Root Infinitives and the Acquisition of Morphological Marking

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1 Introduction

During the Root Infinitive (RI) stage of acquisition, children use non-finite verb forms in matrix clauses that require a finite form. Cross-linguistic work has demonstrated that the length and frequency of the RI stage is related to the "richness" of the verbal morphological paradigm (e.g., Phillips 1996, 2010), suggesting that RIs are closely intertwined with morphological acquisition. How exactly these phenomena are related, however, remains an open question. In this paper, I argue that RIs emerge as a consequence of the acquisition of inflectional categories. Specifically, I propose that children learn which morphosyntactic features are marked in their language via a process of recursive subdivision, and that RIs emerge before the child has learned that tense is marked. I introduce the *Sufficient Contrast Learner* (SCL), a computational model of inflectional category acquisition. A mathematical consequence of this model is that in languages with rich φ-agreement morphology, the resulting subdivision will entail that tense marking is learned more quickly and the RI stage is thus shorter. Using English, French, and Spanish as test cases, I demonstrate that SCL correctly predicts the relevant cross-linguistic differences in the length of the RI stage, while matching well with developmental findings regarding order of acquisition and vocabulary size.

2 Background

2.1 Root Infinitives

The Root Infinitive (henceforth RI) stage has been the subject of much work at the intersection of language acquisition, theoretical syntax, and morphology. During the RI stage, children learning a wide range of tense-marking languages produce non-finite verbs in matrix clauses, for example:

(1) Papa have$_{\text{NFIN}}$ it — English (Legate and Yang 2007)

(2) Dormir petit bébé
sleep$_{\text{NFIN}}$ little baby — French (Legate and Yang 2007)

(3) El otro buscar
the other look-for$_{\text{NFIN}}$ — Spanish (Liceras et al. 2006)

Importantly, the RI stage is gradient: children never produce *exclusively* RIs, nor do they suddenly transition out of this stage (Legate and Yang 2007). Rather, the rate of RI production drops off slowly, sometimes over two or more years (e.g., Behrens 1993, Haegeman 1995, Phillips 2010).

The RI stage is typically viewed as a type of *omission* error and resultant "falling back" on a non-finite default. Indeed, omission errors are widely attested in child language, while substitution errors (e.g., use of a 3rd person agreement marker where a 2nd person one is required) are almost entirely unattested. In an analysis of German agreement, for example, Clahsen and Penke (1992) found that omission errors make up 16-18% of "Simone's" productions, while misapplications constitute a mere 0-2%. Similar differences between rates of omission and substitution have been reported for

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Italian agreement (Guasti 1993), German tense (Behrens 1993, Phillips 2010), English agreement (Harris and Wexler 1996), and Spanish agreement (Pratt and Grinstead 2007).

Given this framing, we can ask whether the omission that triggers RIs takes place in the core syntax or during Spell-Out. Evidence from what Phillips (2010:76) terms "form-position correlations" point to the former: RIs are *syntactically* non-finite. In German, for example, all verbs raise from V → T, regardless of finiteness, but only finite verbs raise from T → C (Adger 2003). Finite verbs thus appear in the first (in the case of topic drop) or second position, while non-finite ones appear clause-finally. Similarly, French verbs raise from V → T in finite sentences, but not non-finite ones; the negative *pas* thus follows finite verbs and precedes non-finite ones (Pollock 1989). In a quantitative study of the productions of the German-learning child "Andreas" (Poeppel and Wexler 1993), Phillips (2010) found that 94.7% of Andreas' finite verbs occurred in the first or second position, while 86% of his RIs occurred clause-finally. In an analysis of French data from Pierce (1989, 1992), Phillips similarly found that 95% of finite verbs occurred before *pas* in negated child speech, but only 0.8% of negated RIs did. This evidence clearly demonstrates that RIs cannot be reduced to a failure at Spell-Out; rather, RIs are *syntactically* non-finite.

