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# Red rats eater exposes recursion in children's word formation

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**Abstract**

The present study examines noun–noun compounds where the internal noun is pluralized (e.g., *new books shelf*), contrary to normal constraints that prohibit such constructions. It is proposed that these apparent violations are licensed by a recursive mechanism where word formation passes into Syntax and back into Morphology. Thirty-six 3- to 5-year-olds were tested on their interpretations of compounds fronted by an adjective. When asked to point to a picture of a *red rats eater*, children preferred a picture where the rats were red over one in which the eater was red. The opposite preference was found when children were asked to point to a *red rat eater*. These response patterns reflect a recursive–syntactic interpretation when the noun is plural, but a non-recursive interpretation when the noun is singular. The results suggest that children's word formation processes allow complex interactions between grammatical systems from early in acquisition.

## 1. Introduction

Advances in our understanding of phenomena often arise from paradoxes. One such paradox is to be found in the area of word formation with respect to the relation between inflection and compounding. On the one hand, we find strong evidence for a constraint on word formation that blocks the insertion of regular plurals inside compounds (e.g., **claws marks*). On the other hand, the constraint appears to be violated in acceptable and attested compounds in the language (e.g., *publications catalogue*, *new books shelf*).

Finding a solution to the paradox requires that we identify a principled

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way to distinguish between the acceptable and unacceptable cases. The present paper seeks to show that, at least in some of the cases, we are required to postulate an interaction between lexicon and syntax. Furthermore, we show that this interaction, in the form of syntactic recursion, is present in children as young as 3 years of age.

The constraints on pluralization in compounding were first pointed out by Kiparsky (1982, 1983) within the theory of Level Ordering in lexical phonology and morphology. In this version of the theory, lexical processes in English are assigned to one of three levels. Level 1 includes processes that tend to affect the phonology of the hosts to which they apply, are semantically unpredictable or both. Affixes that change the stress pattern or vowel structure of their stems – traditionally termed "non-neutral" – are included at this level. Also included at level 1 are other kinds of idiosyncratic forms such as irregular inflections and pluralia tantum. Level 2 includes the "neutral" derivational processes, which do not affect phonology and are semantically predictable. Compounding is also found at this level. Regular inflections are found at level 3.

The constraints on inflection and compounding are explained by the ordering of word-formation rules according to the level at which they are applied. Thus, the insertion of a regular plural (level 3) before compounding (level 2) is not possible (e.g., **claws marks*) since this would require backtracking. Irregular plurals, on the other hand, are assigned to level 1 and may be found inside compounds (e.g., *teeth marks*).

While the contrast between pairs such as *teeth marks* and **claws marks* is striking, some researchers have pointed out counterexamples to the generalization. For example, Selkirk (1982) noted examples such as *Parks commissioner*, *buildings inspector*, *programs coordinator* and others. Selkirk's approach to morphology incorporates word formation into the regular X-bar theory associated with syntax rather than positing ordered levels like Kiparsky. In this system, there is no constraint against regular plurals inside compounds. However, Selkirk notes that such cases tend to have peculiar semantic properties or are used to distinguish different interpretations. For example, in the contrast between *programs coordinator* and *program coordinator*, the former coordinates between programs and the latter coordinates within a program.

A problem with Selkirk's approach is that it fails to explain why regular plurals are blocked in the majority of cases and irregular plurals are not. In fact, the notion of a "counterexample" assumes the existence of a rule which it violates. While it may turn out that Kiparsky's theory is not the best way to model the organization of lexical processes (cf. Pinker, 1991; Pinker & Prince, 1992), it is hard to deny the validity of Kiparsky's generalization regarding plurals inside compounds, which appears to have psychological as well as linguistic support.

Senghas, Kim, Pinker, and Collins (1991) showed that, when adults had to judge the naturalness of novel compounds, those including irregular

plurals were rated as far more acceptable than those including regular ones. The constraint thus seems to be part of adult speakers' competence.

Gordon (1985) showed that even 3- to 5-year-old children are sensitive to the difference between regular and irregular plurals inside compounds. In an elicitation task, children produced compounds containing irregular plurals (e.g., *mice eater*) but avoided compounds containing regular plurals (e.g., **rats eater*). Interestingly, compounds containing irregular plurals are near-zero frequency in English (Gordon, 1985). This means that it is very unlikely that children could have derived their knowledge of the constraint from their language input. Gordon (1985) interprets these facts as indicating an innate constraint on lexical structure such that the ordering effects follow from the system rather than being "learned" in any meaningful sense.

Clahsen, Rothweiler, Woest, and Marcus (1992) replicated Gordon's study in German. Like English, the regular plural in German is $-s$. This is determined by its default use with unusual, derived and borrowed forms. However, unlike English, the $-s$ plural in German has a very low frequency in the language compared to other plural allomorphs such as $-n$, *er* or *e*. The children in Clahsen et al.'s study, like those in Gordon (1985), produced irregular plurals inside compounds and avoided regular ones. Interestingly, some of the German children treated the irregular plural $-n$ as being the regular form. These children omitted the $-n$ plural from inside compounds, producing ungrammatical forms (e.g., **blume-vase*) that went against the compounding pattern in their input (e.g., *blume-n-vase*). These findings strongly support the position that the inclusion or omission of plurals inside compounds has very little to do with the input the child receives, but rather is focused on the notion of regularity in a formal sense.

