EVOLUTIONARY SUPPORT FOR A PROCEDURAL SEMANTICS FOR GENERALISED QUANTIFIERS

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1. Setting the scene

An extensional semantics gives the denotation of expressions as sets of objects, relations between objects, relations between sets of objects, and so on. A predicate is true of an object iff that object appears in the set that is the denotation of the predicate. In a procedural semantics, on the other hand, a predicate denotes a procedure which when given an object determines whether the predicate applies to the object (Benthem & Eijck, 1982).

Extensional semantics has given a coherent and compositional account of the meanings of many determiners ("all", "some", "few") as relations between sets of objects. Semantically speaking, the theory of generalised quantifiers (see for instance Keenan and Westerståhl (1997)) gives a very tidy account meanings of Det+NP expressions (such as "all men", "some tidy bedrooms") as well as many others that occur in the same syntactic environment (some syntactically quite complex, for instance "half the schoolchildren, all the teachers except Bob, and the neighbour's cat"). However the extensional semantics for generalised quantifiers, while capable of describing most of the determiners we see in natural language, also allows the possibility of a vast number of determiners that are not attested. (A determiner is analysed as a relation between sets of objects, so if only three objects exist in the domain then there are $2^{2^4} = 65536$ possible determiner denotations.) Many properties are known that restrict this space (e.g., permutation-invariance, which makes the truth value of a determiner dependant only on the sizes of the sets involved, not the identities of their elements.).

Other properties have been identified as "trends" or "weak universals" (Keenan & Westerståhl, 1997); the vast majority of determiners expressed as simple lexical items are upwards monotonic ("All Englishmen are dirty scoundrels" implies "All Englishmen are scoundrels") a small number are downwards monotonic ("Few Englishmen are knaves" implies "Few Englishmen are cowardly knaves") and very few indeed are not monotonic at all.

2. Evolutionary contribution

Neither extensional nor procedural semantics on their own can explain these trends. However using evolutionary reasoning we can approximate these results using a particular model of procedural semantics based on deterministic finite automata (DFAs; see Benthem, 1987). Monotonicity of quantifiers corresponds to a natural simplicity bias on automata (the denotations of quantifiers). An iterated learning model incorporating this learning bias[a] then explains both a preference for monotone quantifiers and the presence of non-monotone ones (since certain non-monotone quantifiers *can* be learned, given sufficient examples).

Furthermore, an extensional semantics is totally unable to account for the bias towards *upward* monotonicity, while the same learning bias within a procedural semantics can do so. Indeed, the simplicity bias also predicts some of the non-monotonic and downward monotonic quantifiers that are indeed attested ("no", some small exact numbers).[b]

Finally, the iterated learning perspective provides an explanation for a gap between the semantics and the pragmatics of "some" (taken pragmatically to mean "some but not all"). The question is not how such a pragmatic meaning arises, but why it is not fossilised into semantic meaning by the learning process. In this model the upward monotonic DFA corresponding to the semantics is easier to learn than the DFA representing the pragmatic meaning; acquisition of one or the other meaning depends both on how frequently infelicitous examples are provided ("some" used when "all" would also be appropriate) and on the number of examples given (the 'learning bottleneck' of the iterated learning paradigm).

References

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[a] Formally speaking, I use the Minimum Description Length principle (see for example Grünwald, 2005) to drive a DFA learning algorithm using greedy state-merging.

[b] The precise prediction depends on parameter settings of the model, which is unfortunately too crude for a match to real usage to have much independant meaning.