The pragmatics of semantic change: Modeling the progressive-to-imperfective shift[1]

Gunnar LUND — *Harvard University*
Rebecca JARVIS — *Harvard University*
Gregory SCONTRAS — *University of California, Irvine*

Abstract. We implement a computational model of the cyclic progressive-to-imperfective shift, wherein languages with a single imperfective marker grammaticalize new progressive markers that ultimately broaden in interpretation and displace the older imperfective. While Deo (2015) offers a model of this process within the framework of evolutionary game theory, her model ultimately ignores the semantics she takes such care to construct. Our model, conceived within the Rational Speech Act modeling framework, offers a different perspective, operating directly over the utterance semantics. We show how semantic change may be a function of changes in utterance cost—a reflection of morphological complexity or frequency-of-use—as it relates to pragmatic reasoning. Counter to claims that grammaticalization is a process of conventionalization of implicature, our model holds the denotations of aspectual markers static; what changes is how we reason about their use given their changing costs.

Keywords: imperfective aspect, diachronic change, pragmatics, Rational Speech Act models.

1. Introduction

Traditional distinctions between aspectual categories contrast the imperfective with the perfective. Whereas perfective meaning is primarily characterized in terms of temporal boundedness, imperfective meaning is unbounded. Within the imperfective meaning space, several further distinctions may be drawn, though the names (and boundaries) of these categories often vary throughout the literature. Members of the imperfective meaning space include habitual, progressive, and continuous interpretations. Despite receiving different labels, their meanings often overlap.

Languages with two imperfective exponents divide this imperfective space in various ways. We follow Deo (2015) in calling one exponent IMPF, for imperfective, and the other PROG, for progressive. Broadly construed, IMPF is closely associated with what Deo calls "characterizing" readings, where the predicate is said to hold as a matter of habit, but not necessarily *right now* or at the relevant reference time. By contrast, PROG is most closely associated with events in progress: the predicate holds at the reference time, and no claims are made about the predicate holding beyond that point.

This situation is what we see in Present-Day English: the two interpretations arise in the contrast between the simple present tense, (1a), and the progressive *-ing* form of the verb, (1b).

(1) a. John eats cake.
b. John is eating cake.

In (1a), the most likely reading is that John eats cake on occasion; he has not cut it out of his diet. In (1b), the most likely reading is that John is eating cake at (or very near—he might be

[1]We thank the audience and organizers of Sinn und Bedeutung 23 in Barcelona. Thanks also to the participants and organizers of Formal Diachronic Semantics 3 in Norway.

Proceedings of Sinn und Bedeutung 23, vol. 2, pp. 73–90. Universitat Autònoma de Barcelona, Bellaterra (Cerdanyola del Vallès).

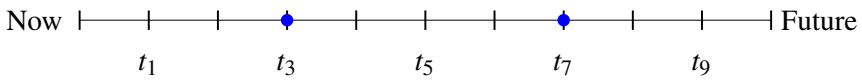


Figure 1: Visual representation of a scenario that could verify a characterizing interpretation. Dots represent indices at which the relevant predicate *P* holds. In this scenario, the predicate holds intermittently over a longer time span.

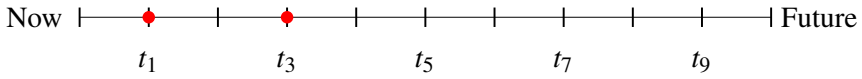


Figure 2: Visual representation of a scenario that could verify an event-in-progress interpretation. Dots represent indices at which the relevant predicate *P* holds. In this scenario, the predicate holds at times close to *now*.

between bites) the time of the utterance.

Figures 1 and 2 offer a way of visualizing the sorts of abstract scenarios that could verify each interpretation. The colored dots correspond to a time index at which some predicate holds. Lower time indices are temporally closer to the reference time (e.g., to *now*), and higher indices are farther in the future. The red scenario in Figure 2, with its events more closely clustered around the reference point, satisfies an event-in-progress interpretation wherein the predicate holds at or near the reference time. By contrast, the blue scenario in Figure 1 spreads its events more consistently over a longer time interval, thereby verifying a characterizing reading that asks after whether the predicate holds more generally.

In Present-Day English, the contrast between simple present and present progressive maps fairly cleanly onto the split between characterizing and event-in-progress interpretations; each form is best suited to a particular interpretation. The simple present is used to describe characterizing scenarios like the blue series in Figure 1. By contrast, the present progressive cannot generally be used to describe scenarios like in Figure 1. Instead, it is used to describe event-in-progress scenarios like the red series in Figure 2, which the simple present cannot be used to describe.

Though (1a) and (1b) have clear interpretive differences in Present-Day English, the meanings associated with these forms are not stable over time. In particular, English exemplifies part of a cross-linguistic trend in which IMPF exponents interact with and ultimately are displaced by PROG exponents. As part of this diachronic trend, IMPF begins as the dominant exponent, being used with both event-in-progress and characterizing readings. In these early stages, PROG optionally—and narrowly—gets used to describe events in progress. Over time, PROG's meaning broadens to capture characterizing scenarios, while IMPF loses the ability to describe events in progress. We see this pattern in the historical development of English.

In Middle English, the simple present was used with both characterizing and event-in-progress readings, as seen in (2a) and (2b).

(2) a. Now hier now ther, now to now fro,
Now up now down, this world **goth** so
(Gower, *Confessio Amantis* 569-570, via Visser, 1966)

b. Now my penne, allas, with which I **write**, **quaketh** for drede
(Chaucer, *Troilus and Criseyde* IV.13-14, via Visser, 1966)

While both (2a) and (2b) use the same simple present verb form, (2a) refers to a general property of how the world "goes," whereas (2b) refers to specific events of writing and quaking taking place at the time of utterance. In contrast to Present-Day English, these differences in interpretation are not linked to a difference in form. The dominant exponent in the Middle English period was IMPF (i.e., the simple present); PROG (i.e., the present progressive) had not yet been innovated or grammaticalized. As a result, both characterizing and event-in-progress interpretations could be communicated via the same general-purpose IMPF exponent. Returning to the abstract scenarios from Figures 1 and 2, in Middle English the simple present could be used to describe both the red and the blue scenarios.

By the Early Modern period of English, the present progressive did serve as a productive grammatical device. However, the situation still contrasted with that of Present-Day English because the simple present could be used to describe a wider range of scenarios. In particular, both IMPF, (3a), and PROG, (3b), could be used to describe events in progress.