However, we are still left with the paradox of the existence of compounds like *publications catalogue*, which allow the internal regular plural despite strong evidence for a systematic and possibly innate prohibition. Could children acquire the exceptions conservatively, one by one, from the input? While this strategy may indeed occur in acquiring some aspects of complex morphology (cf. Pinker & Prince, 1992), there are problems in this particular case. Unless the exceptions were licensed in some way, they would have to be arbitrary exceptions to the rule, and would thereby open the possibility that forms like **claws marks* might be grammatical if people just decided to start using them. Yet this does not seem to be the case. Having heard *publications catalogue* only once, most people find it acceptable, yet they could hear **claws marks* several hundreds of times without ever accepting it as grammatical.

Of course, it is quite likely that some of our judgements are affected by conventionality, or what has been coined up to this time. However, this is different from allowing the possibility that any form could be coined in the future, without apparent constraint. Therefore, the most satisfactory explanation of the facts should be one that is able to determine, in some principled way, which compounds have the potential of including a regular

plural and which do not. If we can find that licensing mechanism, then we can ask whether children are sensitive to it at the same time that they seem to be sensitive to the constraints that differentiate regular from irregular plurals inside compounds.

In considering the range of exceptions to Kiparsky's generalization, there appear to be several different kinds of cases. These include, first, the straightforward pluralia tantum nouns such as *alms-giving*, *arms-manufacturing* and so on. These are not strictly exceptions since Kiparsky assigned them at level 1 in his original theory and therefore they are simply listed as plurals in the lexicon. Gordon (1985) showed that young children produce compounds like *clothes eater* while not allowing regular plurals in compounds like **rats eater*.

A second class of cases includes non-head nouns that are inherently quantificational. If these nouns were to appear in the singular form, they would entail a singular quantity, which might be inconsistent with the intention to denote plural quantities. Hence, a *week-long* event cannot last longer than a week, and thus one is licensed to use the plural as in a *weeks-long seminar*. It is interesting to note that these examples are always headed by a spatial-dimensional or temporal-aspectual adjective such as *long*, *tall*, *deep*, *old* and so on.

The next set of cases is less easily dealt with. These include compounds like *publications catalogue*, *faces research*, *letters policy*, *claims application*, *counterexamples list* and so on. For now, we will characterize these as "heterogeneous" and elaborate on this designation in the Discussion section.

The final class of cases we will consider are those in which the plural noun inside the compound is modified by an adjective. These include cases such as *equal rights amendment*, *new books shelf*, *American cars exposition* and so on. Some of these examples are particularly striking because they are quite unacceptable without the adjective modifying the noun inside the compound (cf. **books shelf*, **cars exposition*).

In the present study we will focus on this last set of cases in examining the developmental issues of how children come to know when plurals are or are not allowed inside compounds. Fortunately, these cases are accessible to testing with young children since they can be formed using relatively simple nouns. The heterogeneous nouns noted earlier are difficult to study developmentally since they tend to be rather abstract, denoting such things as organizational units (e.g., *claims department*), fields of study (*faces research*) and so on.

It will be recalled that regular plurals are normally blocked from appearing inside compounds because they violate the ordering of compounding before regular inflection (Kiparsky, 1982). In recognizing the existence of counterexamples, Kiparsky himself suggested that compounds like *Human Services Administration* could be formed through a recursive procedure.

English allows quite radical recursivity within compounding as attested by examples like *a seat-of-the-pants executive* or *the how-can-it-be-innate-if-it-needs-experience absurdity*, where complete syntactic phrases or even sentences take the non-head position in the compounds (see Lieber, 1988). In fact, such recursion seems quite unlimited, extending to examples like: *the how-can-he-be-a-seat-of-the-pants-executive-if-he-needs-experience absurdity*.

How can recursion explain the existence of regular plurals inside compounds? Basically, one has to allow that, if recursion does occur, then this is different from backtracking and violating ordering constraints. In other words, regular plurals are applied on a first pass[1] and the output of that process is then submitted to compounding on a second pass. Therefore, the application of the plural is rather like the formation of phrases and sentences noted previously, which are also submitted to compounding at a later stage.

Of course, this begs the question of why **rats eater* and **claws marks* cannot be formed through recursion. We address this problem briefly in the Discussion section and more extensively in Alegre and Gordon (in preparation). For now, we will stipulate that this recursion is not completely free, and must be licensed in some way. Since there appear to be identifiable semantic properties associated with regular plurals inside compounds, this gives credence to the possibility that such licensing exists.

Let us consider the case of adjectives modifying nouns inside compounds. A compound like *red rat eater* – with no plural – can be generated in one of two ways: non-recursively, as in Fig. 1(a), or recursively, as in Fig. 1(b).

