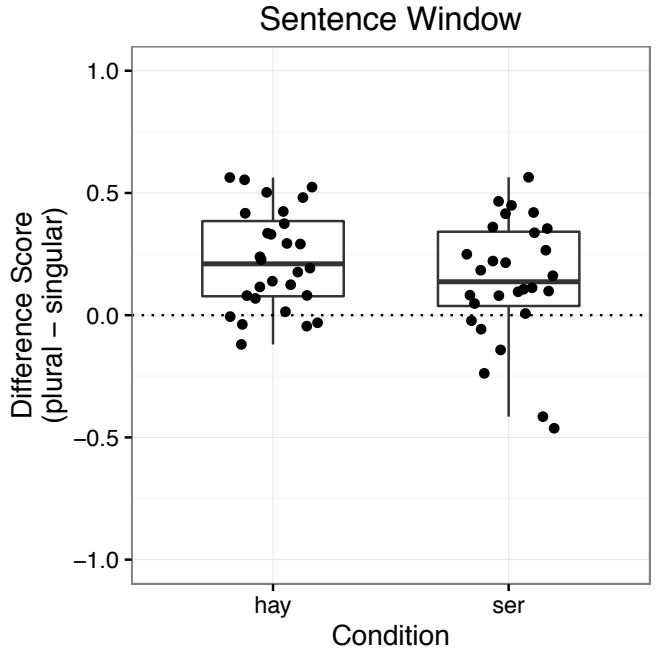


Figure 6a. Proportion looking to the plural image in the determiner window. Each dot represents a participant mean.

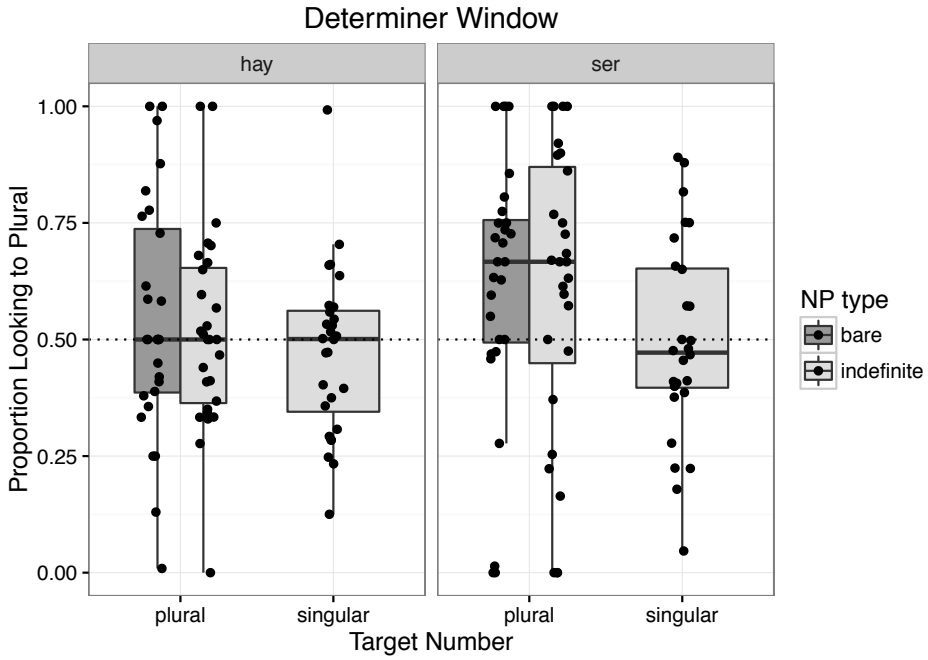


Figure 6b. Determiner window difference scores. Proportion looking to the plural image in plural trials minus proportion looking to the plural in singular trials. Each dot represents a participant.

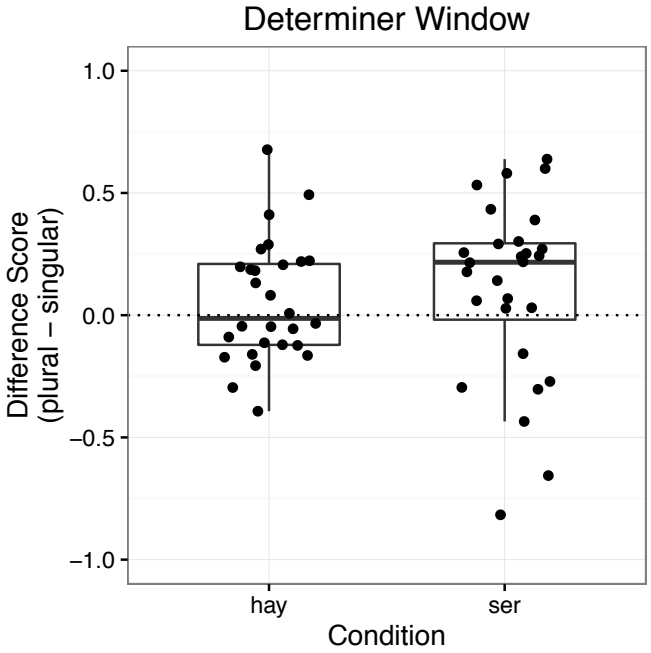


Figure 7. Proportion plural responses in *unos/unas* (“some”) trials in the act-out task plotted against mean difference in proportion looking to the plural picture during the sentence window in plural and singular trials in the eye-tracking task. Darker points represent older participants.