The role of paradigm-external anchoring in simulating the emergence of inflection class systems

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1 Introduction

Abstract models of paradigm change can provide insight into how even the simplest processes can lead to unexpected outcomes, thereby revealing new potential explanations for observed linguistic phenomena. Ackerman & Malouf (2015) presented a seminal model in which inflectional systems reduce in disorder through the action of piecemeal analogical changes. More recently, Round et al. (2021a,b) showed that (1) the model cannot evolve stable, persistent inflection classes, rather all inflection classes inevitably collapse together; but (2) if 'negative evidence', i.e., evidence from inflectional dissimilarity, is factored into analogical inference, the result can be an attraction-repulsion dynamic which enables inflection classes to coalesce (due to attraction) but remain distinct and thus persist without collapsing together entirely (due to repulsion). The cognitive motivation for attending to negative evidence is presented in Round (forthcoming).

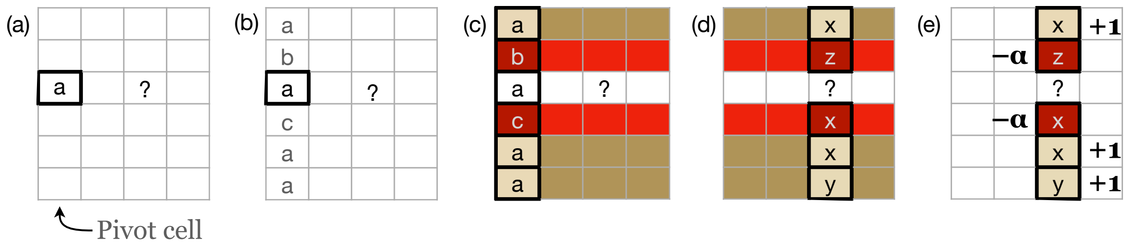
Here we investigate the potential of a third force in inflection class evolution: the anchoring of inflection classes to paradigm-external properties (such as lexical semantics or stem phonology). We compare two conceptions of paradigm-external anchoring, (1) as an analogical force which enters into micro-scale competition with paradigm-internal analogy; and (2) as a soft condition upon paradigm-internal analogy, making some potential paradigm-internal analogies more salient than others, expanding on results by Round et al. (2022).

2 A model of analogical change via paradigm cell filling

Inflection classes are sets of lexemes that share inflectional exponents, a type of 'morphomic', morphology-internal structure, which mediates the mapping between content and form in inflection (Aronoff, 1994; Round, 2015). The constrained organisation of inflection classes appears to limit the complexity of the inflectional system for language users by offering a systematic, recurrent and predictable means of distributing exponents (Carstairs-McCarthy, 2010; Ackerman & Malouf, 2013; Blevins, 2016; Bonami & Beniamine, 2016). However, a matter of ongoing debate is what kind of historical dynamics could potentially lead to such structure (Carstairs-McCarthy, 2010; Esher, 2015; Maiden, 2018). In this paper, we use computational evolutionary models to shed further light on some of the simplest conditions under which persistent and stable inflection class systems can emerge. These insights will contribute both to theoretical investigations into morphomic structure and to the development of increasingly elaborate models of paradigm evolution in future.

We start from the model of Round et al. (2021a,b), which in turn builds on Ackerman et al. (2009) to model inflectional change via a simple mechanism of paradigm cell filling (PCF). The initial input to the model consists of a lexicon in which paradigms are populated with randomly distributed exponents. The PCF process (Figure 1) is as follows: at each cycle, the model must predict a held out value, termed the *focus* (marked '?' in Fig. 1) at the intersection of a focal cell and focal lexeme. To predict the value of the focus, the model (i) picks a non-focal cell, termed the *pivot* (Fig. 1a); (ii) scans the exponents in pivot cells of other lexemes, termed

Figure 1: Paradigm cell filling mechanism after Round et al. (2021a,b). Lexemes are in rows, paradigm cells in columns. The exponent with the highest summed score in (e) is selected to fill the focus, marked '?'. See Section 2 for details.