2.2 Developmental Findings and Cross-Linguistic Differences

Extensive experimental evidence has demonstrated that the properties of the verbal inflectional paradigm – particularly, its "richness" – affect the length and frequency of the RI stage cross-linguistically (e.g., Guasti 1993, Wexler 1994, Phillips 1996, 2010, Legate and Yang 2007). For example, children learning Spanish (Grinstead 1994) and Italian (Guasti 1993) produce RIs infrequently: Grinstead, for example, found that RIs made up about 10% of productions for Spanish learners at 2;0, and 5% by 2;6. RIs are even rarer in child Swahili: Deen (2005) reports a rate of just 0.52% for 3 children ranging from 1;8 to 3;0. In contrast, RIs are produced frequently and for much longer in languages such as Dutch (Haegeman 1995) and English (Harris and Wexler 1996, Phillips 2010); in both languages, the RI may last past 3;0 (Haegeman 1995, Hoekstra and Hyams 1998, Phillips 2010). "Adam" from Brown (1973), for example, was still making extensive use of the RI at 3;0, and "Eve's" RI production rate was near 50% when recordings stopped at 2;3 (Phillips 2010). French falls between these two extremes: production rates of the RI have been reported as ranging from 15% to more than 30% for children from 1;8 to 2;6 (Pierce 1992, Rasetti 2003).

These results are more informative when contextualized in the broader timeline of morphological acquisition. In English, Spanish, and French, φ-agreement generally emerges before tense, aspect, and mood (Brown 1973, Montrul 2004, Prévost 2009). The present progressive *-ing* emerges first in English, typically followed by the third singular *-s*, irregular past tense forms, and finally, the regular past *-ed*, which emerges between 2;0 and 3;0 (Berko 1958, Brown 1973, Kuczaj 1977). In both Spanish and French, φ-agreement emerges early (Aguirre Martínez 1995, Grinstead 1998, Prévost 2009), with person agreement emerging as early as 1;7 in Spanish and number almost immediately after (Montrul 2004). Tense emerges in Spanish beginning at 2;0 (Montrul 2004, Gaya 2001), as does the subjunctive (López Ornat et al. 1994, Aguirre Martínez 1995). The *passé composé*, the first past tense form to emerge in French, begins to emerge around 2;0-2;3 (Brunet 2021), but is not yet productive at this time (Royle 2007). An English-learning child's vocabulary will be at most 500 (at 2;0) to 1000 (at 3;0) words when the regular past tense is learned (Fenson et al. 1994); the maximum vocabulary size at 1;8 is just over 400 for children learning either Spanish or French (Bornstein et al. 2004). Since about a quarter of early vocabulary will be verbs (Bornstein et al. 2004), we expect English-learning children to learn tense marking on at most 250 verbs, Spanish-learning ones on about 100, and French-learning ones to fall in between.

2.3 Previous Accounts of the Root Infinitive Stage

The form-position correlations discussed above have led some scholars to argue that RIs are implicated solely by the core syntax. Optional Infinitive Theory (Wexler 1994), for example, posits that the child does not yet know that main verbs *must* be finite, reflecting a lack of understanding of tense at LF. As such, children know the relevant syntactic operations for finite and non-finite forms but not where each form is required. The Clausal Truncation Hypothesis (Rizzi 1993) states that RIs do not reflect full CPs, but rather truncated structures – perhaps as little as *v*P. Rizzi provides evidence from null subjects and case assignment to support such an analysis. Other analyses posit that the RI stage is implicated by both the core syntax and other factors: Hoekstra and Hyams (1998), for example, argue that the RI arises as a result of underspecified features in the Tense node, but that these features are underspecified as a result of *pragmatic* knowledge. Since auxiliaries in child productions are always finite, some authors (e.g., Boser et al. 1992, Whitman 2018) have also posited that the RI results from the presence of a finite auxiliary that is not realized phonologically.

More recently, Phillips (2010) argues that RIs implicate the child's *performance*, differing only from adult productions in that they fail to merge Tense features with the verb, forcing a fall-back to the "default" RI. In particular, Phillips argues for a competition between two pressures: the cost of accessing the relevant inflected form and the cost of realizing the verb as an RI. This theory directly implicates morphological acquisition, since as the morphological competence grows, the cost of correctly accessing the inflected form will decrease. Under this framing, Phillips argues that languages with "richer" inflectional morphology will have shorter RI stages. However, as Legate and Yang (2007) note, the notion of "richness" is not sufficiently formalized. Legate and Yang provide a quantitative account of the cross-linguistic differences in the RI stage couched in variational learning theory (e.g., Yang 2002). The child's grammar is modeled as a population of hypotheses whose composition changes based on the evidence to which the child is exposed; the RI results from entertaining a grammar that could generate languages such as Mandarin Chinese, which contain no inflectional tense marking. Legate and Yang introduce a measure of the amount of quantitative evidence for a tense-marking grammar in this framework. Applying this measure to English, Spanish, and French, they show that it correctly predicts the cross-linguistic differences in the RI stage.