The bracketing in (a) represents a regular N–N lexical compound modified by the adjective, *red*. In (b), the adjective modifies the noun inside the compound. This means that *red rat* in (b) is an NP constituent,

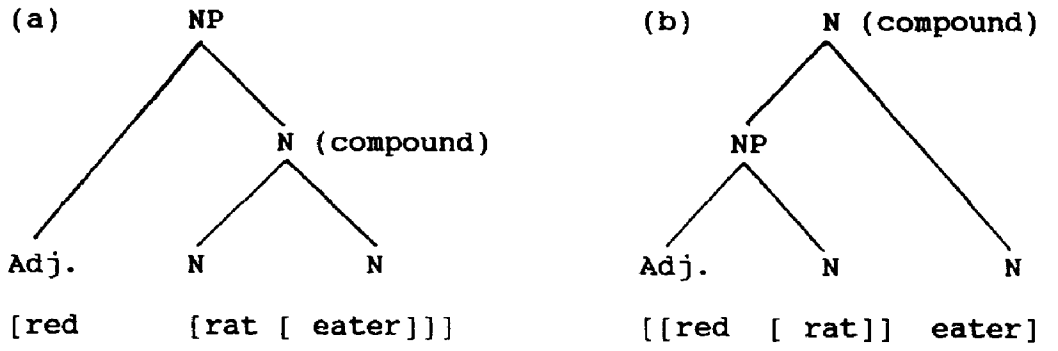


Fig. 1.

[1] There is some disagreement as to whether regular inflection is a lexical or a syntactic process. For our purposes we assume that it is either syntactic or is at some interface between lexicon and syntax.

generated in syntax, which has been recursively fed into the compounding rule. It is interesting to note that the two possible readings of *red rat eater* can be disambiguated by whether the eater is red in (a), or the rats are red in (b).

We can speculate that, in the absence of any other factors, there should be a bias to favor non-syntactic interpretations. From a processing perspective, the incorporation of a recursive NP into the compound requires building extra structure. Under the principle of Minimal Attachment, such unnecessary structure building is avoided if possible (Frazier, 1979, 1987). In addition, one can consider learnability issues relating to the possibility of overgeneration. In particular, we have noted that the recursive machinery for compounding, if left unconstrained, could wildly overgenerate plurals inside compounds, and hence allow constructions like **claws marks*. Therefore, it would be prudent for the child to approach the use of recursion in compounding somewhat conservatively, and not assume such recursion in the absence of definitive evidence in favor of such an interpretation. This basic principle of cautious productivity is endorsed in other examples of semantically constrained rule acquisition such as Dative Alternation, Passive, Locative Alternation and so on (Pinker, 1989).

It is possible to add factors that could trigger a recursive interpretation of a compound. One way to do this would be to add a regular plural to the non-head noun (e.g., *red rats eater*). The presence of the regular plural should be positive evidence for a recursive compound: regular plurals inside compounds are initially blocked, but are possible through syntactic recursion.

In the present study, this hypothesis is tested with young children to examine whether they have recursive devices available during acquisition and whether the use of those devices is conditioned by the necessity rather than the possibility of a recursive interpretation. In other words, we hypothesize that a regular plural used in a construction such as *red rats eater* blocks the non-recursive interpretation in which the eater is red, and necessitates the recursive interpretation in which the rats are red. However, in the absence of the regular plural, there should be no need to resort to the recursive interpretation, and the non-recursive interpretation should be preferred.

## 2. Method

### *2.1. Subjects*

Subjects included 36 children divided into three groups of 12 by age: 3-year-olds (aged 3;1 to 3;11, mean age = 3;6), 4-years-olds (aged 4;0 to 4;11, mean age = 4;7) and 5-year-olds (aged 5;1 to 5;10, mean age = 5;4).

### 2.2. Materials

Pre-test items consisted of eight colored cards (red, blue, brown, white, pink, yellow, black, orange) that were used to ensure that children knew the colors to be used in the main test. The test stimuli included four pairs of pictures each depicting a creature eating several smaller creatures. These included a monster eating rats, a cow eating flowers, a monster eating spiders and a fish eating crabs. In each pair, both pictures were identical except that, in one, the eater was the color used in the verbal description (e.g., red rat(s) eater); in the other, it was the eatees (rats) that were so colored.

### 2.3. Equipment

A Sony Pro Walkman, which produces very high-quality sound reproduction, was used for recording test sessions. For experimenter training and post test analysis of prosodic information we used a digitized speech analyzer and CECIL (Computerized Extraction of Components of Intonation in Language) software connected to an IBM-compatible computer. CECIL allows for an exact measure of many phonological and prosodic properties of natural speech, such as the length of speech segments or pauses and the intonation contour associated with fundamental frequency values.

### 2.4. Procedure

Subjects were tested in day-care centers in the Pittsburgh area, individually, by one of two female experimenters who had previously familiarized themselves with the playgroup.

