THE EMERGENCE OF ARGUMENT MARKING

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The emergence of grammatical role marking and person indexing is modeled in a cognitively motivated, multi-agent computer simulation of language change. As the forms of frequently used words erode and their meanings desemanticize, they develop into maximally short forms with maximally general meanings, which eventually can no longer be used as referring expressions. Using an artificial language that initially does not have any grammatical argument-marking strategy whatsoever, it can be shown how lexical ad hoc solutions for event-role ambiguity develop into case marking, while referring expressions develop into verb indexes.

1. Introduction

Consider example (1) from Turkish. As in many other languages (cf. Siewierska & Bakker, 2009), the verb indexes features of its external argument and the internal argument is marked for its role by a case marker (by means of *-um* and *-i*, respectively).[a] Unless word order were used, without these markers it would be unclear what the argument structure of the sentence is (i.e., who is loving whom).

(1) *Ben sen-i seviyor-um*
I you-ACC love.PROG-1SG
'*I* love you.' Turkish (Derya Demircay, p.c.)

In this paper it will be shown how such argument marking can result from cultural evolution (Deacon, 1997; Smith & Kirby, 2008; Christiansen & Chater, 2008). That is, it is not part of whatever constitutes our inherent language capacity (cf. Pinker & Bloom, 1990; Müller, 2002), but emerges in language as a product of our behavior instead. Rather than reconstructing the developmental history of natural-language markers (cf. e.g. Heine & Kuteva, 2002, 2007), the grammaticalization process will be studied in a computer simulation of artificial-language change. The main hypothesis is that grammaticalization does not merely explain the development and renewal of constructions within an existing system, but can also account for the emergence of the argument-marking system *itself*.

[a] Abbreviations: *1, 2, 3* first, second, third person, *A* actor, ACC accusative, PROG progressive, SG singular, *U* undergoer, *V* verb.

Two relevant studies that should be mentioned in this context are van Trijp (2012) and Beuls and Steels (2013). Both studies simulate the development of grammar in terms of cultural evolution and come to very similar conclusions. For reasons of space, only the important differences will be mentioned here. First, both of these studies are implemented in *fluid construction grammar* (Steels, 2011). This is comforting, in fact, as the different software implementations merely corroborate the mutual findings. With respect to content, Beuls and Steels (2013) are concerned with internal agreement, i.e. the marking of lexical items as belonging to the *same* constituent. The present study, instead, is concerned with marking the relationship *between* constituents (by means of case marking or *external* agreement; cf. Lehmann 1988 for discussion). Here too it will be important to combine elements into constituents, but for this a grouping principle is assumed that stays active throughout all generations (cf. Section 2.5). Van Trijp (2012) does simulate the evolution of argument marking. However, the grammaticalization process that is fundamental to the present proposal is simplified in his study. For example, whereas he assumes a *case strategy* from which eventually a conventional *case system* develops, this strategy is not provided in advance here. Instead, the recruitment and development of markers are an important part of the simulation.

In Section 2, the model will be introduced. Section 3 very briefly discusses two important mechanisms of grammaticalization and the way in which these are implemented. Section 4 shows the results, which are discussed in Section 5.

2. Modeling event communication

WDWTW (for *who does what to whom*) is a cognitively motivated multi-agent model developed by the author in which event communication and the emergence of grammar can be simulated.[b] A population of agents starts out with a shared lexicon of referring expressions only and a "language-ready" brain, which basically means that the agents have a desire for communicative success and are capable of joint attention (Tomasello, 2003; Arbib, 2015).

2.1. *General procedure*

Agents communicate about automatically generated events in their virtual world. The speaker has to find an adequate wording for a target event that is sufficiently distinctive given the situational context in which other events are ongoing too (i.e., if there are similar distractor objects, referential expressions have to be more specific). This crucially involves making clear the distribution of predicate roles over the event participants in the communicated event (e.g., if there's a hitting

[b] A user-friendly version is still being developed and will be distributed via the CRAN archive (R Core Team, 2014). In the mean-time, the codes are available from the author upon request.

event, who does the hitting and who is being hit). If the hearer correctly identifies the event the speaker is talking about, the agents mark the successful usage of the words that constitute the utterance, remember the exact meaning for which the words were used, and next either switch turns to go on with their conversation or end it, after which two new agents are randomly selected for a new conversation (cf. Steels' 1997 *language games*).