The current approach is deeply inspired by that of Legate and Yang. In particular, I emphasize their argument that "a theory of RI, in addition to providing an insightful description of the RI stage, must also provide a specific model of how the child exits the RI stage (and why there should be an RI stage to begin with)" (Legate and Yang 2007:317). Our model, the *Sufficient Contrast Learner* (Section 3.1), provides such a mechanistic account of the emergence and subsequent demise of RIs as a byproduct of the acquisition of inflectional categories. Specifically, the model predicts that *richer φ-agreement paradigms will correlate with shorter RI stages* in languages in which agreement emerges before tense. Following Legate and Yang, I evaluate the Sufficient Contrast Learner on English, French, and Spanish; in all three languages, φ-agreement emerges before tense marking (Section 2.2). I demonstrate that this proposal both accounts for the cross-linguistic differences in the length of the RI stage (Section 4.1) and matches well with developmental findings regarding order of acquisition and vocabulary size (Section 4.2).

3 Proposal: Root Infinitives and Inflectional Categories

I propose that the RI stage emerges as a consequence of the acquisition of inflectional categories. Which subsets of morphosyntactic features are contrastive, and are thus eligible to be mapped to phonological realizations, varies across languages thus must be learned from the input: while English contrasts ±PAST in its verbal morphology, for example, Mandarin Chinese does not. Similarly, Spanish productively contrasts first vs. second person while English does not. I argue that RIs emerge before the child learns that tense is marked in their language, and provide a quantitative, recursive account of this learning process, drawing on Payne (2022) and Payne and Yang (to appear).

Specifically, I argue that inflectional categories are learned by recursively subdividing the input based on morphosyntactic features found to be *sufficiently contrastive*, in a way that is formalized below. This approach entails that for languages in which φ-agreement emerges before tense marking, tense marking must be learned separately for each agreement marking. For example, if the child learns that ±SINGULAR is marked and subdivides their lexicon accordingly, then they must learn later than e.g., ±PAST is marked *independently* for singular and plural forms. This provides a direct explanation for cross-linguistic differences in the length of the RI stage: languages with "richer" agreement morphology will make *more* subdivisions since more morphosyntactic features are contrastive in these languages; tense marking will thus be learned separately over resultingly smaller subsets of the lexicon. A mathematical consequence of our approach, outlined below, is that proportionally *less* positive evidence is needed to form a generalization over smaller subsets of the lexicon. The resulting prediction is that tense marking will be learned more quickly – and thus that the RI stage will be shorter – in languages with "richer" agreement morphology. Indeed, English marks only 2 agreement categories (±3SG), while French marks 3 (first plural, second plural, other), and Spanish marks 5-6, depending on the dialect. As reviewed in Section 2.2, the RI stage is the shortest in Spanish and the longest in English, with French falling in between; this is exactly the prediction made by our model. We now turn to a formalization of this proposal.

3.1 The Sufficient Contrast Learner

I present the *Sufficient Contrast Learner* (SCL), built on the model of inflectional category learning proposed by Payne (2022, 2023). SCL is motivated by children's early ability to segment inflected forms and relate them to their stems (Kim 2015, Marquis and Shi 2012, Kim and Sundara 2021). Following Payne (2022, 2023), I propose that children use this ability to track **collisions** – a single lemma appearing in multiple inflected forms – and use these as a cue to learn inflectional categories. If the child hears *walk* and *walked* and knows they are related, for example, this provides a cue that their language marks ±PAST. However, a single collision does not provide sufficient evidence that the corresponding morphosyntactic feature(s) are contrastive: it would be incorrect to conclude from *I am - you are*, for example, that English productively contrasts first and second person. At the same time, the sparsity of the input entails that most lemmas will appear in only a fraction of their possible inflected forms (Lignos and Yang 2016). As such, a child may not encounter a given collision for a given lemma simply by chance – the relevant inflected forms don't happen to appear in their input – rather than because the relevant morphosyntactic features are not contrastive for that lemma. How, then, do we quantify *sufficient* evidence that a feature is contrastive?

