

Indirect negative evidence and defectivity

1 Introduction

Children acquiring a language learn not only what they can say, but also what they must not. On one hand, children generate sentences they have clearly never before heard (“my teacher holded the baby rabbits” [1]). At the same time, for most speakers of English, *pants* and *shorts* are obligatorily plural, *beware* can only be used imperatively, *forgo* lacks a simple past tense (**forwent*, **forgoed*), *methinks* can only be used in the first person singular present (e.g., **methought*), and *stride* lacks a past participle (**stridden*, **strided*) [2]. This phenomena is known as **defectivity**, and defective lexemes are said to exhibit **inflectional** (or **paradigmatic**) **gaps**. Defectivity has been known since ancient times and has been documented in dozens of languages. Russian, for instance, has about a hundred defective nouns and verbs (for example, the noun *кочерга* ‘fire iron’ and the verb *победить* ‘win’ both have incomplete paradigms [3, 4]), and modern Greek has over two thousand nouns lacking a genitive plural (including frequent words such as *κοπέλα* ‘girl’ [5, 6]). Despite all this, the mere existence of defectivity is an embarrassment for nearly all approaches to word formation [7–11] and an open problem in the theory of language acquisition.

Language acquisition researchers have long assumed that language is learned primarily on the basis of **positive evidence** (i.e., words or sentences heard by children) rather than **negative evidence**—such as explicit grammatical corrections from caregivers—since the latter are quite rare in speech to children [12]. How then might children acquire defectivity? One proposal for argues that children obey a principle of **lexical conservatism**, a principle which holds that speakers are reluctant to extend patterns to novel lexemes in the absence of positive evidence [3, 4, 13, 14]. However, it is difficult to reconcile this principle with children’s behavior in *wug*-tasks [15]. An alternative proposal holds that children acquire defectivity via **indirect** (or **implicit**) **negative evidence** [5, 6, 16, 17], i.e., they infer defectivity when a possible word is in some sense “conspicuously absent”, a notion formalized below.

This proposal attempts to operationalize and test the hypothesis that children acquire patterns of defectivity via indirect negative evidence hypothesis, by performing a large-scale computational and statistical analysis of defectivity in Greek and Russian. These languages are chosen because they have extensive, carefully-documented patterns of defectivity (Table 1).

2 A model of indirect negative evidence

There are two features that make a possible word conspicuously absent. The first is **absolute frequency**: the possible word must be quite rare if not unattested. However, in richly inflected languages like Greek and Russian, children are likely to hear complete paradigms for few if any lexemes [18] in the course of acquisition. It is necessary also that the frequency of a possible word also exhibit **divergence from expected frequency**; i.e., be much lower frequency than one might expect, all else held equal. The proposed model assumes that the frequency of an inflected

Greek [5, 21, 22]	2,203
Russian [3, 4, 23]	103

Table 1: Number of defective lexemes as indicated in the cited dictionaries.

	OpenSubtitles [24]	CCNet [25]
Greek	126m	242m
Russian	45m	782m

Table 2: Number of sentences available.

word w (e.g., *eyes*) is a function of the frequency of its lexeme l (EYE) and of the morphological features it expresses f (noun plural), and that lexeme and morphological feature frequency are statistically independent.¹ Then the expected probability of a wordform is the product of its lexeme probability p_l and its morphological feature probability p_f . Some proposed statistics for quantifying the divergence between expected and observed probabilities are shown below.

$$\begin{aligned}
\delta_w &= \underbrace{p_w - p_l p_f}_{\text{absolute divergence}} & L_w &= \underbrace{\log p_w - \log p_l - \log p_f}_{\text{log-odds ratio}} & z_w &= \frac{p_w - p_l p_f}{\underbrace{\sqrt{s_l^2 s_f^2 + s_l^2 p_f^2 + s_f^2 p_l^2}}_{\text{standard score } (s^2: \text{ sample variance})}}
\end{aligned}$$

3 Approach

The p_l and p_f probabilities can be directly estimated using maximum likelihood estimation (or add- α smoothing) from a corpus in which words are labeled with their lexeme and morphological features. To perform this labeling, we will use a state-of-the-art neural network-based morphological analyzer [19]—the winning system in a recent shared task on morphological analysis in context [20]—applied to hundreds of millions of sentences extracted from freely-available corpora of television subtitles and web text (Table 2).

Morphological analysis will produce the statistics needed compute absolute frequency and divergence from expected frequency. It is possible that some lexemes will be too rare for reliable estimation, or that some wordforms will show the statistical profile of “conspicuous absence” for reasons unrelated to defectivity. Therefore, the association between measures of conspicuous absence and dictionary descriptions of defectivity will be measured using the point-biserial correlation, and multiple logistic regression will be used to measure these statistics’ ability to discriminate between defective and non-defective wordforms. These statistics will also allow us to perform quality control and assurance on dictionary descriptions of defectivity. All analyses will be performed in the PI’s lab, equipped with 7 NVIDIA 1080 GTX GPUs.

4 Significance and Outcomes

The proposed work represents the first attempt to test, at scale, whether indirect negative evidence could be used to acquire patterns of defectivity. The results—whether positive or negative—will allow for the preparation of a journal article detailing the methods and results. Furthermore, all data and code will be made available under a permissive open-source license. Finally, the

¹Note that a model in which lexeme and morphological features frequencies are non-independent would produces expected probabilities identical to the observed probabilities, unless a third conditioning factor is introduced.

results will be used as a pilot study for an NSF grant extending the proposed approach to many additional languages, and validating dictionary descriptions of defectivity with grammaticality judgments and lexical decision tasks. A brief timeline is given below.

- July 1st–July 31st: automated morphological analysis
- August 1–August 31st: statistical evaluation and error analysis
- September 1st–December 31st: manuscript preparation

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