(3) a. What **do** you **read**, my lord?
(Shakespeare, *Hamlet* II.2.191)
b. Now my spirit **is going**; I can no more.
(Shakespeare, *Antony and Cleopatra* IV.15.58-59)

While both of the examples in (3) describe particular events in progress, the verb forms used nonetheless differ. Both the simple present and present progressive could be used, that is, to describe a scenario like the red series in Figure 2. However, as in Present-Day English, only the simple present could be used to describe the blue series in Figure 1.

The various stages of English are summarized in Table 1. Starting in the Middle period, English had a multi-purpose IMPF that could describe both event-in-progress and characterizing scenarios. In the period between Middle and Early Modern English, the present progressive (PROG) was innovated. The simple present (IMPF) retained both event-in-progress and characterizing interpretations in Early Modern English, as it had in Middle English, and the present progressive came to serve as an additional exponent specialized for event-in-progress interpretations only. By Present-Day English, the interpretations associated with PROG have not changed (PROG can only describe events in progress), but the interpretations associated with IMPF have narrowed: IMPF can only be used to describe characterizing scenarios.

In some languages (though not English, at least not yet), the progression continues such that IMPF gets displaced even further, with PROG's usages expanding to include characterizing interpretations. We find this pattern in Tigre, a Semitic language spoken in Eritrea. In (4a) and (4b), the verb appears in the progressive, which is formed periphrastically from the imperfective with an additional tense auxiliary.

(4) a. ʔana nəʔus ʔət ʔana kəldol ʔət bet məhro **ʔəgayas ʔalko**
I small while being I every time to school **go-IMPF be-PST.1SG**
"When I was young, I used to go to school every day." (Raz, 1983)

		Scenario	
Language	**Exponent**	Event-In-Progress	Characterizing
Middle English	PROG		
	IMPF	✓	✓
Early Modern English	PROG	✓	
	IMPF	✓	✓
Present-Day English	PROG	✓	
	IMPF		✓
Present-Day Tigre	PROG	✓	✓
	IMPF		✓

Table 1: Summary of the interpretations associated with the present progressive (PROG) and simple present (IMPF) at various stages in the history of English, as well as in Present-Day Tigre.

b. ħəna həda:y **nətfarrar** **hallena**
we wedding **go out-IMPF be-PRES.1PL**
"We are going out to the wedding." (Raz, 1983)

In (4b), PROG receives an event-in-progress reading: the speaker is in the process of going to the wedding at the time of utterance. However, crucially, in (4a), the progressive is used to describe a characterizing scenario: going to school was a regular occurrence in the speaker's childhood. Given its ability to describe characterizing scenarios, we see that the interpretations associated with PROG have broadened. Returning once again to the scenarios in Figures 1 and 2, in Tigre PROG is still the only exponent that can describe an event-in-progress scenario like the red series. In contrast to English, however, both IMPF and PROG can describe the blue characterizing scenario.

This progression of change, with PROG emerging, broadening, and ultimately displacing IMPF, is said to constitute a grammaticalization pathway, whereby a progressive exponent takes on the role of an imperfective exponent. It should be noted that this pathway only follows one direction: progressive takes on the role of imperfective, but not vice-versa. This particular pathway resembles a Jespersen cycle (van der Auwera, 2009), with PROG eventually replacing IMPF and then the progressive-to-imperfective change beginning anew. In other words, the logical conclusion of the broadening of PROG's associated interpretations would have PROG entirely displace IMPF. At that point, the language would again have a single, multi-purpose exponent for expressing both characterizing and event-in-progress scenarios, and so the change could begin once again with the innovation of an event-in-progress-only PROG′.

The question that immediately arises is what drives the progressive-to-imperfective shift such that we commonly find it cross-linguistically. The current paper offers an information-theoretic answer to this question that we cash out in terms of pragmatic reasoning about shifting utterance costs. Our proposal gets articulated as a computational cognitive model of language understanding, formalized within the Rational Speech Act modeling framework (Frank and

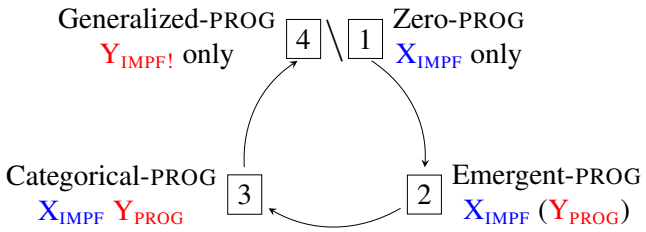


Figure 3: Visual representation of the four stages assumed in Deo's (2015) account of the progressive-to-imperfective shift. In stages 1 and 4, a single exponent describes both characterizing and event-in-progress scenarios. In stage 2, the language innovates a progressive exponent that optionally gets used for event-in-progress scenarios. In stage 3, both exponents are fully productive and each gets used to describe a single scenario type.

Goodman, 2012; Goodman and Frank, 2016). Drawing our inspiration from the semantic proposal and game-theoretic model of Deo (2015), we show how both production behavior (i.e., frequency of use) and comprehension behavior (i.e., the interpretations available) can change as a function of utterance costs. Section 2 reviews the relevant background from Deo (2015). Section 3 takes a closer look at the connection between form and meaning in the context of diachronic change. In Section 4, we present our computational model of the progressive-to-imperfective shift, and then explore our findings in Section 5. Section 6 considers the implications of our findings for the progressive-to-imperfective shift and theories of semantic change more broadly. Section 7 concludes.

2. Background: Deo's stages

Deo (2015) assumes that the progressive-to-imperfective shift occurs in four discrete stages, with distinct transitions between the stages; these stages are summarized in Figure 3. The shift begins in the *zero*-PROG stage, as in Middle English, where the language has only an IMPF exponent. Context or syntactic devices such as adverbials serve to distinguish the various readings of IMPF. One of these devices may eventually be recruited as a grammatical PROG exponent, at which point the language transitions into the *emergent*-PROG stage. Often, these new PROG exponents originate in locative constructions, as well as in verbs having a meaning like *standing* (Bybee and Dahl, 1989; Bybee et al., 1994). For instance, the Yagari progressive prefix *no-* has its origins in a verb *yano* 'to exist', used in locative and existential constructions (Renck, 1975). More broadly, in the *emergent*-PROG stage, IMPF remains the dominant aspectual device, but PROG may optionally be used to describe events in progress; Early Modern English existed in this stage.