In the main test, children were presented with four pairs of pictures of an animal of some sort (cow, fish, monster) eating various organisms (flowers, crabs, rats, spiders). In each pair, one of the pictures had the eater painted in the target color and the other had the things being eaten painted that color (see section 2.2). While the present group of children would most likely know the common colors, it was important to ensure that this was the case. Therefore, we carried out a short pretest in which children were presented with eight colored cards and were asked to point to a particular color for each of the colors used in the main test. There were no errors on this pretest.

For the test items, in a between-subjects design, half of the children in each age group were randomly assigned to a plural condition, and the other half were assigned to a singular condition.

The children were presented with each pair of pictures and were asked to identify the creatures in them and their colors. For example, for the *red rat(s) eater* pair, they were prompted to say that both pictures depicted a

monster eating rats, and in one picture the monster was red and the rats blue, while in the other picture the monster was blue and the rats red. Following that, children in the *singular condition* were asked: "can you point to the picture that shows a *red rat eater*?" Children in the *plural condition* were asked: "Can you point to the picture that shows a *red rats eater*?" The same pattern of questioning was used in all four pairs of items.

### 2.5. Experimenter training

Unfortunately, there was a possible confounding factor that needed to be controlled for in this experiment: compounds like *red rat(s) eater* are potentially ambiguous only under a pattern of even pronunciation that avoids prosodic cues such as stress, pause or pitch contour. Any pattern of prosodic difference may bias one bracketing over the other. Since we wanted to test only the effect of the regular plural, we needed to determine that such prosodic cues were not present during testing.[2]

With regard to stress patterns, these are determined linguistically by rules such as the compound stress rule (stressing the first member of a compound), and nuclear stress rule (stressing the head of a phrase) (Chomsky & Halle, 1968). In the present study, since one reading of *red rat(s) eater* requires *rat(s)* to be the left member of a compound, and the other reading requires it to be the head of an NP, these two rules act to cancel each other out, resulting in identical stress patterns for the two readings. Using the S (strong) W (weak) notation of metrical phonology, we can show that the metrical trees associated with two readings of this compound result in identical stress assignments (Fig. 2).

While the stress assignments in this case are not differentiated, it is possible to differentiate the two readings by exaggerating pausing and intonation contour. With respect to pauses, it is clear that heavy pausing at word boundaries can differentiate the two readings of a compound. However, pausing is quite optional and not clearly noticeable in connected natural speech. Similarly, pitch contours, articulated by fall–rise patterns in fundamental frequency ($F_0$) at word boundaries could also provide unwanted intonation cues to structure (See Cooper & Sorensen, 1981, for a discussion). However, intonation also is not prominent in these constructions in normal speech, because of the equivalent metrical structures noted previously. For both pause and intonation, biasing information would only occur if the speaker were attempting to focus on a particular structure as when contrasting, say, a *RED rat eater* with a *GREEN rat eater*.

[2] While these problems could have been dealt with by spliced tapes or speech synthesizers, we were reluctant to introduce such artificial measures that could seriously hamper the collection of representative responses. Such reluctance was based on past experience with artificial stimuli (Chafetz & Gordon, 1989).

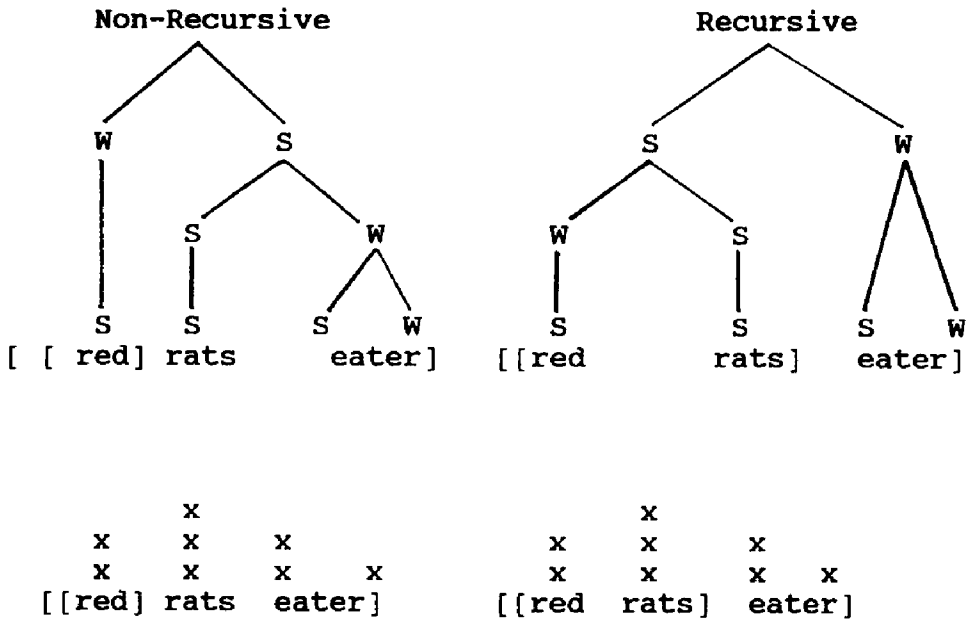


Fig. 2.