Our answer comes from the Tolerance-Sufficiency Principle (TSP, Yang 2016), a computational threshold for the amount of positive evidence necessary to form a linguistic generalization. The TSP is based on the hypothesis that a child will form a generalization when it is more efficient to do so, and has found support in several experiments with precisely controlled conditions (e.g., Schuler 2017, Koulaguina and Shi 2019, Emond and Shi 2021, Li and Schuler 2023). Under the TSP, a learner calculates two values for a given process R: N, the number of items in the learner's lexicon which fit R's description, and M, the number which both fit R's description *and* have been observed to obey R. Items counted towards M will thus be a subset of those counted towards N; an item can be counted towards N and not M either because it has not been attested in the relevant context in the input or because it has been attested but disobeys R. These values are used in the TSP as follows:

(4) **The Tolerance-Sufficiency Principle**: a process R applicable to N items and attested applying to M of these items is productive if and only if:[1]

$$N - M \leq \theta_N = \frac{N}{\ln N}$$

An interesting mathematical consequence of the TSP is that it requires proportionally less positive evidence to generalize for smaller values of N. For example, when $N = 10$, $M \geq 6$, or 60% of N, will pass the TSP, while when $N = 100$, $M \geq 79$, or 79% of N, will pass.

SCL takes in input incrementally, in the form of (*lemma, inflected form*, FEATURE SET) triples. The lemma is encoded as a part of the input to model children's early segmentation and relation of inflected forms. I assume that morphosyntactic features are determinable from the input by the child, such that the task of the learner is only to learn which subsets of these features – and thus which inflectional categories – are marked. When a new input item is encountered, SCL searches its lexicon for other inflected forms of the same lemma to determine if a collision is present. If at least one collision is present, SCL considers all pairs of inflected forms in which it has seen the

[1] I make the additional requirement that $N > 5$, since for extremely small values of N, the TSP does not require that M be a majority of N (e.g. $\theta_3 = 2$).

given lemma in order of decreasing type frequency, defined as the sum of the number of lemmas occurring in each inflectional category. For a collision between inflected forms *A* and *B* (e.g. *walk-walked*), SCL searches its lexicon for other words appearing in inflection *B* (where *B* occurs with fewer lemmas than *A*). If a sufficient number – as defined by the TSP – of lemmas appearing in inflection *B* also appear *in a different form* in inflection *A*, then SCL learns that the corresponding morphosyntactic feature(s) are contrastive. The corresponding features are defined by choosing from $A \setminus B$ and $B \setminus A$ the set with the smallest cardinality. For example, if SCL encounters a collision between $\{3$, SG, PRESENT$\}$ and $\{$PAST$\}$, the features it determines as corresponding to the collision will be ±PAST, since $|\{\text{PAST}\} \setminus \{3, \text{SG}, \text{PRESENT}\}| = 1$ is less than $|\{3, \text{SG}, \text{PRESENT}\}| \setminus \{\text{PAST}\}| = 3$. When a productive contrast is found, SCL subdivides its lexicon based on the corresponding morphosyntactic feature(s). As further input is taken in, the same method is applied recursively within each resulting set: SCL may first subdivide its lexicon based on a productive ±PARTICIPLE contrast, then learn that learn that $\pm\{3$, SG$\}$ is contrastive for -PARTICIPLE forms, and so on.

As a model of the acquisition of inflectional categories, SCL explains both the cross-linguistic differences in the length of the RI stage and its gradient nature. As outlined above, we expect more subdivision early in learning for languages with richer φ-agreement under SCL. This will mean that tense marking must be learned over resultingly *smaller* subsets of the lexicon, which, due to the mathematical consequences of the TSP outlined above, predicts that *relatively fewer* collisions must be seen in order to learn tense marking. As such, we expect tense marking to be learned earlier in languages with richer φ-agreement under SCL. At the same time, during the stage in which the learner only knows that φ-agreement is marked in their language, it is highly unlikely that any morphological process will be productive: a Spanish-learning child at this stage, for example, would group *amas, amabas, amaras, amaste*, etc. because all of these forms mark the second singular. This explains why the child may produce the RI at this stage, as well as its gradient nature: if there is not yet a productive rule to inflect a given form, then the child must rely entirely on lexicalized inflected forms with the desired agreement. The sparsity of the input entails that the child will not see – and thus cannot memorize – every inflected form they wish to produce (Lignos and Yang 2016). In the absence of such forms and of a productive rule for inflection, it is reasonable to expect that the child may resort to an RI as some sort of "default" representing the omission of inflectional marking (Section 2.1). As such, the gradience of the RI results from the presence or absence of a memorized form realizing the desired agreement. As the learner further subdivides its lexicon, the inflectional categories in the grammar will become increasingly specific and will begin to be productively mapped to form; RI productions will begin to decrease as a result.

