

SELECTION DYNAMICS IN LANGUAGE FORM AND LANGUAGE MEANING

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This paper describes evolutionary dynamics in language and presents a genetic framework of language akin to those of Croft (2000) and Mufwene (2001), where language is a complex system that inhabits, interacts with and evolves in communities of human speakers. The novelty of the present framework resides in the separation between form (phonology and syntax) and meaning (semantics), which are described as two different selection systems, connected by symbolic association and by probabilistic encoding of information.

1. Selection systems

General frameworks for complex adaptive systems, or selection systems (Gell-Mann, 1994; Hull, Langman & Glenn, 2001) fit systems as diverse as biology, immunology, the history of science, and language. *Selection* consists of iterated cycles of replication, variation and adaptation so structured that adaptation causes replication to be differential. *Replication* involves the (mostly faithful) iteration of the information contained in *replicators* (also called schemata and vehicles), which encodes the structure of the *interactors*. The principle of *variation* says that selection needs variants of the replicators to select from. These variants encode adaptations to the environment. *Adaptation* refers (a) to the effect of the developmental pressures on the replicators that affect development of the interactor and (b) to the effects of the environmental pressures on the interactors that affect replication.

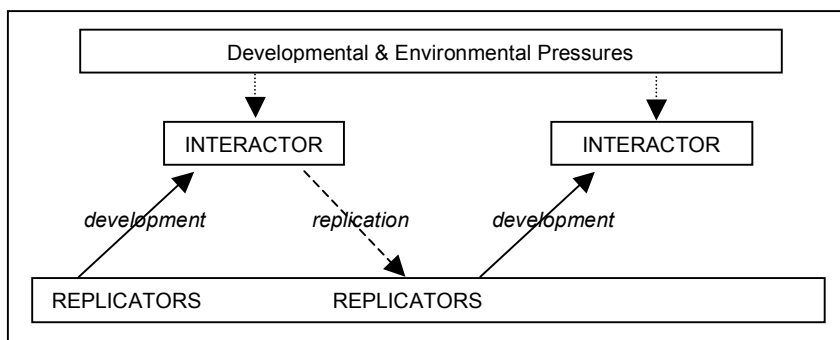


Figure 1. Elements and mechanisms of a selection system.

As shown schematically in Figure 1, during development, the information contained in the replicators unfolds to produce an interactor. Normal replication results in copies of the same replicators being produced into the replicator pool.

I propose that there are two instantiations of this selection system in language, one related to phonology and syntax (PS) and another one related to semantics. In the PS system, the interactor is a speaker's ability to process phonology and syntax (PS) in his or her native language, specifically the set of learned PS concept-to-form mappings and the replicators are tokens of PS use in speech. In the PS system, semantics plays the role of an environmental pressure providing concepts to be mapped onto forms by the interactor -the PS interactor is adapted to concepts.

In the semantic system, the interactors are linguistic utterances and the replicators are the concepts that exist in speakers' brains and that are replicated, or copied, in other speakers' brains by means of the interactors. Here, the PS system is an environmental factor determining how concepts are encoded into and decoded from utterances. It is important to emphasize that while PS replicators are found in speech, semantic replicators exist in speakers' brains (and while PS interactors reside in the brain, semantic interactors exist as speech).

The asymmetry between form and meaning in language has been pointed out by several authors (e.g. Tomasello, 2003; Davidson, 2003) and several facts support the evolutionary distinction between PS and semantics. One is the timescale of their evolution: PS patterns of change are slower and more systematic than semantic ones, for instance change in one sound induces change in the rest of the phonological space over decades, which has led to systematic sound change patterns informing comparative method language phylogenetic classifications. PS patterns of change seem to be, then, language-internal. Semantic change, on the other hand, occurs much faster, with words changing meaning, new words being introduced in a language, and replacing old ones all the time, without systematic effects on the lexicon (Aitchison 2001), reflecting the interaction of humans with their environment.

According to the proposed framework, PS is learned through long-term, repeated exposure to a probabilistically structured input, whereas semantics (symbolic associations) is learned through other mechanisms, which may only involve a single exposure to a word. Evidence of the possibility of learning PS without semantics include Pierrehumbert (2003) and Monaghan, Chater and Christiansen (2005)'s studies showing that exposure to language-internal probabilistic cues such as acoustic and/or distributional patterns can lead to learning phonological and syntactic categories, respectively. Also, musical syntax learning relies on input-internal probabilistic patterns - and it seems to be processed in the same neural areas as auditory language comprehension (Maess et al., 2001). Cultural learning of birdsong syntax in oscines relies on song-internal cues from tutors (Beecher & Brenowitz, 2005). Patients suffering from

fluent aphasia can produce syntactically complex speech, but their processing of meaning is impaired.

