Signaling under uncertainty
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Conventions are like fires: under favorable conditions, a sufficient concentration of heat spreads and perpetuates itself. The nature of the fire does not depend on the original source of heat. Matches may be the best fire starters, but that is no reason to think of fires started otherwise as any the less fires.

David Lewis, *Convention: A Philosophical Study*

Communication is a complex social affair of which much is still little understood. It is therefore unsurprising that models of language, its use, and its transmission do not purport to provide fully accurate descriptions but involve substantial abstraction and simplification. We turn to such models not for their detail or exactness but for their explanatory force, with the goal “[... to refine, systematize, and expand the menu of available explanations” (Ylikoski and Aydinonat 2014:23) by uncovering likely “systematic patterns of counterfactual dependence” (Woodward 2004:191). This investigation used models to better understand the relationship between factors that shape language (use) and properties or outcomes evidenced in natural language. In what follows, we reflect on our analysis along these more general lines. Section 6.1 discusses what the past chapters suggest about the relationship between semantics and pragmatics. Section 6.2 reviews methodological challenges faced by this kind of research. We argue that meeting these challenges calls for a pluralistic approach, in which we view our own efforts as being embedded.

6.1 On Semantics and Pragmatics

At the beginning of this investigation we posed two broad questions. The first question concerned the role of pragmatics in light of semantics. The second question reversely asked about the role of semantics in light of pragmatics. We can now reflect on how much headway we made in answering these questions.
**Why leave to pragmatics what semantics can do?** At first sight, it may seem as if semantic conventions ought to be as precise and constraining as possible. Under the assumption that such conventions are largely shared by interlocutors, this would leave less room for uncertainty and ensuing misunderstanding. The maxim for optimal linguistic design this view suggests is that to each meaning ought unequivocally correspond a unique form. Even under this view, it would still be useful to recruit mutual reasoning or contextual information in situations in which some uncertainty is unavoidable. Factors that may promote such supplementary reliance on pragmatics include open communities, changing and noisy environments, as well as change in semantic conventions effected by synchronic and diachronic processes yet to be adopted by all. In other words, even under the view that semantics should do much of the heavy lifting necessary for communication to succeed, pragmatics may still come into play to quench uncertainty where it is unavoidable.

This investigation focused on cases where relying on pragmatics was not necessary but an option; either in terms of linguistic choice or as a viable evolutionary outcome. In the case of ambiguity, we looked at lexica with unambiguous alternatives (Chapter 3), and analyzed the evolutionary competition of such lexica against less and more ambiguous alternatives (Chapter 5). In the case of scalar implicatures, we analyzed the evolutionary competition of lexica that rely on pragmatics to convey upper-bounds for weak scalar alternatives and those that enforce such bounds lexically (Chapter 4). The reason for looking at such cases was to elucidate whether pragmatics fulfills other roles as well. Roles where it comes into play not only due to environmental or biological constraints that necessitate it. Overall, the past chapters paint a different picture of the relationship between semantics and pragmatics than that of pragmatics playing solely a supplementary role.

Pragmatics, broadly construed, endows interlocutors with flexibility to react to different contexts of interaction by scaffolding on underspecified semantic conventions (Chapter 3 and 5). Intuitively, less precise semantics leave more room for pragmatic refinement. Such pragmatic refinement can offer better fits to the context of interaction and interlocutors involved in it than fixed precise semantics as it enables for linguistic material to be flexibly repurposed. Put differently, laxer semantic conventions endow pragmatic language users with the ability to convey a wide array of speaker meanings in an efficient, effective, and flexible manner. In this way, an utterance such as “I am cool” can inform the hearer about the speaker’s wellbeing; be used to decline an offer; describe temperature, popularity, trustworthiness; or something different altogether. Whether this ability confers its users with a functional advantage ultimately depends on the context(s) in which communication takes place (Chapter 3 and 5). Generally speaking, and ignoring side conditions such as agents’ rationality and their beliefs about each other’s expectations, the more varied yet informative contexts are, the more functionally advantageous it can be to rely on contextual information to guide inference.
Additionally, leaving to pragmatics what semantics could – in principle – do, may be explained not only in functional terms. In some cases, underspecified semantics may also be easier to acquire than more precise counterparts (Chapter 4). The explanation of pragmatic recruitment then lies not (solely) on communicative advantages that it can confer but on factors that shape the semantic conventions that enable for pragmatic inference in the first place. In this case, their learnability.