The use of PROG to signal events in progress eventually becomes conventionalized, and the language moves into the *categorical*-PROG stage. In this stage, both exponents are obligatory and they are used to express different interpretations: IMPF receives a characterizing interpretation, while PROG receives an event-in-progress interpretation—this is the situation in Present-Day English. Deo suggests that the transition from the *emergent-* to *categorical*-PROG stage is driven by the literal meanings of the two forms. In her semantics, to which we turn presently, PROG is semantically stronger than IMPF. This asymmetry in the entailment relations results in a scalar implicature, where the use of the semantically weaker IMPF implies that the semanti-

cally stronger PROG does not hold. In other words, by using IMPF, a speaker might imply that her utterance should not receive an event-in-progress interpretation, since PROG is specialized for event-in-progress uses but PROG was not used. Deo suggests that the conventionalization of this implicature results in the transition to a *categorical*-PROG stage.

Finally, the language moves into the *generalized*-PROG stage, wherein the IMPF form falls out of use entirely, leaving the language with the PROG exponent for expressing both characterizing and event-in-progress meaning. Note that the *generalized*-PROG stage is formally equivalent to the *zero*-PROG stage, with the erstwhile PROG now serving as the IMPF exponent. Deo suggests that the transition from *categorical*- to *generalized*-PROG might be due to a learner's bias toward simpler grammars: as PROG's frequency of use increases, a learner might be more likely to incorrectly generalize PROG's interpretations to include characterizing ones as well as events in progress. At a certain point, the learner encounters IMPF so infrequently in the input that it no longer serves as a viable device.

2.1. Deo's semantics

The key transition for Deo is the one between the *emergent*- and the *categorical*-PROG stages (stages 2 and 3 in Figure 3). As mentioned above, Deo assumes that this transition is driven by scalar implicature. To see how, we must consider Deo's semantics.

For Deo (2009, 2015), both IMPF and PROG feature universal quantification over a partitioned time interval. IMPF and PROG differ in that the partitioned interval over which IMPF quantifies is a (possibly improper) superinterval j of the reference interval i, a contextually-determined interval of time relevant to the evaluation of the utterance. The superinterval over which IMPF quantifies is constrained to have the reference interval as its initial portion ($i \subseteq_{ini} j$); PROG quantifies over the reference interval itself. More precisely, both IMPF and PROG quantify over regular partitions of the relevant intervals.

The semantic difference between IMPF and PROG is given in (5). In (5a), $\mathscr{R}_j^c$ is a regular contextual partition of the superinterval j; in (5b), $\mathscr{R}_i^c$ is a regular contextual partition of the reference interval i. $\text{COIN}(P,k,w)$ holds when P is true at some partition cell k (i.e., a time index) in w. The smaller the partitioned interval, the smaller the partitions and the closer each individual partition is to *now* (i.e., the reference time). As a result, as the interval shrinks in size, the predicate must hold at times closer to *now* in order to satisfy the COIN relation. The larger the partitioned interval, the farther each partition cell is from *now* and the farther apart each cell-overlapping event may be.

(5) a. $[\![\text{IMPF}]\!] = \lambda P \lambda i \lambda w. \exists j [i \subseteq_{ini} j \wedge \forall k [k \in \mathscr{R}_j^c \rightarrow \text{COIN}(P,k,w)]]$
b. $[\![\text{PROG}]\!] = \lambda P \lambda i \lambda w. \forall k [k \in \mathscr{R}_i^c \rightarrow \text{COIN}(P,k,w)]]$

Since both intervals start at the reference time, smaller intervals correspond to event-in-progress readings, as the predicate must hold at times close to *now*; larger intervals correspond to characterizing readings, as the predicate may hold farther into the future and be more sporadically distributed over time. See Figure 4 for a visual representation of these intervals and interpretations. In the figure, the reference interval i is represented by the red partitioned box. Here, PROG holds of the red scenario, since one event (i.e., dot) occurs within each cell of the partition. By contrast, PROG does not hold of the blue scenario, since no blue dot occurs within

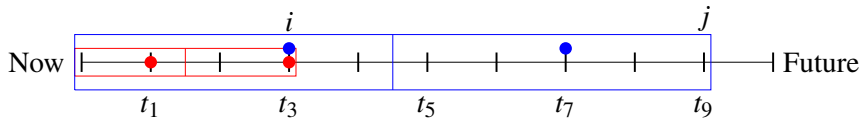


Figure 4: Visual representation of PROG (red) and IMPF (blue) verifying scenarios, where dots represent indices at which the relevant predicate *P* holds. The red box represents the reference interval *i*, and the blue box represents a superinterval *j*.

the leftmost cell in the partition of *i*. However, IMPF does hold of the blue scenario, since we can find a larger interval *j* (one possible choice of *j* is indicated here by the blue partitioned box) for which each cell contains a blue event. Trivially, IMPF also holds of the red scenario, since we could choose *j* in this case to be exactly the reference interval *i*. In other words, whenever PROG holds, IMPF also holds because the superinterval relevant to IMPF can always be the reference interval satisfying PROG.

In a system where both PROG and IMPF are active, given that PROG describes a narrower set of scenarios than IMPF, the use of PROG entails IMPF. This asymmetry leads to a run-of-the-mill scalar implicature whereby the use of IMPF implies that PROG does not hold (a speaker would use the stronger PROG if it were true), which suggests that the predicate fails to hold for the contextually-salient reference interval (i.e., the interval of which PROG would have been true). In other words, the use of IMPF rules out the narrower set of interpretations PROG wold have delivered, which eliminates event-in-progress readings for IMPF. Conversely, the use of PROG suggests that the predicate does not hold *beyond* the reference interval, ruling out characterizing and habitual readings that extend into the future beyond the reference interval. By conventionalizing the implicature, speakers arrive at the *categorical*-PROG stage where IMPF and PROG are used to signal characterizing and event-in-progress scenarios, respectively.

2.2. Deo's model

To model the progressive-to-imperfective shift, Deo treats the discrete stages in Figure 3 as pairs of speaker-hearer strategies—in other words, culturally-transmitted conventions—for communicating about the world. A speaker must either address a phenomenal (roughly, event-in-progress) or a structural (roughly, characterizing) inquiry using either PROG or IMPF to do so. In principle, both forms are capable of addressing both types of inquiry; at issue are the conventions of use and interpretation: whether a speaker uses PROG or IMPF to address phenomenal or structural inquiries, and whether a hearer interprets PROG or IMPF as addressing phenomenal or structural inquiries. Conventions are successful to the extent that they lead to successful communication (i.e., to the extent that they align across speakers and listeners), and their success makes the convention more appealing (and more prevalent) in the population. Using the tools of evolutionary game theory, Deo models the dynamic system in which these conventions are selected, propagated, and changed over time. See also Yanovich (2017) for a proposed refinement to Deo's model operating according to these same principles.