evidence lexemes (Fig. 1b), classifying them as possessing a 'matching' (green in Fig. 1c) or 'contrasting' (red in Fig. 1c) pivot compared to the focal lexeme; (iii) inspects the exponents of focal cells in the evidence lexemes (Fig. 1d) and scores exponents of matching lexemes positively (as $+1$) and of contrasting lexemes negatively (as $-\alpha$, where α is a non-negative value set by the experimenter); (iv) sums the scores for each exponent type in the focal cell and selects the highest-scoring for the focal exponent. Round et al. (2021a,b) show that when only positive evidence is taken into account, i.e., when $\alpha = 0$, inflection classes will invariably collapse together as the PCF process continues to repeat, whereas when negative evidence is attended to, i.e., $\alpha > 0$, it is possible for distinct inflection classes to emerge and persist stably.

3 Adding sensitivity to paradigm-external properties

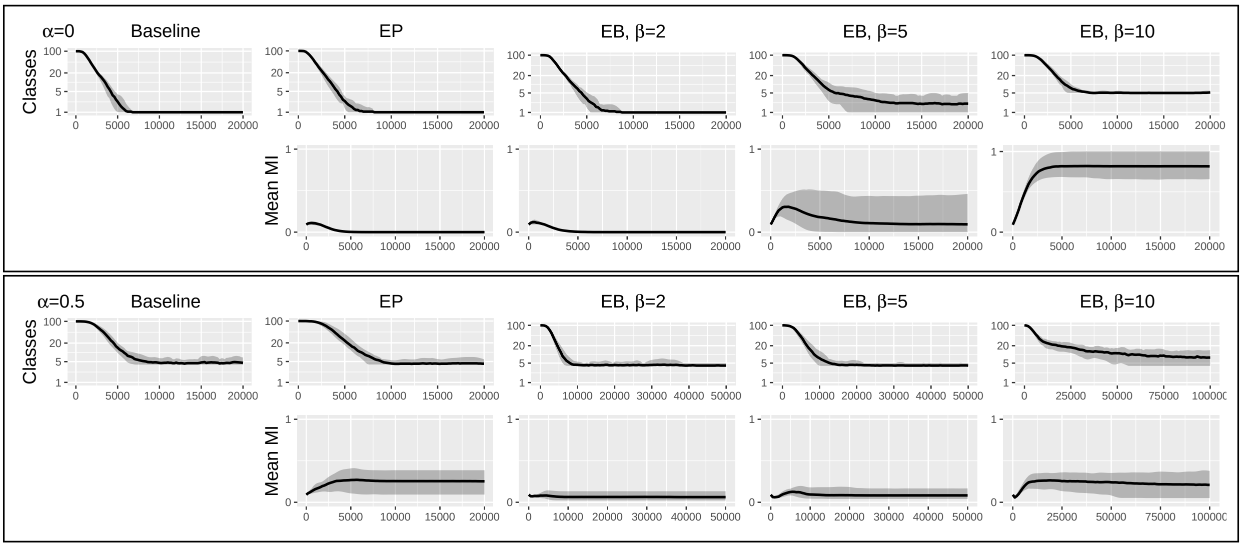
Here we ask whether persistent inflection classes can also emerge via a second mechanism. In the model of Round et al. (2021a,b), the PCF process is affected solely by the inflectional exponents. However analogical change and inflectional predictability are known to be influenced by other lexical properties (Guzmán Naranjo, 2018). We therefore enrich the model, to investigate the contribution of such properties to inflection class emergence. For each lexeme, we add one more discretely-valued property—effectively one more column in Figure 1—which can be interpreted as any non-paradigmatic lexical property, for instance semantic (animate v. inanimate nouns), syntactic (intransitive v. transitive v. ditransitive verbs) or phonological (types of stems).