While in both Chapter 4 and Chapter 5 our analysis ultimately involved an interaction between functional pressure and learnability, there are some important differences between these explanations. In the first case we have an adaptive trait: the evolution of semantics that enable for pragmatic ambiguity exploitation is, to a large extent, a consequence of selection for greater communicative efficiency. If the environment allows for pragmatic inference to be advantageous then a balance between constraining semantic conventions and their pragmatic refinement is struck. The second case is not that of an adaptation per se, but rather a consequence of linguistic knowledge being shaped by its cultural transmission, with pragmatic reasoning enabling for the maintenance of underspecified semantics without incurring functional deficiencies.\footnote{One might argue that the learning algorithm employed in language acquisition or learners’ inductive biases are adaptations on their own. This may well be so (see Christiansen and Chater 2008 for arguments to the contrary), but the point here is just that there is a difference. The former case, where there is a clear functional advantage, is an instance of “selection in action” (Ridley 2002:10): the type in question outcompetes alternatives in terms of communicative efficiency. The latter case is one where the type evolves by a combination of a functional advantage over some types and a learnability advantage over others that do not rely on pragmatic reasoning in communication.}

These predictions rest on relatively weak assumptions about agents’ cognitive capacities. For ambiguity exploitation or scalar inferences to evolve, we only required agents to reason about each other’s literal signaling behavior (level-1 reasoning); for them to exhibit a tendency toward utility maximization from their subjective perspective; and for them to exhibit a tendency toward posterior maximization in language acquisition. This is a desirable prediction when it comes to explanations of pervasive outcomes with multiple evolutionary starting points (Paternotte and Grose 2017). It suggests the (model internal) requirements for the emergence of these synergies between semantics and pragmatics to be relatively low, which is what we would expect of pervasive and cross-linguistically well attested properties.

Why leave to semantics what pragmatics can do? The above should not be taken to suggest that semantics plays a supplementary role to pragmatics either.

First, we should not forget that shared semantic conventions are often necessary to get pragmatic reasoning off the ground (Chapter 2). Silence, a grunt,
or an utterance in a language the hearer does not speak arguably seldom constrain the space of possible meanings sufficiently to ensure that communication succeeds. Moreover, systematic pragmatic inferences, such as scalar implicatures, build on semantic constraints and their relationship to one another. As put by Searle (1971:190), often “meaning something when one says something is more than just contingently related to what the sentence means in the language one is speaking.”

Second, our analysis suggests that there are conditions under which more constraining semantics emerge as natural and stable evolutionary outcomes. This can happen when the context of interaction is static, leaving no evolutionary grip for ad hoc pragmatic inferences to latch on underspecified semantics (Chapter 5); or it can happen when rationality is low (Chapter 4 and 5). In either case semantic specialization wins over the potential for refinement that pragmatics fosters.

In the case of a static context, e.g., when there is a single context governed by a fixed distribution over states, populations may adopt functionally efficient semantic conventions that do not rely on pragmatics but are semantically well-tailored to the context. In other words, if there are no situations in which the flexibility that pragmatics enables for can be cashed out then leaving to pragmatics what (shared) semantics can do is either functionally disadvantageous; or, at best, a neutral trait (Chapter 3 and 5). Moreover, in this case semantics that are narrowly specialized to the context are also easier to acquire than those that harbor ambiguity (Chapter 5).

The other important case in which semantic precision may be favored over pragmatic recruitment is relative to agents’ rationality. Pragmatic inference involving mutual reasoning needs to be fueled by some degree of rationality. Less constraints on the semantic side ask more of reasoners: they not only need to learn the semantic conventions of their community but also need to appropriately deploy them pragmatically to achieve communicative goals. Less rational agents are accordingly better served with more constrained form-meaning associations that leave less room for uncertainty and misunderstanding. Reversely, less is often more if agents are rational (in tendency, see Chapter 4 and 5 for qualification).