4 Evaluation

To test the proposal outlined above, I train SCL on English, French, and Spanish; these are the languages explored by Legate and Yang (2007), and φ-agreement emerges before tense marking in all of them (Section 2.2). To model a plausible early vocabulary, I extract the most frequent inflected forms from the CHILDES database (MacWhinney 2000) and intersect these with the UniMorph database (McCarthy et al. 2020) to annotate them with the relevant morphosyntactic features. Intersection with UniMorph gives input of the form (*walk, walks*, $\{$VERB, PRESENT, 3, SINGULAR$\}$): that is, triples of lemmas, inflected forms, and morphosyntactic features. The English data consists of 4196 inflected forms (1280 stems) taken from the Machester, Wells, and Belfast Corpora (Theakston et al. 2001, Wells 1981, Henry 1995). The Spanish data consists of 999 inflected verbs (310 stems) taken from the Fernandez/Aguado corpus, and the French data consists of 1500 inflected forms (483 lemmas) taken from the Paris corpus (Morgenstern 2006). While the English and Spanish data is orthographic, I phonologically transcribe the French data using the Lexique French lexical database (New et al. 2004), since some syncretisms in the French paradigm are not reflected in the orthography. SCL takes in input incrementally in order of decreasing frequency, since frequency is highly correlated with order of acquisition (Goodman et al. 2008).

The recursive subdivision of SCL allows us to visualize the learning trajectory as a tree. For example, the learning trajectory in Fig. 1 shows that the model first learns that participles (±PTCP)

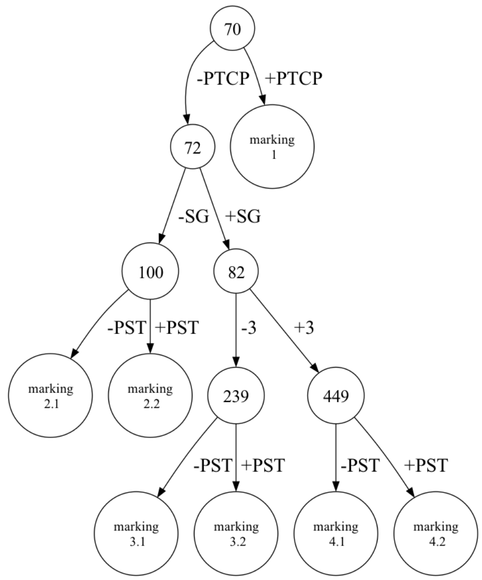

Figure 1: The results of the SCL model trained on English.

are marked, then recursively learns that ±SG is marked for the +PTCP forms, and so on. Each node is annotated with the number of inflected forms in SCL's vocabulary when it learns that the given feature(s) are contrastive: in Fig. 1, for example, SCL learns that ±PTCP is marked on 70 inflected forms. Nodes of the form "marking *x*" indicate a point at which no more collisions were found and an inflectional category was learned. The path from the root to these nodes gives the features they realize (e.g., marking 2.1 realizes {-PTCP, -SG, -PST} in Fig. 1), and the value of *x* indicates that this is x^{th} category to be learned. Values of the form *x.y* specifically indicate when a single subdivision results in the simultaneous acquisition of two inflectional categories. For example, the present (4.1) and past (4.2) third singular both emerge from a single subdivision (on ±PST) in Fig. 1.