After some time, agents procreate, at which point their offspring inherit their lexicon with minor modifications to the meanings of those words that have not been used until then, and without the usage history. This they develop themselves, partly by interacting with their parents, which die a bit later. As the development and maintenance of a conventional lexicon are not of primary concern here and have been successfully modeled elsewhere moreover (cf. e.g. Hurford, 1989; Hutchins & Hazlehurst, 1995; Steels, 1997, and Kirby, 2000), the present simplifications seem warranted.

2.2. *Representation of meaning*

The agents of WDWTW live in a very abstract virtual world to which none of our concepts apply. For example 'hitting', which was used for illustration above, does not mean anything to them. Still, it is possible to provide the agents with a mental lexicon that is similarly organized as ours, for present purposes at least.

According to Wierzbicka (1996), all natural-language concepts can be decomposed into meaning primitives such a CONCRETE, HUMAN, MALE, etc. (cf. e.g. also Guiraud, 1968). Similarly, in a way, Gärdenfors (2000) argues that concepts are sets of values on different meaning dimensions. Thus, we can think of a cat as something that is time-stable, concrete, alive, four-legged, tailed, etc. Abstracting away from the quality of the dimensions that organize our mental lexicon, concepts can be modeled as vectors specifying values on a number of numerical meaning dimensions: For example, instead of our animacy dimension with the values animate and inanimate, agents may have a binary dimension with values 0 and 1. By default, the object lexicon of the agents is organized along nine such abstract dimensions, the first five of which are binary, the next four make a nine-way distinction (but this and virtually all other settings of the model can be manipulated). The increasing distinctionality is loosely motivated by the fact that nodes higher-up in a taxonomy bisect the world in major types (e.g. actions vs things, concrete vs abstract; i.e. mostly the distinctions grammar cares about), whereas nodes further down use a more fine-grained classification (e.g., types of animal).

Verbs are similarly specified, with the addition of one or two *perspectival* roles, viz. the *external* and, in case of a two-place predicate, *internal argument* role.[c] These are characterized using vector representations too. And as for nouns, one could think of each meaning dimension as one that is grammatically relevant

[c]The external argument is the participant whose perspective on the event is taken by the corre-

in natural language (±instigating, ±intentional, ±affected, etc.), although such notions have no meaning in the model. Values on external dimensions are on average higher than values on internal ones to implement prominence preferences known from natural language (subjects are preferably human, volitional, in control, etc.; cf. Dowty, 1991).

The forms and meanings of 999 nouns and 499 verbs are randomly generated. The two nouns that have the highest values across all dimensions are used for first and second person reference.

2.3. *Event generation*

Agents find themselves in situations in which a differing number of automatically generated events is going on. One of the events is the target event, which is the one the hearer should single out on the basis of the speaker's description. The other events provide the distractor objects and actions.

Events are combinations of two or three vectors: one for the event action, one for the more active event participant (the *actor*), and, in case of a transitive event, one for the less active participant (the *undergoer*; after Van Valin, 1999). The participants that figure in the situation are dependent on the *common ground* of the speech participants, which they develop while they talk. The common ground consists of the things that have been discussed in the current conversation. Initially, it consists of the speech participants themselves and (the meanings of) three randomly selected lexical entries. Other objects have a small probability of entering the scene. Elements from the common ground are assigned a number of external roles (in which the same element may figure in multiple events). Next, on the basis of these elements' propensities and affordances, action predicates are sampled from the mental lexicon (using a real-world example, dogs more often found running than flying). Finally, for each two-place predicate that is selected, a second argument is sampled from the mental lexicon on the basis of its role-qualifications for the internal role. The degree of confirmation to such role expectations is set by model parameter. In the present settings roughly one third of the objects will never be combined with a given role and most are only incidentally so. Only the top 5% of most qualified objects is used with a reasonable frequency.

Note that the events that are thus generated consist of instantiated meaning representations (i.e., the mind determines what happens). This is of course not very realistic, as in the real world, the concepts we have are generalizations of the things we perceive. But we can exploit this connection the other way around with the same net result (adding some random noise to the meanings that constitute the events): Both in reality and in the model, there is considerable overlap in what

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sponding verb. For example, the same event in which a book first belongs to John and later to Mary can be conceptualized as *John sold a book to Mary* taking the perspective of John or as *Mary bought a book from John*, with Mary as the external argument.

people/agents think and what they experience.