To ensure that there was no biasing prosodic information available to the child, we took two measures. First, we trained the experimenters to avoid prosodic cues through feedback from spectral displays of pitch contours. Second, we tape recorded all experimental sessions and later analyzed pause and intonation contour to determine whether there had been any biasing prosody associated with the different interpretations of the stimulus compounds. This analysis included (1) measurements of pause length at the first and second word boundaries within each compound (e.g., *red . . . rat(s) . . . eater*), which would identify lengthening that might favor either a recursive or non-recursive interpretation, (2) fall–rise patterns in fundamental frequency at those same boundaries, which correlate with the strength of those boundaries for the speaker and listener – junctures representing phrase boundaries tend to show greater changes in $F_0$ than those within phrases (Cooper & Sorensen, 1981). Details of these analyses are provided in Appendix A. The analyses showed no differential prosodic information that could be interpreted as determining the pattern of responses that we found. In nearly all cases there was no difference between the singular and plural condition with regard to prosodic properties of the items. Only when we conducted 45 separate *t*-tests on individual items did we find three significant differences – about the number to be expected by chance – and in these cases, the differences were all in the opposite direction than we would expect if they were biasing the children to respond in the way that they did.

## 3. Results

All subjects were able to identify the pre-test colors, and remained in the experiment completing all items without difficulty. In both singular and plural conditions, we scored responses in terms of number of recursive interpretations indicated by picture choices. The highest possible score for a subject was 4 and the lowest possible score was 0. Table 1 shows mean scores and standard deviations by Age and Condition. An ANOVA revealed a substantial Condition effect ($F(1, 34) = 18.552$, $p < 0.001$) while the Age effect and the Age × Condition interaction were not significant ($F(2, 33) = 0.753$ and $F(2, 33) = 0.946$ respectively).

With respect to the predictions, the data from this study are quite unambiguous in supporting them. Children in the Singular condition behaved conservatively, tending to interpret compound test items as not involving any syntactic constituent. Children in the Plural condition were more likely to interpret their compounds as containing an NP. Since the only difference between conditions was the presence or absence of a plural, then this clearly was the trigger for producing opposite response patterns.

Despite the strength of these findings, there are some alternative possibilities that must first be dealt with in interpreting the results. First, it is possible that the only meaningful behavior observed in this experiment is a conservative (non-recursive) interpretation of compounds in the Singular condition. Given that children know that regular plurals are ungrammatical inside compounds (Gordon, 1985), the presentation of items like *red rats eater* could create confusion in children, leading to a random pattern of responses. If this were the case, then the data associated with the Plural condition would reflect randomness in responding rather than a systematic bias to favor a recursive interpretation. In such a case, we could still have a significant main effect but not for the reasons we are claiming.

To evaluate this alternative explanation, we carried out a *t*-test on the data from the plural condition, comparing against chance responding with respect to the choice of pictures (i.e., choosing a mean of two of each picture type in the four presentations). The results of the *t*-test revealed a significant difference ($t(17) = 2.75$, $p < 0.01$).

Table 1
Mean number of recursive interpretations (four responses per condition, *SD* in parentheses)

| | Age | | |
|---|---|---|---|
| | 3-year-olds | 4-year-olds | 5-year-olds |
| Singular | 1.0 (0.89) | 0.67 (1.2) | 1.5 (1.52) |
| Plural | 3.33 (0.52) | 2.5 (1.38) | 2.5 (1.38) |

Another possible factor that might confound the interpretation of these results was mentioned previously. We discussed the possibility that prosodic information might play a role in cuing children into the observed pattern of responses. We took several measures to ensure that the stimuli for singular and plural conditions were not biased in this way, and the spectral analyses showed that we were successful in this regard (see Appendix A). As an added safeguard, we also performed correlations on children's responses with pause length information from the stimuli. These analyses are detailed in Appendix A, revealing no significant association between children's responses and pause length.

## 4. Discussion

The present study strongly supports the following conclusions: 3- to 5-year-old children make a subtle distinction between the presence or absence of a regular plural inside a compound when fronted by an adjective. Specifically, when the regular plural is present, they interpret the adjective as modifying the internal noun. In the absence of a plural, the adjective modifies the compound as a whole. This difference has been shown to be the result of purely morphosyntactic processes, and not due to children responding randomly or paying attention to prosodic cues.

In previous studies (Gordon, 1985; Clahsen et al., 1992), it has been consistently shown that children allow irregular plurals inside compounds but not regulars. The results of the present study extend our knowledge of the organization of the morphological system in young children. The data show that children do, in fact, allow regular plurals inside compounds, but only if they are preceded by an adjective. Since children interpret the adjective as being part of an NP constituent with the first noun (e.g., [$_{NP}$red rats]), then this supports the interpretation that the plural is licensed by a recursive procedure from syntax back into morphology.

Once again the power of linguistic analysis in very young children seems remarkable in comparison to their other cognitive skills at this age. Also, it seems unlikely that children as young as 3 years of age could have been regularly exposed to instances of compounds containing regular plurals, and modified by adjectives. This is because nearly all of the attested examples we know of denote high-level concepts like *new books catalogue*, *equal rights amendment* and so on.