While Deo's evolutionary model does well to capture her stages of the progressive-to-imperfective shift, it does so without making use of her proposed semantics. In place of the semantics we have linguistic conventions, and the connections from one to the other are left unsaid. It re-

mains to be seen whether a model that operates directly over the semantics of PROG and IMPF can successfully capture changes in conventions such that PROG's usage expands to cover the cases previously handled by IMPF.

3. Form and meaning

As we search for inspiration for our own model of the diachronic shift in aspectual markers, here we take notice of another change concomitant with the changes in meaning in the progressive-to-imperfective shift: changes in form. Grammaticalization processes usually involve the loss of phonetic and morphological material, as well as a change in syntactic category. As a construction progresses along a grammaticalization pathway, its form changes in tandem with its meaning. The pathway of forms is often referred to as a *cline*. For instance, Hopper and Traugott (2003) propose the following cline for verbal grammaticalization:

(6) Full verb > Vector verb > Auxiliary > Clitic > Affix

Cross-linguistic evidence suggests that when a verb form undergoes grammaticalization, it tends to follow the pathway above. The English verb *have* is an example of this change, starting as a fully lexical verb, then finding use as an auxiliary, and eventually further changing to a clitic as in *we've* (Hopper and Traugott, 2003).

Generalizing further, clines follow the schema in (7), though individual cases of grammaticalization often skip some stages along the chain:

(7) Content item > Grammatical word > Clitic > Inflectional affix > (Zero)

As change progresses, the item undergoing the change loses both syntactic independence and phonological and morphological weight. A critical component of a cline is its unidirectionality: we overwhelmingly see forms lose weight, but rarely do they gain it (Hopper and Traugott, 2003; Lehmann, 2015; see also Börjars and Vincent, 2011, for a discussion of the status of directionality in grammaticalization theory).

Imperfective and progressive forms follow the same general trend. Early progressive forms are often morphosyntactically heavier than imperfective forms, and lose material as they grammaticalize. Turkish provides evidence of this pattern: the Old Turkic lexical verb *yor* 'to walk' first became an auxiliary verb with progressive meaning, and then became the progressive suffix *-iyor* in Modern Standard Turkish (Clauson, 1972; Lewis, 1967; Erdal, 2004). In other words, as PROG took hold in Turkish, its form slimmed down.

If progessive forms are younger than imperfective forms and start heavier than imperfective forms, we should expect that progressive exponents are morphosyntactically heavier than imperfective exponents synchronically. This, in fact, bears out. Bybee and Dahl (1989) report that, using data from Dahl's (1985) crosslinguistic survey of tense and aspect systems, imperfective forms are morphologically reduced compared to progressive forms. In that survey, eighteen of nineteen progressive exponents are periphrastic (i.e., heavy and prominent), while seven of seven imperfective exponents are bound morphemes (i.e., light and less prominent).

The progressive-to-imperfective shift, then, is not merely a process of meaning change. It is also a process of morphological and phonological change. As the progressive exponent grammaticalizes, it usually loses phonological material and syntactic independence. In languages

with distinct progressive and imperfective exponents, the progressive is often phonologically and syntactically heavier. This morphological asymmetry is true in the case of English, where the progressive involves both a tensed form of the auxiliary *be* and a verbal suffix, while the present marker is a simple suffix. We propose that when it comes to modeling the progressive-to-imperfective shift, one should take these morphological facts into account.

One way to treat these morphological facts is in terms of shifting utterance costs. Speakers expend effort as they choose and select their utterances. Longer, less frequent collocations are costlier than their shorter, more frequent cousins. Thus, the morphological slimming-down of PROG exponents as they increase in frequency while grammaticalizing can be modeled as a decrease in the cost of uttering PROG relative to IMPF. In the following section, we present a model of the progressive-to-imperfective shift that operates over these shifting costs while reasoning about the utterance semantics.

4. The RSA model

We model the pragmatic reasoning that strengthens and refines the interpretations of PROG and IMPF within the Bayesian Rational Speech Act (RSA) framework, where speakers and listeners reason recursively about utterances and the world states those utterances describe (Frank and Goodman, 2012; Goodman and Frank, 2016, Scontras et al., electronic). In our model, a "lifted-variable" RSA variant, listeners also reason about the partitioned reference interval (I_{ref}) and superinterval (I_{sup}) under discussion. Put differently, our model assumes that listeners have uncertainty about the precise reference and superintervals that are relevant when interpreting utterances that appeal to grammatical aspect. Thus, we treat PROG and IMPF as vague, underspecified, or ambiguous utterances whose meaning gets fixed via active pragmatic reasoning (Lassiter and Goodman, 2013; Scontras and Goodman, 2017).

We model states of the world $s \in S$ as sets of indices at which the relevant predicate P holds. To allow for tractable inference, we imagine time as an interval bound between 0 and 10, with 0 corresponding to now (i.e., the reference time) and 10 corresponding to the distant future. We generate S as the powerset of the set of five atomic indices, less the empty set:

$$S = \mathscr{P}(\{t_1, t_3, t_5, t_7, t_9\}) - \emptyset$$

The partitioned intervals I_{ref} and I_{sup} all find their lower bound at the reference time, 0. Possible upper bounds include all integers from 4 to 10 with equal probability, with the constraint that the upper bound of I_{sup} be at least as great as the upper bound of I_{ref}. Intervals are partitioned into two equal-sized parts. Figure 5 represents I_{ref} $[0,3]$ (red box) and I_{sup} $[0,9]$ (blue box), together with two separate states: $\{t_1, t_3\}$ (red dots) and $\{t_3, t_7\}$ (blue dots). In the first state, the predicate holds at time indices t_1 and t_3; in the second, the predicate holds at t_3 and t_7. For purposes of model exploration, we treat the distinction between event-in-progress and characterizing scenarios as a gradient one: the closer the relevant indices are to the reference time, the more relevant the interpretation is to the event-in-progress reading; the farther the relevant indices are from the reference time, the more relevant the interpretation is to the characterizing reading. Thus, in Figure 5, only the event-in-progress scenario holds at t_1.