We test two ways in which paradigm-external information could contribute to PCF. The PCF mechanism will never change the paradigm-external properties of lexemes. In the first, 'External Pivot' (EP) model, paradigm-external properties can be selected as the pivot, in which case their similarities and differences determine whether evidence lexemes as classified as 'matching' or 'contrasting'. In the second, 'External bias' (EB) model, the paradigm-external properties are never pivots, thus the 'matching/contrasting' classification is determined solely by inflectional exponents, however, evidence lexemes whose paradigm-external property matches that of the focal lexeme receive an enhanced salience, which is implemented within the scoring procedure (Figure 1e) by multiplying the scores of these evidence lexemes by a weighting multiplier, β.

4 Results and discussion

We present simulations without negative evidence ($\alpha = 0$) and with it ($\alpha = 0.5$), using 3 models: the Baseline model (Round et al., 2021a,b), the External Pivot model and the External Bias model (with $\beta \in \{2, 5, 10\}$). Inflectional systems contained 100 lexemes with 8 cells. For comparability with earlier models (§1), each cell and also the paradigm-external property had 5 possible exponents/values, initialised randomly. The PCF process was then iterated and the evolution of

Figure 2: Simulation Results. Upper panel without negative evidence ($\alpha = 0$); Lower panel with it ($\alpha = 0.5$). In each panel, Upper row: number of classes (plotted on a nonlinear scale); Lower row: mean MI between paradigm cells and the extra-paradigmatic property. Horizontal axis: number of PCF cycles. Black lines show means, grey ribbons 80% of the variation, for 20 repetitions. Models are: Baseline, External Pivot (EP) and External Bias (EB; with $\beta \in \{2, 5, 10\}$).



the system measured in terms of the number of distinct inflection classes and the mean of the mutual information (MI) between each inflectional cell and the external property. Results appear in Figure 2. We comment on classes, then mean MI.

Without negative evidence, the EP model shows negligible difference from the baseline. All inflection classes collapse together. This was true even when we biased the model to select the paradigm-external properties as the pivot 10× as frequently as paradigm cells. Thus we conclude that taking paradigm-external properties as pivots in analogical change does not promote the emergence of persistent inflection classes. In contrast, the EB model does lead to the emergence of 4 or 5 persistent inflection classes when $\beta = 10$, and to classes that are long-lived—though fewer in number, and not indefinitely persistent—when $\beta = 5$. Classes collapse when $\beta = 2$. Thus, inflection classes can emerge and persist when the weighting of evidence lexemes is strongly biased (but not when weakly biased) on the basis of paradigm-external similarity.

With negative evidence, 4 or 5 inflection classes reliably emerge, even in the baseline model. The EP model shows negligible difference from the baseline. This indicates again that when external properties function as analogical pivots, they have little impact. Results from the EB model are similar to those from the EP model when $\beta = 2$ and $\beta = 5$. However, when $\beta = 10$, a more interesting dynamic plays out. Inspection of the classes reveals that while 4 or 5 classes slowly emerge, they pass through early stages containing multiple micro-classes (small variations on the theme), with the micro-classes aligning closely with the external properties. However, the micro-classes subsequently collapse, eventually leaving only the 4 or 5 macro-classes.

When inflection classes emerge, mean MI in Figure 2 indicates the degree to which the class memberships of lexemes align with their paradigm-external properties. (When the classes collapse, MI trivially goes to zero.) Here we see that although stable classes arise without negative evidence ($\alpha = 0$) in the EB model with strong bias ($\beta = 10$), those classes are distributed in the lexicon in very close alignment with lexemes' external properties, and thus exhibit little 'morphological autonomy' (Aronoff, 1994). Only in models with negative evidence do the emergent classes diverge significantly from the paradigm-external properties.

5 Conclusions

Round et al. (2021a,b) showed that with negative evidence, piecemeal analogical changes can lead to emergent and persistent inflectional classes. Here we confirm that paradigm-external anchoring can also do so, but in the absence of negative evidence, the emergent classes exhibit little morphological autonomy. This suggests that negative evidence may be indispensable for the emergence of truly autonomous inflection classes. We find that when external anchoring is combined with negative evidence, a mix of autonomous and non-autonomous patterning emerges, much as in real inflection class systems (e.g. Bybee & Moder, 1983). This dynamic interaction is a new and fascinating finding that warrants further investigation.

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