Even if such constructions are more frequent in the child's input than we think, it is not clear what set of facts could lead children, in a reliable way, to conclude that regular plurals inside compounds are indicative of recursion from syntax. It would be much simpler to assume that plurals are optional inside compounds, especially if the child had heard some examples of the exceptional cases like *awards ceremony*.

On the other hand, if we allow that children tend to prefer analyses based

on structural considerations (cf. Crain, 1991; Crain & Nakayama, 1987), then generalizations invoking recursive structures might be quite natural. Perhaps children do not need to figure out that syntactic recursion is allowed in compounding if they never entertain the possibility that such processes might be prohibited in the first place. Children may not start out with the assumption that different parts of the grammar such as syntax and morphology are restricted in their interaction.

In the present case, such a scenario would lead to a relatively simple account of the present results. On hearing "red rats eater", the child knows that *rats eater* is disallowed in the grammar (Gordon, 1985). He or she assumes that there must be a constituent comprising *red* and *rats* which, by their categorical assignments, would constitute an NP when combined. This is then inserted inside the compound without any concern about interactions between lexicon and syntax.

If this is the kind of learning mechanism employed by the child, then the present results could be considered a relatively straightforward product of that mechanism. However, there are some serious problems that would have to be considered within this relatively simplistic scenario.

One problem is that the child would have to come to know that recursion between lexicon and syntax is not applied freely across the board for different linguistic constructions. In English, the syntactically recursive constructions occurring inside compounds appear to be restricted to Modifier–Noun compound types. Thus, Lieber (1988) finds examples of compounds formed by: NP–N (*employee-of-the-month program*), PP–N (*around-the-world flight*), VP–N (*an ate-too-much headache*), AP–N (*a pleasant-to-read book*), and CP–N (*I-told-you-so attitude*). She finds no examples headed by categories other than Noun such as NP–V, VP–V, AP–V, NP–A, VP–A, AP–A and so on.[3]

Furthermore, the child would have to figure out what parameter settings are invoked by the language being acquired, since there is a large degree of variation in this regard. For example, Spanish does not allow any recursion within compounds, while Wari', an indigenous Amazonian language, does not have noun-headed compounds but does allow syntactic recursion within Verb-headed compounds as in (1), which is a single compound word with a verb-initial head (Everett, 1994; Everett & Kern, in preparation).[4]

| | | | | |
|---|---|---|---|---|
| (1) | Pan' corom mama' | pin | 'awi | nana |
| | fall enter go(pl) | completely | completely | 3p:rp/p |

[3] Steve Pinker (personal communication) points out that the lack of V-headed recursive compounds could be a consequence of the rarity of any kind of V-headed compounds in English in general.

[4] Evidence that this is a compound rather than a sentence derives from word-stress patterns, non-compositionality of meaning, and the ability to take compound-external arguments. 3p:rp/p denotes "3rd person, realis past/present".

"They all fell into the water"

Clearly, then, the child not only has to determine whether recursion in compounding exists in the language, but must also determine which forms are allowed and which are not. Depending on the language, complex compounds might be quite rare in the child's input, which makes the task of explaining this piece of acquisition not at all trivial.

Even if we stay within English compounding, the problems remain extremely complex and difficult to account for in terms of acquisition. In the present study, we have examined only one kind of exception to the no-plurals-inside-compounds generalization: those fronted by adjectives. But this does not exhaust the exceptions list. Recall from the Introduction that we identified cases such as *publications catalogue*, *faces research*, and *claims application*, which are not fronted by an adjective and which we characterized as being "heterogeneous".

A full discussion of these cases goes beyond the scope of the present paper, but we suggest that these constructions can be distinguished from the disallowed cases, such as **claws marks*, on semantic grounds. Based on adult grammaticality judgments, Alegre and Gordon (in preparation) have confirmed that heterogeneity is a property associated with acceptable regular plurals inside compounds.

These constructions tend to highlight or make relevant a degree of diversity among the elements designated by the internal noun. The plural *–s* seems to add the meaning "many types" rather than the standard "many individuals". For example, in the compound *publications catalogue*, the plural does not simply indicate that the catalogue contains many publications, but that it contains many *different* publications. One would not, for example, have a catalogue that listed multiple instances of a single publication.

In fact, we find that a large number of attested compounds containing regular plurals tend to have heads that promote this kind of heterogeneity of the non-head constituent. These include heads such as *research*, *catalogue*, *list*, *report*, and *department*. Adult acceptability judgments show that compounds headed by these types of nouns and containing regular plurals are more acceptable than matched compounds with heads that do not promote heterogeneity (e.g., *rocks research* vs. **rocks pile*) (Alegre & Gordon, in preparation).

Since the heterogeneous interpretation is required to license regular plurals inside compounds, then compounds such as **claws marks*, which do not lend themselves to a heterogeneous interpretation, would be disallowed on semantic grounds.