We consider three possible utterances: PROG, IMPF, and a NULL utterance corresponding to the speaker's saying nothing at all. To implement the uncertainty with respect to the relevant

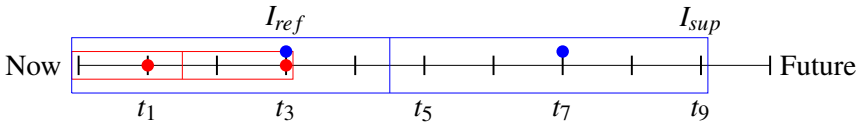


Figure 5: Visual representation of PROG (red) and IMPF (blue) verifying scenarios, where dots represent indices at which the relevant predicate P holds and boxes represent partitioned intervals.

partitioned intervals (i.e., I_{ref} and I_{sup}), we parameterize the interpretation function $[\![.]\!]$ so that interpretations depend on specific values of these parameters; the utterances receive the semantics in (8), a partial reformulation of Deo's semantics in (5).

(8) a. $[\![\text{PROG}]\!]^{I_{ref},I_{sup}} = \lambda s.\ \forall k[k \in I_{ref} \rightarrow \text{COIN}(P,k,s)]$
b. $[\![\text{IMPF}]\!]^{I_{ref},I_{sup}} = \lambda s.\ \forall k[k \in I_{sup} \rightarrow \text{COIN}(P,k,s)]$
c. $[\![\text{NULL}]\!]^{I_{ref},I_{sup}} = \lambda s.\ \texttt{true}$

In Deo's semantics, the requirement that the reference interval i be a subinterval of j guarantees that PROG entails IMPF, since IMPF involves existential quantification over these possibly improper superintervals. If PROG is true of the reference interval i, then certainly there exists an improper superinterval j—i itself—to satisfy IMPF. In contrast, our version of Deo's semantics does not maintain this entailment: since IMPF no longer involves existential quantification over superintervals, it is possible to choose particular values of I_{ref}, I_{sup}, and the world state s so that PROG is true but IMPF is not. Still, in a purely statistical sense, it remains true under our semantics that given a random world state s and pair of intervals $I = \langle I_{ref}, I_{sup} \rangle$, IMPF is more likely to be true than PROG, signalling that PROG is semantically stronger. In other words, when PROG is true, IMPF is extremely likely to also be true. Out of the 868 possible $\langle s, I \rangle$ pairs, IMPF is true of 543, while PROG is true of only 377. Crucially, of the 377 pairs of which PROG is true, IMPF is true of 365. However, when I_{ref} is particularly small, I_{sup} is particularly large, and the events in s are strongly clustered around the reference time, it is possible for PROG but not IMPF to truthfully describe s. This occurs in 12 of the pairs, and an example is shown in Figure 5; here, PROG holds because at least one red dot (i.e., at least one time index at which the predicate holds) falls in each half of I_{ref}, but IMPF does not hold because the dots are so tightly clustered that they do not fall in the second half of I_{sup}. Also note that IMPF certainly does not entail PROG, as IMPF holds for the blue dots in Figure 5 but PROG does not.

Utterance interpretation involves three levels of inference. At the base, the literal listener (L_0) interprets utterances according to their literal semantics; L_0 updates beliefs about the state of the world s (i.e., $P(s)$) conditioned on the semantics of u, together with some specified I_{ref} and I_{sup}. These interval variables are "lifted" to be resolved at a higher level of inference, giving rise to the "lifted-variable" classification for our RSA model (cf. Scontras et al., electronic). Hearing some utterance u with specific intervals in mind, L_0 returns a distribution over possible states s compatible with the literal semantics of u parameterized by I_{ref} and I_{sup}:

$$P_{L_0}(s|u, I_{ref}, I_{sup}) \quad \propto \quad [\![u]\!]^{I_{ref},I_{sup}} \cdot P(s).$$

One level up in the reasoning chain, the pragmatic speaker (S_1) chooses an utterance u to communicate some observed s to L_0 with respect to some specific I_{ref} and I_{sup}. S_1 makes this choice

by maximizing the probability that u would convey s to L_0 while minimizing the utterance cost ($C(u)$); the temperature parameter $\alpha > 0$ controls S_1's optimality when maximizing utterance utility. Thus, S_1 returns a distribution over possible utterances u given some observed s, I_{ref}, and I_{sup}:

$$P_{S_1}(u|s, I_{ref}, I_{sup}) \quad \propto \quad exp(\alpha \cdot [log(P_{L_0}(s|u, I_{ref}, I_{sup})) - C(u)]).$$

Above S_1, the pragmatic listener (L_1) observes u and updates beliefs about s, together with the likely values for I_{ref} and I_{sup}. Thus, L_1 uses u to jointly infer the state of the world and the relevant intervals. L_1 performs this inference by reasoning about the process that generated the observed u: the probability that S_1 would have chosen u to communicate about s relative to some specific I_{ref} and I_{sup}. L_1 returns a joint distribution over states and intervals that are likely to be described by the observed u:

$$P_{L_1}(s, I_{ref}, I_{sup}|u) \quad \propto \quad P_{S_1}(u|s, I_{ref}, I_{sup}) \cdot P(s) \cdot P(I_{ref}) \cdot P(I_{sup}).$$

We use L_1 to model interpretation behavior. To model utterance use (i.e., speaker production behavior), we need one last layer of inference: a pragmatic speaker (S_2) who chooses utterances to communicate some observed state s to L_1 (Savinelli et al., 2017, Scontras et al., electronic). S_2 makes this choice by (softmax) maximizing the probability that L_1 would arrive at s from u, summing over the possible values for the intervals I_{ref} and I_{sup}. S_2 thus returns a distribution over utterances u for communicating the observed s to L_1:

$$P_{S_2}(u|s) \quad \propto \quad exp(\alpha_2 \cdot [log \sum_{I_{ref}, I_{sup}} P_{L_1}(s, I_{ref}, I_{sup}|u) - C(u)]).$$

To generate model predictions, we fix the free parameters of the model: the prior probabilities, α parameters, and utterance costs. By manipulating the relative costs of PROG and IMPF, we model their prevalence and morphological weight in a language at a particular stage of aspectual marking.

5. Model predictions

Figure 6 plots model predictions from two separate layers of our RSA model: L_1, which represents comprehension behavior (i.e., how the relevant utterances get interpreted), and S_2, which represents production behavior (i.e., how the relevant utterances get selected to communicate various states of affairs). Each facet of the plot represents a different hypothetical stage in the diachronic progression from progressive to imperfective. Each stage is characterized by the relative costs of the two utterances: from the first stage, where PROG is seven times as costly as IMPF, through the middle stage, where PROG and IMPF are equally costly, to the final stage, where IMPF is seven times as costly as PROG. The cost values for these stages are chosen arbitrarily; the values capture both the relative frequency and relative morphological weight of a given form, independent of its meaning. The precise costs assigned to IMPF and PROG at each stage are given in Table 2. For all stages, the α parameters are held constant at a "default" value of 1 (i.e., no scaling). Additionally, every world state s is assumed to be equally likely a priori.