Taking stock, we can see semantics as providing (near-)global constraints on form-meaning associations taken to be shared by a community. Pragmatics endows language users with the ability to refine upon them locally, depending on the context of interaction and on whom one interacts with (Chapter 3). Of course, for pragmatic language use to lead to successful coordination, the mechanisms through which semantic conventions are refined also need to be shared and mutually recognized. If the sophistication of agents is low or the environment is static enough for the distinction between global and local to collapse then semantics can take over most of the functions suggested above. Reversely, communication of ecologically rational agents in rich environments foments the kind of divisions of labor between semantics and pragmatics we see in natural language.
6.2. Change, Outcomes, and Factors of Influence

While these results may be intuitive after the fact, we showed that divisions of labor between semantics and pragmatics arise from complex interactions between (i) agents’ cognitive make-ups (signaling behavior or learning mechanisms), (ii) relevant pressures (functional pressure on efficient communication or learnability), and (iii) the context(s) in which communication takes place. The outcome of such interactions can effect linguistic change that is adopted by a population, but also to the coexistence of different divisions of labor (Chapter 4). The latter result is important as it highlights the fact that semantic conventions and pragmatic rules operating on them are unobservable by themselves. Language users and learners witness only the observable effects of their interaction. Different divisions of labor can therefore lead to largely indistinguishable overt signaling behavior and coexist.

6.2 Change, Outcomes, and Factors of Influence

Just as biological evolution, linguistic change has no foresight. If agents adapt and thereby optimize information transfer, they do so with respect to their interlocutors and the context of interaction in the present (Chapter 3; Pate and Goldwater 2015); not with regard to longer term optimizations of their language (use). That is to say that pervasive properties of natural language (use) are not products of explicit deliberation or design undertaken by their users. As already noted in the introduction, the behavior of an individual at a given time is consequently not necessarily informative about the effects that linguistic pressures have (had) on her language and behavior in longer time stretches.

In Section 2.2 we expanded on this issue from a methodological perspective. Among others, we argued that explanations of linguistic properties need be explicit about how relevant factors that may give rise to them interact. First, this is necessary to add force to the explanation of a linguistic property. An explanatory analysis should add to our understanding of the conditions under which a property comes to light or changes, and why this happens. Second, modeling the interaction of relevant factors explicitly is necessary because they can interact in non-trivial ways, rendering direct inference from factors to outcomes difficult, if not impossible. Framed more positively: a better understanding of linguistic properties is gained through the inspection of the interaction of factors such as individual-level behavior, the environment in which communication takes place, the communicative task at hand, population dynamics and transmission perturbations that affect how linguistic knowledge is passed on.

Analogous difficulties are faced in the opposite direction: if the interaction between language (use) and pressures that apply on it are non-trivial, then we are seldom justified to draw strong inferences from outcomes about the factors that may have caused them.

While well known, we raise these general issues because they easily creep into
evolutionary analysis. More so if it is seemingly intuitive. One illustrative case where there is growing interest in using evolutionary outcomes as diagnostics for underlying causes is found in the iterated learning literature. Recall that even weak inductive learning biases can have striking effects on an evolving linguistic system (Chapter 4 and 5). Much effort has accordingly been devoted to investigating what kind of biases there are. Some prominent examples are mutual exclusivity (Merriman et al. 1989, Clark 2009; see Chapter 5), simplicity (Chater and Vitányi 2003, Kirby et al. 2015; see Chapter 4), regularization (Hudson Kam and Newport 2005) and generalization (Smith 2011). If inductive biases can come to play such an important role, we might reasonably expect outcomes of iterated learning to show traces of the biases that shaped them. That is, we might expect “that systems of knowledge or behaviour [such as language and its properties] transmitted by iterated learning evolve to reflect the biases of individuals involved in transmission” (Kirby et al. 2014:110; see also, e.g., Kalish et al. 2007). As already argued in Chapter 5 in relation to Perfors and Navarro 2014 and rephrased above, it is nevertheless questionable how much we can learn about biases, or any other factors, from an outcome alone. Iterated learning, one may want to argue, presents a special case in this respect. The mathematical characterization of Griffiths and Kalish (2005; 2007) suggests that, under certain conditions, language evolution through iterated learning converges to the prior.\footnote{In a nutshell, the main conditions are that there is a transmission chain – not influenced by factors beyond learning itself, such as language use or the environment –, that every agent uses the same production and learning algorithms, that they all have the same prior, and that they sample from the posterior ($\gamma = 1$ in our notation; see Griffiths and Kalish 2005; 2007 for details).}