In the discussion of these data, Alegre and Gordon (in preparation) point out that the property of heterogeneity for plurals inside compounds can be derived from morphosyntactic structure. The notion of heterogeneity can be roughly translated to mean "many types". This would be equivalent to a

combination of the features [+plural] and [+generic]. This combination of features needs to be assigned to the internal noun of the compound.[5] The [+plural] feature is obviously assigned by the regular plural affix. The [+generic] feature must be assigned by the compound rule itself.[6] This requires that the plural be formed syntactically, and recursively inserted into the compound formation rule (much like the case of *red rats eater*).

The full analysis of these issues is considerably more complex than the present discussion suggests. Furthermore, one might consider that the degree of complexity involved outweighs the advantage gained by deriving heterogeneity rather than stipulating it as a feature. However, these proposals, along with those regarding adjective-modified compounds, do provide a principled way for the child to determine the acceptability or otherwise of regular plurals inside compounds. The present paper attempts to show that at least part of this account appears to reflect children's early dispositions in interpreting plurals inside compounds.

## Acknowledgements

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## Appendix A

### *A.1. Analysis of prosodic information*

We obtained recordings from 33 of the 36 test sessions, with three being lost to experimenter error. Pauses between compound constituents were measured along with the $F_0$ values responsible for the articulation of pitch contours. The reliability of the pause measurement was determined by re-measuring a random sample of 32 pauses by an independent rater, yielding $r = 0.898$, $p < 0.001$. For $F_0$ pitch values, an independent rater

[5] Notice that this is different from what is generally termed a "generic plural" such as the object of the sentence *I hate rats*. The generic reading here derives from the lack of a determiner, making the expression non-referential. The plural here is incidental since non-plural mass nouns have the same generic reading in the null-determiner context (*I hate water*). Clearly, in this case, there is no generic feature assigned, no association of generic and plural features, and hence no heterogeneous reading.

[6] The assignment of generic features by the compounding rule could derive from the fact that all internal nouns in compounds are, in fact, generic (Di Sciullo & Williams, 1988).

measured a random sample of 47 items. These yielded a correlation with the original rater of $r = 0.95$, $p < 0.001$.

### A.2. Pause

If there were biasing cues in the present study, we should find longer pauses at the first boundary in the Singular condition, and at the second boundary in the Plural condition. For the first boundary, mean pause values are given in Table 2. There is not even a trend of longer pauses in the Singular group. None of the five two-tailed *t*-tests comparing Singular versus Plural conditions reached significance. In fact, when all four compounds are considered together, the difference between conditions is virtually zero. Since independent *t*-tests are a very liberal approach to the evaluation of prosodic cues, the lack of significance is telling.

As a further test, we examined the correlations of children's responses with pause length. If children's responses were guided by pause length, a significant negative correlation should be expected (positive values are associated with syntactic interpretations). These coefficients are given in Table 2, which shows no clear trend in any direction for the compounds considered either individually or together.

For the second boundary, the analysis was more difficult because there was no pausing in six of the eight compounds. These included all plurals which have an /s/–/i/ transition (e.g., *rats-eater*), and singulars with an /r/–/i/ transition (*flower-eater*; *spider-eater*). Notice that this eliminates the possibility that the pause at the second boundary is longer for the plural condition. This leaves only two singular compounds (*rat eater* and *crab eater*) in which the nouns ending in the stops /t/ and /b/, respectively, allowed for the second pause to be measured.

Second pauses could not be compared across conditions with these data,

Table 2
Length of first pause in compound stimuli (mean length in seconds)

| | Pause plural | Pause singular | *t* | *r*[a] |
|---|---|---|---|---|
| (1) Red rat(s) eater | 0.071 | 0.086 | 2.01 | 0.005 |
| (2) Brown flower(s) eater | 0.103 | 0.102 | −0.14 | −0.176 |
| (3) Pink spider(s) eater | 0.078 | 0.068 | −0.37 | −0.170 |
| (4) Red crab(s) eater | 0.106 | 0.100 | −0.51 | 0.142 |
| All compounds | 0.090 | 0.090 | 0.01 | −0.044 |

*Note:* All *t*-tests (two-tailed) are non-significant.
[a] Correlation between pause length and children's recursive responses.

but it was possible to evaluate the extent to which children's reponses were guided by their length. If that were the case, a significant positive correlation should be expected between pause length and recursive responses. Correlations between second pause length and children's responses yielded $r = -0.023$ for *red rat eater* and $r = 0.33$ for *red crab eater*, both non-significant, and in opposite directions.

In summary, the distribution and length of pauses in the experimenter's presentation of the compounds cannot explain children's differential patterns of responses in the two testing conditions. Not only do pauses seem to be about equally distributed across conditions but also children did not seem to guide their responses by this information.