2.4. *Word selection, role marking and person indexing*

In order to communicate an event, the speaker matches what it perceives to the meaning representations in its mental lexicon. The match between the referents in the virtual-world and the lexical semantics of the words available in the lexicon of the agent is evaluated by calculating the average (absolute) difference per meaning dimension, and subtracting this from 1, in which dimensions that are not specified are ignored. A score of 1 shows a perfect match, a 0 shows maximal deviation. The referential expressions that the speaker selects need not have a perfect semantic match, they only have to be sufficiently distinctive given the distractor objects in the situational context (cf. Grice, 1975). In principle, however, words do have to agree in person with their referents (e.g., a first-person referent should be referred to with a first-person word).

The order in which words are considered for expression does not only depend on their semantic match. Also semantic specificity and usage frequency play a role (Balota & Chumbley, 1985). More frequent and general words with a comparable match are ranked before less frequent and general ones. The first word that is found sufficiently distinctive given the context is selected for production.

In the absence of grammatical argument-marking strategies, agents initially have to use lexical ad hoc solutions to make clear who does what to whom. If the role distribution follows from the semantics of the ingredients for free, nothing extra needs to be done (e.g. the abstract equivalent of a reading event in which a book and a man are involved). If not, an agent has to add a word specifying the predicate role of one of the participants to make it clear. For example, to say that a man saw a woman it could say *woman man looker see*.

For sake of ease, a correspondence is assumed between the dimensions specifying the nouns and those of the verb roles. Thus, the same vector-comparison method determining the match between a word and its referent can be used to establish the role qualification of an argument (its *typing* score, after Aristar, 1997). If the typing score of a participant for its intended role is not significantly higher than the one of the other participant for this role, the role does not follow automatically. The resulting ambiguity only needs to be resolved at one of the arguments, as the role of the other one follows automatically. As the example with *looker* shows, this initially involves lexical expressions that specify idiosyncratic predicate roles. Once more grammatical expressions develop, these can be used instead (cf. Section 3).

Whereas role marking thus serves a clear communicative goal, the reasons for indexing person features are much less obvious. Although some have claimed an identification function (cf. Lehmann, 1995), possibly with a corresponding processing gain (Hawkins, 2002), it might well be nothing but historical junk (although it may be too stable for that; cf. Dahl, 1995, 269; Collin, 2015). Whatever

its synchronic merits, its presence too can be explained as a result of grammaticalization.

2.5. *Grouping, event identification, and representation updating*

Adding role markers requires the hearer to correctly group together arguments and their markers (for the speaker could also have used *woman man looker see* to say that someone saw a manly woman). In the model, all possible groupings are fully explored, after which the interpretation with matches best with any of the events in the situation is considered the intended one, and the corresponding event is assumed to be the target event. If the target event is correctly identified, the frequency scores and usage histories of the words in the utterance are updated.

3. Development of argument marking

In the course of time, words may grammaticalize. In natural language, grammaticalization is a gradual, diachronic process in which lexical items become less autonomous in various ways (Hopper & Traugott, 2003; Heine & Kuteva, 2007; Haspelmath, 1998). Two important mechanisms in this process are *erosion* (some forms being pronounced sloppily and eventually becoming represented accordingly) and *desemanticization* (some meanings becoming more general as a function of the different contexts in which they are used). If a meaning becomes more general, it can be used in even more contexts, and if a form becomes too short to stand on its own, it is suffixed to its host (Bybee, 1985). From this, it straightforwardly follows that popular lexical role markers may develop into case markers.

The development of indexing requires an extra ingredient. According to Ariel, referential pronouns for highly accessible referents can get reduced to the extent that they are no longer perceived as referring expressions, because of which more pronounced argument copies have to be added. As local persons are consistently highly accessible (Ariel, 1999, 221), this process mostly involves the speaker and addressee. A third-person example is given in (2). In standard French, the pronouns *il* 'he' and *elle* 'she' are referential expressions that make a gender distinction (e.g., *La jeune fille est venue hier soir. Elle est danseuse.* 'The girl came yesterday evening. She is a dancer.'); in non-standard French, *il* has become an agreement marker that no longer refers nor distinguishes gender.