4.1 Cross-Linguistic Differences in the RI Stage

Under the current proposal, the RI stage persists until the child learns that their language marks tense productively. As discussed in Section 2.2, the RI stage is the longest in English and the shortest in Spanish, with French falling in between. In the current framework, this means that tense marking should be learned earliest in Spanish and latest in English, with French again falling in the middle. This is precisely what SCL predicts: in Fig. 1, we see that the model learns that tense is marked across the English paradigm at 449 inflected forms (188 lemmas). In other words, at the point when markings 4.1 and 4.2 are learned, SCL has already learned that tense marking is obligatory for *all other parts* of the paradigm: at 100 inflected forms for markings 2.1 and 2.2 (namely, plurals), and at 239 for markings 3.1 and 3.2 (namely, non-third-person singulars). Similarly, in Fig. 2, we see that tense marking is learned across the French paradigm by 343 inflected forms (124 lemmas). This corresponds to the fact that tense marking is acquired extremely early for non-first-person verbs (at 33 inflected forms, as indicated by the learning of +NFIN in marking 1), and later for first-person verbs (marking 5). Finally, in Spanish (Fig. 3), we see that tense marking is acquired across the paradigm by 237 inflected forms (103 lemmas). Note that all subdivisions made during the third level of recursion in Fig. 3 correspond to tense marking, by either subdividing on ±NFIN or ±PRS. Thus, in terms of both the number of lemmas (103 vs. 124 vs. 188) and the number of inflected forms (237 vs. 343 vs. 449) at which tense marking is learned, SCL makes the correct prediction: namely, that tense marking is learned fastest in Spanish and slowest in English, with French falling in the middle.

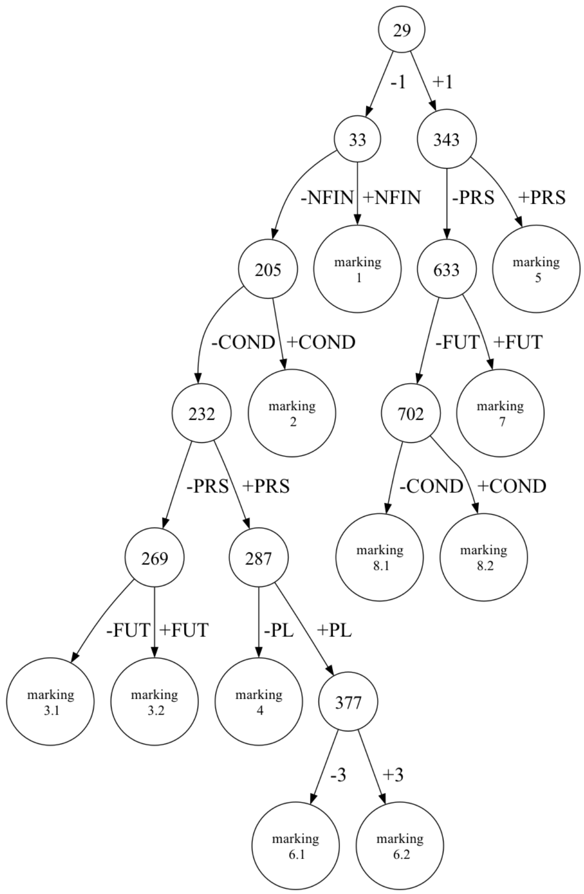

Figure 2: The results of the SCL model trained on French.

4.2 Order of Acquisition and Vocabulary Size

I also evaluate SCL against developmental findings regarding order of acquisition and vocabulary size. In English (Fig. 1), SCL correctly predicts the participle to be learned first (marking 1, at 70 inflected forms/34 lemmas), followed by the third singular (±SG at 72 inflected forms/35 lemmas and ±3 at 82 inflected forms/40 lemmas), and the past tense (449 inflected forms/188 lemmas); this matches well with the developmental findings reviewed in Section 2.2. Further, the prediction that the past tense will be acquired by 188 verb lemmas is a developmentally-plausible one given vocabulary sizes at 3;0 (Fenson et al. 1994, Bornstein et al. 2004). In French, the early emergence of φ-agreement is mostly borne out (Fig. 2): SCL first subdivides on ±1, then learns markings such as ±NFIN and ±PRS. However, the rather late emergence of ±3 (markings 6.1 and 6.2) matches less with developmental findings; it also brings the total number of verb lemmas that SCL learns from up to 232, though tense emerges at only 124. While 124 is a reasonable prediction given the findings reviewed in Section 2.2, future work should further investigate the late acquisition of ±3 predicted by SCL. In Spanish, the early emergence of φ-agreement is also mostly borne out: person and number markings make up the early subdivisions in Fig. 3. However, number marking also emerges later: at markings 5, 7, and 13, at as many as 704 inflected forms (229 lemmas). SCL generally predicts that aspect emerges after tense marking, fitting developmental findings (Jacobsen 1986). However, there is little evidence of the later emergence of the subjunctive or imperative (Section 2.2) – SCL may simply require more data to learn these markings. The prediction that tense marking will emerge across the paradigm by 103 verb lemmas is in line with developmental findings (Bornstein et al. 2004).