In contrast, symbolic association can be learnt without language-internal probabilistic cues: apes are able to learn symbolic associations, but there is no evidence that they need to be sensitive to language-internal probabilistic cues or that they using PS-structured language forms (Terrace et al., 1979; Savage-Rumbaugh, 1993). Learning of naming in humans seems to depend on consistent cooccurrence of words with objects or actions in the environment as well as other language-external cues such as social ones (Hollich et al., 2000). And patients of Broca's aphasia have difficulties with sounds and syntax, but their comprehension (and therefore, their word form-meaning associations) remains relatively intact.

PS and semantics are, then, evolutionarily independent and show different evolutionary timescales and so can arguably be treated as a separate selection system. In the proposed framework, however, a semantic system is assumed to pre-date and to be a pre-requisite for human language emergence, and the two systems are intimately linked in a symbiotic relationship where each system provides necessary environmental requirements for the other.

2. Phonology and syntax

This section deals with an instantiation of the general selection system in the case of PS. Figure 2 illustrates this instantiation. Following Croft (2000) and Mufwene (2001), the level of the species is the language spoken in a community.

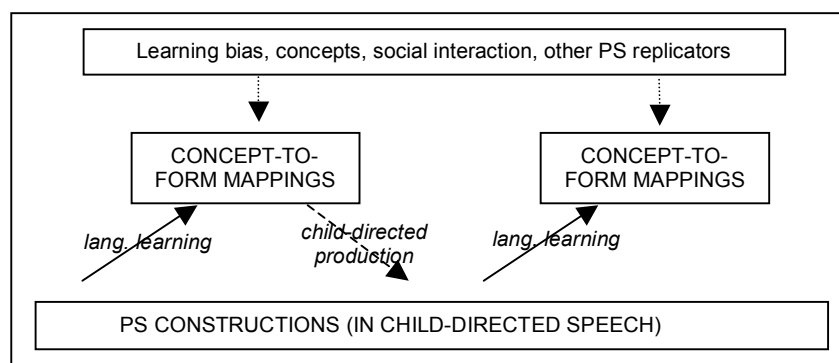


Figure 2. Dynamics of the Phonology and Syntax selection system.

The *interactors* are individual speakers' PS capacities, or the set of concept-to-form mappings that a speaker has learned. These interactors develop from the interaction between the PS replicators present in the speech that speakers have been exposed to and pressures such as the learning bias, the structure of

concepts and social factors. We can describe the interactor as the PS structure that develops around concepts to form a multi-level lexicon. PS contributes to that lexicon several layers of organisation, such as phonological, morphological and syntactic categories. It can also be described as symbolic association: the links or mappings between concepts and forms. The *replicators* are PS constructions found in speech, particularly in child-directed speech. Examples of replicators include sounds (phonetic realisations) and sound combinations that have a frequency or a conditional dependency, for instance frequent vs. infrequent phoneme combinations or long-distance sound combinations marking agreement.

As for the encoding of PS replicator information, while in biology genetic information is encoded digitally in the chemically (and temporally) stable sequence of bases in DNA molecules, in the case of PS, replicators are encoded statistically in the more imprecise and temporally unstable speech stream. Unlike spatial DNA, speech unfolds over time, making it impossible to go back to retrieve a piece of information obscured by noise. Statistical encoding solves this by providing information that becomes increasingly robust as the input sample grows larger. Moreover, statistical encoding is an adaptation to the developmental pressure on PS replicators to be learned by humans, and matches human probabilistic learning abilities. Mechanisms for *variation* in the replicator pool include language contact (Mufwene, 2001) and Lass's (1990) linguistic exaptation. Mechanisms for propagation of variation include social and prestige factors (Labov, 1972; Croft, 2000).

In PS *replication* the interactors copy their input replicators in their output speech, and this speech contributes to the development of a new PS interactor (in the brain of a new child). In this system, the interactor begins to "reproduce" before its development is complete - children begin to speak before they have a stable PS interactor. Notwithstanding the effects of horizontal transmission of unconventional speech from child to child, I assume that they are normally reversed by a larger amount of conventional speech from adults. Also, speakers continue to be exposed to speech over their whole life, however, I assume that, the PS system develops during the sensitive period for language learning in humans and reproduces during child-directed speech, when a suitable stimulus (an infant) elicits speech containing replicators that are optimally fitted to the learning biases. One prediction of this framework to be tested empirically is that, because the learning bias does not change over the cultural timescale, the PS of child-directed speech should show less variation between speakers both synchronically and diachronically than adult-directed speech, where other more labile pressures such as communication or prestige factors are at play.