### *A.3. Pitch*

Pitch contour is articulated by changes in fundamental frequency ($F_0$). According to Cooper and Sorensen (1981), the strength of the boundary

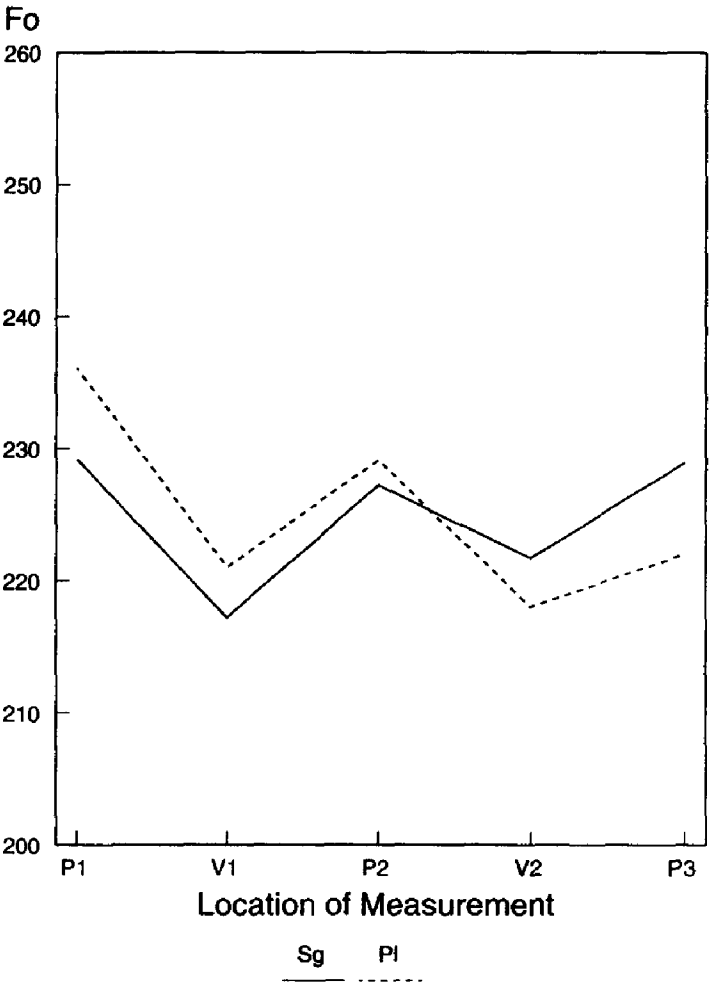


Fig. 3. Average values of $F_0$ for intonational peaks and valleys.

between two constituents, imposed by the speaker, is reflected in the magnitude of the fall–rise pattern in $F_0$ at the boundary. For the present case, a biased speaker should produce greater fall–rise patterns in the first boundary and reduced ones in the second boundary for the singular condition, and vice versa for the plural condition.

The falling portion of the fall–rise pattern in each boundary is contained in the last stressed syllable before the boundary, and is measured from peak (P) to valley (V). The rising portion of the pattern is measured from the valley of this same syllable to the peak at the beginning of the next stressed word. Fig. 3 shows the mean fall–rise patterns for singular and plural compounds.

There were two basic analyses carried out on these data. In the first, we simply calculated *t*-values associated with differences between singular and plural conditions at each peak and valley for each compound, yielding 20 separate tests, plus five more for the averaged data in Fig. 3. This tests for basic predictions about the heights of peaks and valleys in the data. The second test is more informative in that it takes the difference scores for P1 − V1, P2 − V1, P2 − V2 and P3 − V2 and compares them across the singular and plural conditions.

For the first analysis, there were only three significant values on the 25 *t*-tests (one-tailed) and all were in the opposite direction to that predicted for a biased speaker. Therefore, this test found no support for the existence of a bias despite the liberal use of independent *t*-tests.

Table 3
Transition values in fundamental frequency (Hz) for compound stimuli

| | | P1 − V1 | P2 − V1 | P2 − V2 | P3 − V2 |
|---|---|---|---|---|---|
| Compound 1 | Sg. | 18.2 | 12.4 | 3.86 | 13.6 |
| | Pl | 19.37 | 11.43 | 5.0 | 18.5 |
| | *t* | −0.29 | 0.25 | −0.27 | −0.42 |
| Compound 2 | Sg. | 5.46 | 8.13 | 9.86 | 7.93 |
| | Pl. | 11.28 | 5.35 | 10.64 | −3.64 |
| | *t* | −0.91 | 0.5 | −0.1 | 1.84* |
| Compound 3 | Sg. | 7.5 | −9.7 | −3.0 | 2.9 |
| | Pl. | 19.23 | −5.3 | 7.15 | −3.84 |
| | *t* | −1.65 | −0.39 | −1.15 | 0.71 |
| Compound 4 | Sg. | 16.14 | 24.21 | 15.71 | 2.21 |
| | Pl. | 9.61 | 20.0 | 22.69 | 6.0 |
| | *t* | 1.65 | 0.68 | −1.2 | −0.44 |
| All compounds | Sg. | 12.14 | 10.18 | 7.33 | 7.11 |
| | Pl. | 15.05 | 8.01 | 11.01 | 4.87 |
| | *t* | −1.04 | 0.57 | −1.06 | 0.47 |

* $p < 0.05$, one-tailed.

The difference scores evaluating the amount of change between peaks and valleys are given in Table 3. Again, these were compared for the singular versus plural condition using the liberal multiple *t*-tests (one-tailed). Of the 20 tests, only one was significant and again this was in the opposite direction to that predicted for a biased speaker.

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