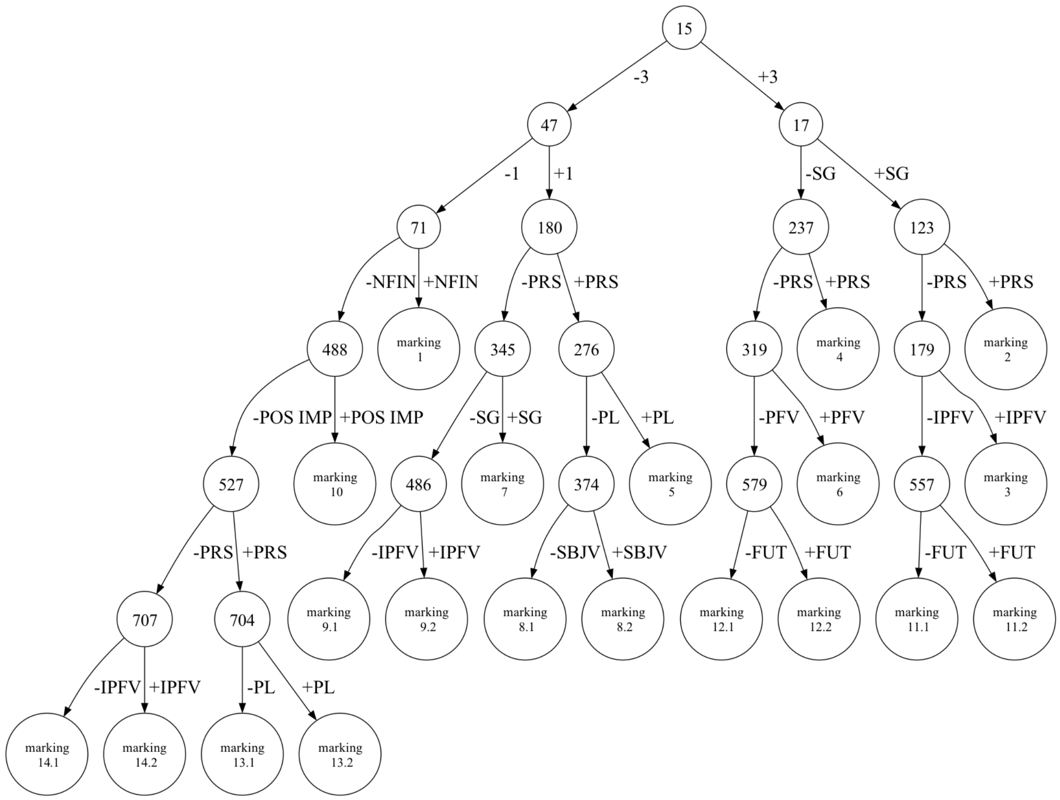

Figure 3: The results of the SCL model trained on Spanish.

5 Discussion & Conclusion

In this paper, I proposed an account of the RI stage as a consequence of the acquisition of inflectional categories: it persists until children learn that tense is marked in their language. Specifically, I argued that children recursively subdivide their input as they learn which morphosyntactic features are contrastive in their language, and proposed the *Sufficient Contrast Learner* as a model of this process. A mathematical consequence of SCL is that it will require proportionally less evidence of tense marking when considering smaller subsets of the input, allowing it to learn that tense is marked *earlier* than when considering larger subsets. As such, SCL predicts that in languages in which φ-agreement marking emerges before tense marking, richer agreement paradigms will lead to learning that tense is marked sooner, and thus to a shorter RI stage. I have shown that when trained on plausible inputs of Spanish, French, and English, SCL correctly predicts the cross-linguistic differences in the length of the RI stage as a consequence of the acquisition of inflectional categories. Additionally, SCL matches well with developmental findings regarding order of acquisition and vocabulary size across the three languages, though it sometimes predicts a later emergence of φ-agreement than has been observed empirically. While the current work focused mainly on cross-linguistic differences in the *length* of the RI stage, cross-linguistic differences have also been observed in the *frequency* of the RI stage (Section 2.1). While this proposal can account for the gradience of the RI stage as a consequence of the sparsity of the input and use of memorized forms in the absence of a productive rule (Section 3.1), future work should further pursue the predicted cross-linguistic differences in RI production rates within this framework. One avenue for doing so would be combining SCL with a model that maps inflectional categories to phonological form, in order to predict more exactly where the RI will emerge and thus how frequent it will be cross-linguistically.

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