Starting with the L_1 predictions (darker bars in Figure 6), we note the gradual expansion of PROG's interpretive possibilities as IMPF overtakes it in cost. In the initial stages where PROG

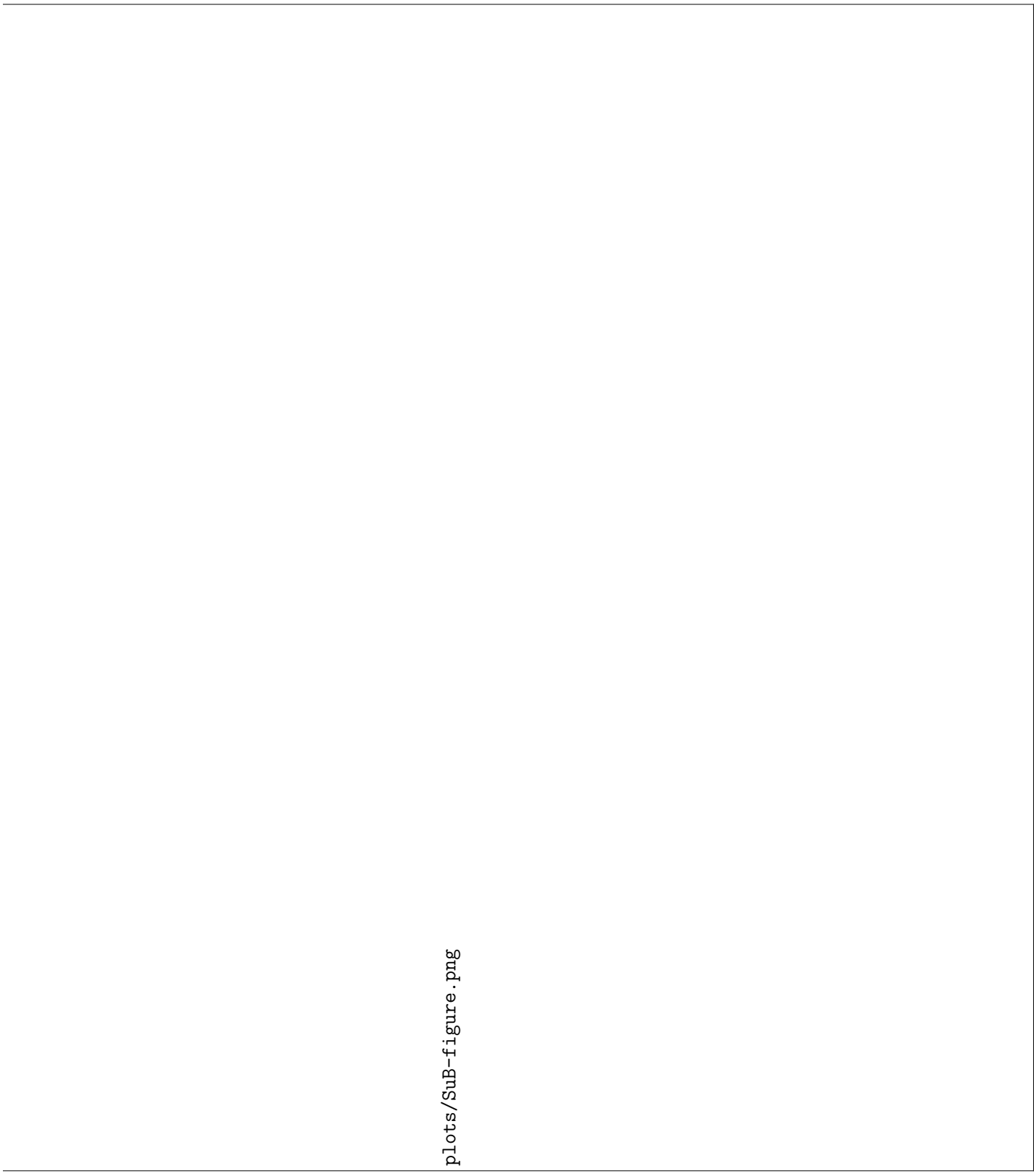
	Cost	
Stage	IMPF	PROG
Stage 1	1	7
Stage 2	1	5
Stage 3	1	3
Stage 4	1	1
Stage 5	3	1
Stage 6	5	1
Stage 7	7	1

Table 2: The costs of IMPF and PROG at each stage in Figure 6. In early stages, PROG has a higher cost than IMPF, while IMPF has a higher cost in later stages.

is significantly more costly (i.e., less frequent and morphologically heavier) than IMPF, PROG is interpreted almost exclusively as describing time indices close to the reference time; in other words, hearing PROG in the initial stages, L_1 interprets the utterance as describing events in progress. At Stage 4, where PROG and IMPF are equally costly, the two interpretations are largely overlapping, with PROG favoring states close to the reference time and IMPF signalling states farther into the future. This interpretive pattern persists, becoming slightly more pronounced, as IMPF overtakes PROG in cost.

While L_1's predictions indicate how a listener would interpret an utterance were they to hear it, the flip side of the communicative coin, S_2, models how likely the utterances are to be produced in the first place. As Figure 6 (lighter bars) demonstrates, S_2's behavior changes dramatically from Stage 1 to Stage 9. In the initial stages where PROG is much costlier, S_2 uses IMPF almost exclusively to communicate about all of the time indices. In other words, the prohibitive cost of PROG leads to a multi-purpose IMPF. Conversely, in the final stages where IMPF is much costlier, S_2 uses PROG almost exclusively to communicate about all of the time indices. It is only in the intermediate stages where PROG and IMPF are equally costly that S_2 regularly uses both utterances.