Accordingly, we may expect human experiments using iterated learning to not only show traces of but actually reveal which biases are at play (e.g., Jacoby and McDermott 2017). This idea is problematic without qualification. Learning and typology certainly influence each other. After all, learnability is a necessary condition for culturally transmitted properties to see the light of day. However, learning outcomes and typology are by no means faithful reflections of each other (Bowerman 2010), and, more often than not, “iterated learning is doing more than just revealing the prior biases of learners” (Cornish 2011:173), as discussed in Section 4.5. Additionally, other factors and forces than learning biases may also systematically perturb the transmission of linguistic knowledge and thereby contribute to the shaping of language. Beyond the role that functional pressure on efficient communication plays, we saw that state frequencies can also affect the iterated transmission of linguistic knowledge (Chapter 5; see also Perfors and Navarro 2014). Additionally, whether learners tend to maximize the posterior (Kirby et al. 2007), the size of the population from which learners receive their input as well as whether biases are heterogeneous (Ferdinand and Zuidema 2009) can, among many others, also influence whether outcomes come to reflect inductive biases faithfully.
Another source of transmission perturbation that we have neglected so far but deserves brief mention in relation to this discussion is noisy perception: agents’ imperfect perception of the world. The general idea is straightforward. If the world is not always perceived accurately, regular stochastic errors in the perception of states can lead teachers to produce utterances that deviate from their production behavior had they witnessed the state correctly. Similarly, learners may mistake utterances as applying to different states than the ones witnessed by the teacher who produced them. For instance, when learning the meaning of a vague adjective such as *tall* from utterances like “Jean is tall”, agents may have diverging representations of how tall Jean actually is, even if she is in a shared perceptual environment. Over time, this may lead to the emergence of certain linguistic properties, in this case vagueness, not for functional reasons nor because of an inductive bias, but solely due to perceptual factors.

In Brochhagen and Franke (2017), we looked at some effects that noisy perception can have on iterated learning. The three simple case studies we analyzed are reproduced in Appendix C. The finding relevant to this discussion is that, indeed, regularities in misperceptions of states can have striking and possibly explanatory effects on language evolution. Such misperceptions can lead to biases of inferring the “wrong” teacher type if noise makes some types err in a way that resembles the noiseless behavior of other types. That is, such an environmental factor can, in principle, induce transmission perturbations that look as if there was a cognitive bias in favor of a particular type, simply because that type better explains the noisy behavior.

We mention noisy perception to underscore the issue raised by the relation between linguistic outcomes and their causes. If our arguments in the past chapters and the results that followed from them are on the right track, then actual communication and the environment in which it takes place can play non-negligible roles in shaping a linguistic outcome. Reasoning on the basis of a subset of factors will deliver correct explanations only if we accurately identified the ones that are relevant to the phenomenon at hand. Taken together with the difficulty of disentangling the effects that different factors have on a complex evolving system such as language, our general methodological takeaway is that a pluralistic stance needs to be adopted. What is needed are models that allow us to ask whether linguistic phenomena are due to learning (biases), environmental factors, functional pressure, or interactions thereof. The models we proposed in this investigation allow us to do exactly this. The application of the replicator-mutator dynamic in Chapter 4 can tease apart functional pressure and effects of iterated learning; its variant in Chapter 5 allows for the analysis of the effects that different state frequencies have on communication and learning; and the noisy iterated Bayesian learning model in Appendix C is a neutral model of cultural evolution that appeals to neither functional competition nor differential learnability among types (see also Reali and Griffiths 2009). As showcased throughout this investigation, this family of models is well compatible with probabilistic models of language use.
at the individual level, or other formalisms of linguistic choice for that matter. This speaks to their applicability to a wide-range of questions concerning natural language, its use, and its transmission. This investigation applied them to novel questions about the relationship between semantics and pragmatics, delivering some, if modest, answers.