(2) *Ma femme il est venu.*
my:F wife AGR is come
'My wife has come.' French (Heine & Kuteva, 2002, 234)

In the model, all lexical items (including those for local persons) initially are fully specified semantically and have equally long forms of expression. Words that are frequent or predictable (because of the context or prior usage) are pronounced sloppily, which is instantiated as going back in the alphabet for the last

letter of a form and deleting it altogether if this is no longer possible. Sloppy pronunciation does not lead to a change of lexical representation for the speaker. But if the hearer is still unsure about the form of a word because it has not used it sufficiently frequently yet, it will adapt its representation on the basis of what it hears (Nettle, 1999). Desemanticization is modeled by progressively removing meaning dimensions along which most variation is attested in the usage history. Deletion takes place only after certain frequency thresholds have been reached. For a first dimension to be removed, a word has to be used in 1% of the utterances, for the final dimension it has to be used in 50%.

4. Results

To test the hypothesis that argument-marking systems develop from grammaticalization, two lineages are tested. In the first, desemanticization and erosion do not apply, in the second they do. Examples of typical utterances after 44 generations are given in (3). As can be seen in (3-a), in the absence of grammaticalization, speakers still use lexical ad hoc solutions (as the glossing of *lusolal* means to reflect) and indexing does not develop. In the lineage in which grammaticalization does apply, agents begin in the same way, as shown in (3-b) (word-order variation is random and can be ignored). Over time, however, utterances very similar to the Turkish example in (1) emerge. The marker *-tu* in (3-c) originated as the noun *tusedul*. Because of erosion, it now has to be suffixed to its host, and because of desemanticization, it lost three of its meaning representations, hence its gloss as a general undergoer marker. Note that the etymological source of the second-person index *-da* in (3-c) is also used in (3-b), where it still is fully specified and of maximal length. After 44 generations, it grammaticalized to the degree that it can no longer refer as a result of which a new word with more expressive power has to be recruited.

(3) a. *nuriret unudede amoduse lusolal*
1 unudede.V 2 unudeder
'You unudede me.' (Lineage 1, 44th generation)

b. *daniset namimin sulalet inenono*
2 naminin.V 1 namininee
'You naminin me.' (Lineage 2, first generation)

c. *otosa namimin-da su-tu*
2 naminin.V-2 1-U
'You naminin me.' (Lineage 2, 44th generation)

5. Discussion: results, implications and limitations

Using a cognitively motivated computer simulation of language change, it was shown how the emergence of grammatical argument marking can be modeled as a result of cultural evolution.

Case markers straightforwardly develop as a result of grammaticalization. As relative frequency plays a role in word activation, lexical items that have previously been used for role disambiguation are more likely to be considered again. As there are maximally only two roles to be kept apart, namely the external and internal one, the role marker often need not be very specific. Thus, a previously used marker is often found good enough, as a result of which its frequency of usage increases further, as well as the variation of its usage contexts. Because of the former, its form is likely to erode; because of the latter, its meaning is likely to bleach. Eventually, as illustrated in (3-c), this may lead to a the model equivalent of a case marker (Lestrade, 2010): a maximally short form with a minimal number of meaning dimensions specified that marks its host for its function or type of dependence.

Although the synchronic functionality of indexing is debated, its development too can easily be modeled, especially for local persons. Recall that speech participants are part of the common ground by default and therefore figure in many events. Because of the resulting frequent and varied usage, words referring to local persons are prone to erosion and desemanticization. But differently from role markers, which do not have a referential function, once the form of a referential expression becomes too short to refer properly, a more expressive copy has to be added (following the proposal of Ariel, 1999). As a result, erstwhile local pronouns end up indexing the person of their helpers.

Of course, whether these findings extend to argument marking in natural languages too depends on (the ecological validity of) the model implementation. Care was taken to include independently motivated subroutines only. Moreover, virtually all model assumptions are parameterized and can thus be tested independently. The most problematic assumption at present seems to be the way in which words are selected from the mental lexicon, as we simply don't know yet how this works exactly. Also, language change involves more than just grammaticalization and grammaticalization involves more than erosion and desemanticization. But although the ecological validity of the model can thus be questioned, it still seems that only minimal assumptions about the initial linguistic system have to be made for an argument-marking system to develop.

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