Taking in account both the L_1 and the S_2 predictions, we begin to get a clearer picture of the stages in the progressive-to-imperfective shift. The *emergent*-PROG stage, where PROG constructions are often periphrastic and less frequent, involves PROG constructions with a high utterance cost (i.e., morphologically complex and infrequent) relative to that of IMPF (Bybee and Dahl, 1989; Dahl, 1985). At this stage—spanning the early stages of our model—PROG is used almost exclusively with event-in-progress readings, but its high cost leads to an overall preference for IMPF for both event-in-progress and characterizing scenarios. As PROG's morphology streamlines, its cost lowers and it gets used more frequently. This leads to the *categorical*-PROG stage—the middle stages in our model—where the preference is for PROG to describe event-in-progress readings while IMPF describes characterizing ones. Already at the intermediate stages we see a broadening of PROG's meaning, but the cost symmetry between PROG and IMPF allows each utterance to carve out its own space of usage. In the *expanding*-PROG stage—the later stages of our model—PROG's meaning broadens yet more, and the relative cost of IMPF leads to an overall preference for PROG for both event-in-progress and characterizing scenarios; PROG has displaced IMPF in its usage. We thus see how considera-


plots/SuB-figure.png

tions of utterance cost—without any shift in the semantics of the aspectual forms—can lead to the various stages of the progress-to-imperfective shift.

6. Discussion

By taking into account the shifting morphology that accompanies shifts in meaning, we are able to model changes in aspectual meaning while reasoning directly about utterance semantics. Our model thus captures the progressive-to-imperfective shift while reasoning pragmatically about a stable utterance semantics but changing utterance costs. Note that we have used Deo's semantics for theoretical continuity; any semantics with a similar entailment asymmetry between PROG and IMPF would deliver the same qualitative pattern of results. In what follows, we consider the implications of these results for our understanding of the progressive-to-imperfective shift and for theories of grammatical change more broadly.

6.1. Gradience of stages

The gradient predictions of our model suggest that the progressive-to-imperfective shift does not occur in discrete stages, but rather proceeds gradually as a function of changing utterance costs. This finding is supported by the empirical facts. Languages falling in, say, the *categorical*-PROG stage show subtle differences in their use of aspectual markers. In Bybee et al.'s (1994) study of three languages with an imperfective/progressive distinction, the authors found that the exponents in these languages overlap considerably in their domains of use.

For example, Yagaria, a language spoken in Papua New Guinea, has both a zero-marked imperfective and a progressive prefix *no-* (cf. Renck, 1975, via Bybee et al., 1994). The zero-marked IMPF "relates actions in the present, or, as 'historic present', relates actions which took place in the past" (Renck, 1975: 86). IMPF gets used less frequently than PROG, which can describe both events in progress and habitual actions (i.e., characterizing scenarios), as in (9).

(9) ba no- d- on- e
sweet potato PROG eat- 1p- IND
'we are eating sweet potatoes now' or 'we usually eat sweet potatoes'

The view of the progressive-to-imperfective shift presented in Section 2 has nowhere to account for this pattern. The problem lies in the discrete stages. Yagaria does not fall into the *categorical*-PROG stage (i.e., stage 3), since its PROG can be used with both event-in-progress and characterizing scnearios. It also does not fall into the *generalized*-PROG stage (stage 4), since IMPF still serves as a viable option for characterizing scenarios. Rather, Yagaria exists somewhere between the two stages.

Another problematic language for the discrete-stages view is Alyawarra (Pama Nyungan; Australia), which has an older imperfective exponent *-ima* and a progressive exponent *-iyla* (Yallop, 1977, via Bybee et al., 1994). These markers have largely overlapping domains of use, but *-iyla* "is preferred for the description of present happenings" (Bybee et al., 1994, 145-6). However, Bybee et al. (1994) point out that progressive *-iyla* has a fairly wide distribution, finding use with both stative predicates and habitual contexts, as in (10).

(10) nga angkiyla alyawarra, ra angkiyla arirnta
2.S.NOM speak:PROG Alyawarra, 3.S speak:PROG Aranda.
'You speak Alyawarra, he speaks Aranda'

As with Yagaria above, Alyawarra's multi-purpose PROG in the context of a grammatical IMPF fails to fit neatly into the discrete-stages view. Moreover, the Alyawarra case seems to differ from the Yagaria case because here the older IMPF is still actively used alongside the newer PROG (cf. the asymmetry of usage in Yagaria).

In fact, we already encountered data along these lines when we considered Tigre in Section 1 above. There, we saw that in Tigre PROG can be used for both event-in-progress and characterizing scenario. Like Yagaria and Alyawarra, Tigre seems to fall somewhere between the *categorical*-PROG and *generalized*-PROG stages. The Tigre imperfective, however, has also acquired a "new" futurate interpretation—we return to this point in the following subsection.

These data suggest that languages do not fit neatly into a view where the progressive-to-imperfective shift proceeds in discrete stages. All three of these languages seem to fall somewhere in Deo's *categorical*-PROG stage, yet each behaves differently in subtle ways. The gradient nature of our model is well-suited to capturing these facts. Indeed, we see already in Figure 6 that as PROG takes hold in the language, its usage expands to cover characterizing scenarios *even in the presence of a viable* IMPF *alternative*. This is precisely the pattern we find in Yagaria, Alyawarra, and Tigre.

6.2. Futurity and IMPF

Our model further predicts that imperfectives begin to take on futurate uses: in the later stages, both interpretation and production behavior for IMPF begins to shift toward later time indices (blue bars in Figure 6). Again, this prediction appears to bear out in the language data. To see how, we return again to Tigre.

We presented a somewhat simplified view of the Tigre details above. In fact, the language has an imperfective present verbal form and two periphrastic progressive forms, one for past situations and the other for present situations (Raz, 1983). Like Alyawarra, both exponents enjoy frequent use. The imperfective form is used with stative predicates, habitual actions, and the historic present. Crucially, IMPF is also used to indicate futurity. The two uses of IMPF are illustrated below, where (11a) involves a habitual interpretation of IMPF, and (11b) involves a future interpretation.

(11) a. ʔət bet məhro kəl dol ʔassabuħ sʕassamaːn ʔəgayəs
To school all time in the morning at eight o'clock go-IMPF.1SG
'I go to school every day at eight o'clock in the morning.'
b. haqo kəlʔe ma salas məʕəl ʔaqabbəl
after two or three day return-IMPF.1SG
'After two or three days, I shall return.'

Kui (Dravidian; India) represents another example of this shift toward the future. The so-called "future" in Kui, a suffix *-in*, has both future uses and characterizing uses. Thus, IMPF in (12) is ambiguous between the two readings (Winfield, 1928).

(12) ānu tāki-i
1SG walk-IMPF
'I shall walk.' or 'I walk.'