A *developmental pressure* affecting PS interactors and acting on the structure of PS replicators in speech is the learning bias, that is assumed to include a sensitivity to probabilistic PS patterns in speech (for a mechanism underlying such sensitivity see e.g. Maye, Werker & Gerken, 2002). This

pressure is usually masked in a situation of normal language transmission because the structure of speech is already adapted to it, and for a given speaker, the PS replicators in her output speech are the same as those of her input speech. Only in situations of strong language contact, or during language emergence, when the input to a new generation is not already adapted to the learning bias, is the pressure's effect unmasked. (This can be studied by examining the outcome of replication when the input contains two different probabilistic replicators, for instance by adding mixed stimuli to Maye, Werker and Gerken's 2002 experiments, or by revisiting data from pidgins and creoles).

3. Semantics

An *environmental pressure* affecting PS replication and acting on PS interactors is the structure of the concepts. I argue that semantics is itself a selection system (see Figure 3).

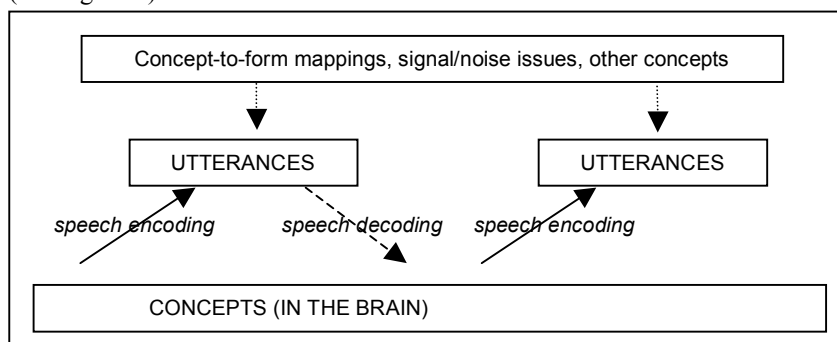


Figure 3. Dynamics of the Semantics selection system.

Moreover, I propose a symbiotic relationship between the PS and the semantic systems as each provides the environmental conditions necessary for the existence of the other.

In the semantic system, the *interactors* are speech utterances. Utterances develop from the interaction between pressures like the speaker's PS skill, the information capacity of the acoustic channel in the face of potential noise, and semantic replicators. The semantic *replicators* are concepts, specifically those transmissible through language, that exist in people's brains. They include the concepts behind words and constructions, and the relationships between them. *Variation* in the concept pool may arise for instance from contact between concepts in the brain.

Replication, or transmission of one concept from one brain to another, is mediated by the utterance. The encoding (development) of an utterance and its subsequent decoding (replication of the concept) is carried out thanks to the PS interactor's mappings between concepts and forms. So the PS interactor is an

environmental pressure affecting the semantic system. This illustrates the symbiotic relationship between the PS and the semantic systems, where each poses *pressures* on the other. Concepts can only be mapped onto utterances (semantic system) thanks to the PS interactor (the concepts-to-forms mappings, or symbolic association). Indeed, the human PS interactor would not exist in the first place if there were no concepts (semantic replicators) to be mapped onto forms. Additionally, there is a relationship of the PS-plus-semantics symbiotic system and its human hosts: language is an adaptation that increases human fitness, so natural selection favours the genes that provide language with the neural substrate it needs.

There are two meeting points between the PS and the semantic selection systems. In the *brain*, the concept-to-form mappings (the PS interactor) are adapted to the concepts that need to be communicated, and to how they are structured. This adaptation is embodied in symbolic association. If the PS system were not able to capture concepts, it would not increase human fitness and would not have been favoured by natural selection. In *speech*, utterances (as semantic interactors) need to be adapted to their substrate, namely the (probabilistically encoded) structure of the PS replicators, which is necessary for the easy acquisition of PS by humans. Again, if the PS replicators' encoding did not match human infants' learning biases, the PS system could not be replicated or transmitted over human generations.

4. Conclusion

I have presented a novel genetic framework to study the evolutionary dynamics of language. In this framework, phonology and syntax on the one hand and semantics on the other are best understood as two separate selection systems with different evolutionary dynamics and timescales, yet intimately intertwined in a symbiotic relationship where each system provides environmental factors that are crucial to the other system's existence. This symbiosis between PS and semantics is based on symbolic association and probabilistic encoding. Considering the two systems as separate in this way helps to explain the mutual influences between form and meaning in language and formalizes aspects of the relationships between linguistic representations in the brain and in speech. Finally, the proposed framework generates a prediction that can be tested empirically, namely the reduced PS-replicator variation in child-directed speech with respect to adult-directed speech.

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