In fact, this prediction bears out quite generally: imperfectives are a common source of future exponents. Many of these exponents obtain their future use after having their domain of use constrained by a competing progressive, though they usually retain some of their more general imperfective meaning (Bybee et al., 1994, 153, 276). Thus, these future uses are usually later developments, after a progressive exponent has generalized in use quite broadly. This is precisely the pattern our model predicts.

6.3. Consequences for theories of grammatical change

Theories of grammatical change vary, but ultimately often involve a change in the core meaning of a lexical item. For example, several theories argue that implicatures or other "invited inferences" become incorporated into the asserted meaning of a lexical item (Eckardt, 2006; Traugott and Dasher, 2002). Other theories argue that the conceptual structures associated with a word change over time (Danchev and Kytö, 1994), perhaps involving a kind of metaphoric transfer (Heine et al., 1991; Hopper and Traugott, 2003). While some cases of grammaticalization may require such a lexical change, however it may be implemented, our model suggests that the progressive-to-imperfective shift does not require the lexical entries of PROG or IMPF to change at all. Instead, factors *external* to interpretation may change—in this case the cost of the utterance (a function of morphological complexity and frequency of use)—but the denotations of the lexical items themselves can remain constant.

If this line of thinking is on the right track, then understanding the pragmatic factors at play external to grammar is at least as important to understanding changes in grammar as understanding the shifting semantics. As a consequence, when considering diachronic changes in meaning, it is also necessary to take into account morphosyntactic reduction and other changes in form and usage. The current work demonstrates how these latter factors alone can lead to changes in interpretation without any changes in the semantics. Indeed, this conclusion was assumed already in Deo's model, where what shifts are the speaker-hearer conventions, not the semantics of PROG and IMPF.

7. Conclusion

The interpretation and use of grammatical aspectual devices changes with time: progressive exponents slowly broaden in meaning, encroaching on the territory of the older imperfective. Inspired by Deo's (2015) model of this change, we have offered our own model within the RSA modeling framework. With a strength asymmetry in the semantics of PROG vs. IMPF, interpretation depends crucially on the utterance costs, and these costs change as a function of the morphology and frequency of use. While there surely exists a need for semantic reanalysis in cases of grammatical change, or model provides a proof-of-concept for the notion that interpretation and use can change as a function of the relative costs of the relevant utterances. Thus, we have shown how pragmatic reasoning can drive semantic change.

References

van der Auwera, J. (2009). The Jespersen cycles. In E. van Gelderen (Ed.), *Cyclical Change*, pp. 35–71. Amsterdam: Benjamins.

Börjars, K. and N. Vincent (2011). Grammaticalization and directionality. In H. Narrog and B. Heine (Eds.), *The Oxford handbook of grammaticalization*. Oxford: Oxford University Press.

Bybee, J. L. and Ö. Dahl (1989). The creation of tense and aspect systems in the languages of the world. *Studies in Language 13*(1), 51–103.

Bybee, J. L., R. D. Perkins, and W. Pagliuca (1994). *The evolution of grammar: Tense, aspect, and modality in the languages of the world*. Chicago: University of Chicago Press.

Clauson, G. (1972). *An etymological dictionary of pre-thirteenth-century Turkish*. Oxford: Clarendon Press.

Dahl, Ö. (1985). *Tense and aspect systems*. Oxford: Basil Blackwell.

Danchev, A. and M. Kytö (1994). The construction *be going to* + infinitive in Early Modern English. In D. Kastovsky (Ed.), *Studies in Early Modern English*, pp. 59–78. Berlin: De Gruyter.

Deo, A. (2009). Unifying the imperfective and the progressive: Partitions as quantificational domains. *Linguistics and Philosophy 32*(5), 475–521.

Deo, A. (2015). The semantic and pragmatic underpinnings of grammaticalization paths: The progressive to imperfective shift. *Semantics and Pragmatics 8*(14), 1–52.

Eckardt, R. (2006). *Meaning change in grammaticalization: An enquiry into semantic reanalysis*. Oxford: Oxford University Press.

Erdal, M. (2004). *A grammar of Old Turkic*, Volume 3. Leiden: Brill.

Frank, M. C. and N. D. Goodman (2012). Predicting pragmatic reasoning in language games. *Science 336*(6084), 998–998.

Goodman, N. D. and M. C. Frank (2016). Pragmatic language interpretation as probabilistic inference. *Trends in Cognitive Sciences 20*(11), 818–829.

Heine, B., U. Claudi, and F. Hünnemeyer (1991). *Grammaticalization: A conceptual framework*. Chicago: University of Chicago Press.

Hopper, P. J. and E. C. Traugott (2003). *Grammaticalization*. Cambridge: Cambridge University Press.

Lassiter, D. and N. D. Goodman (2013). Context, scale structure, and statistics in the interpretation of positive-form adjectives. In T. Snider (Ed.), *Proceedings of SALT 23*, pp. 587–610. CLC Publications.

Lehmann, C. (2015). *Thoughts on grammaticalization* (3 ed.). Classics in Linguistics. Berlin: Language Science Press.

Lewis, G. (1967). *Turkish grammar*. Oxford: Clarendon Press.

Raz, S. (1983). *Tigre grammar and texts*. Malibu: Undena Publications.

Renck, G. L. (1975). *A grammar of Yagaria*. Canberra: Department of Linguistics, Research School of Pacific Studies, The Australian National University.

Savinelli, K., G. Scontras, and L. Pearl (2017). Modeling scope ambiguity resolution as pragmatic inference: Formalizing differences in child and adult behavior. In *Proceedings of the Thirty-Ninth Annual Conference of the Cognitive Science Society*, pp. 3064–3069.

Scontras, G. and N. D. Goodman (2017). Resolving uncertainty in plural predication. *Cognition 168*, 294–311.

Scontras, G., M. H. Tessler, and M. Franke (electronic). Probabilistic language understanding: An introduction to the Rational Speech Act framework. Retrieved from https://www.problang.org.

Traugott, E. C. and R. B. Dasher (2002). *Regularity in semantic change*. Cambridge: Cambridge University Press.

Visser, F. T. (1966). *An historical syntax of the English language*, Volume 2. Leiden: Brill.

Winfield, W. W. (1928). *A grammar of the Kui language*, Volume 245 of *Bibliotheca Indica*. Calcutta: Asiatic Society of Bengal.

Yallop, C. (1977). *Alyawarra: An aboriginal language of Central Australia*. Canberra: Australian Institute of Aboriginal Studies.

Yanovich, I. (2017). Analyzing imperfective games. *Semantics and Pragmatics 10*.