THE EMERGENCE OF MORPHOSYNTACTIC CASE SYSTEMS

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Despite centuries of research, the origins of grammatical case are more mysterious than ever. This paper addresses some unanswered questions through language game experiments in which a multi-agent population self-organizes a morphosyntactic case system. The experiments show how the formal part of grammatical constructions may pressure such emergent systems to become more economical.

1. Introduction

Case has long been considered as a universal category, but the abundance of counter evidence from diachronic studies and linguistic typology has forced linguists to go back to the drawing board. Many scholars nowadays agree that case is constructed in some way (Croft, 2001), so any evolutionary account of case has to explain *why* and *how* a speech population may succeed in doing so.

The *why* question seems obvious at first glance: to mark *event structure* (i.e. the relations between events and their participants). However, not all languages have evolved a case system but instead exploit a different strategy for marking event structure, such as word order (English) or verbal marking (Swahili). There are also more radical languages such as Riau Indonesian (Gil, 2008) that hardly ever indicate 'who did what to whom' and leave it up to the listener to infer the correct meaning from the context. If event structure can be communicated successfully without overt marking, the *why* question already becomes less obvious. Consequently, a number of recent studies seek answers in innate biases and function-independent iterated learning (see for instance Moy, 2006), but none of these attempts have shown how a case system may evolve.

A different answer, suggested and demonstrated by Steels (2004), is that case is *culturally* selected for communication because it reduces the cognitive effort that a listener needs for interpretation. Building on these first experiments, earlier Evolang contributions have shown how a multi-agent population can self-organize a case system and repurpose it if it starts to decay (van Trijp, 2008, 2010). The case systems that evolved in this work exhibited a degree of polysemy and grammatical complexity that go well beyond the one-to-one mappings that are typically

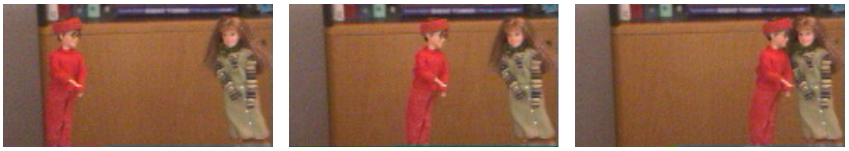

Figure 1. In the experiments, agents play language games in which they describe real-world events to each other. In this scene, one puppet is moving towards another one.

found in experiments on artificial language evolution, as can be gleaned from the following examples where *-tux* marks the actor of an event and *-pav* and *-my* behave like locative case markers (illative and elative):

(1) *Boy -tux move-inside house -pav*
boy case-12 entered house case-5
'The boy entered the house.'

(2) *Jack -my go-away Jill -tux*
Jack case-10 walk away from Jill case-12
'Jill walked away from the boy.'

Despite promising results, a number of important issues remain. First, all case systems that evolved in these experiments were semantically much more coherent than the abstract case systems found in natural languages. For example, the nominative case in German marks the Patient of an event in passive constructions rather than the Agent as in active constructions. Secondly, while the experiments successfully operationalized the *language strategy* that allows speakers to establish a case system, it is still an open question how such a strategy itself originates through cultural evolution.

This paper tackles these two issues through language game experiments that explore a syntactic route to the development of case. Assuming that more 'economical' case systems have a selective advantage over costly ones (in the sense of required memory), the experiments show how the formal properties of an emergent system may cause a feedback loop that steers the linguistic behavior of language users in novel situations. This feedback loop is not caused by case-specific learning biases, but rather by general cognitive functions such as coercion.

2. Description Games

Case is explored by modelling situated dialogs (i.e. language games) in which case becomes relevant. Here, agents play *description games* with each other about real-world events (Steels, 2004) as depicted in Figure 1.

2.1. *Scenario of a Description Game*

Here is the scenario of the description game:

1. Assume a population N of agents and a world W consisting of a set of individual objects that participate in dynamic events (such as walking).
2. Each game, two agents are randomly selected from the population to act as the speaker and listener. Both agents observe the same scene and build a situation model (i.e. a factbase for their current experiences).
3. The speaker *conceptualizes* a meaning to express and *produces* an utterance for expressing that meaning.
4. The listener *parses* the utterance into a meaning and *interprets* it.
5. If the listener can interpret the meaning without conflicts with his situation model, he signals agreement and the game succeeds. If not, the game fails.

2.2. *Assumptions and Scaffolds*

The agents are no blank slates but start with some knowledge and capacities in order to focus on case. First, the agents are assumed to have joint attention and to build up the same situation model to exclude interferences from perceptual differences. Events are perceived through a camera (Steels, 2004). The agents are able to recognize 6 monovalent events (such as *appear*), 12 bivalent events (such as *grasp*) and 3 trivalent events (such as *give*). Each scene contains maximally 7 objects.

Events and objects are represented as a series of facts in the agent's situation model using a first order logic representation. A factbase for the scene in Figure 1 may look as follows: {∃ e, x, y: boy(x), girl(y), walk(e), walker(e, x), walk-destination(e, y)}, which includes an explicit representation of the participant roles 'walker' and 'walk-destination'. The meaning space contains 39 unique participant roles.

Each language game, the speaker conceptualizes a *participant frame*, which can be any combination of an event's participant roles. There are three possibilities in the current example: two frames only overtly express one participant (corresponding to *the boy is walking* and (someone) *is walking to the girl*) and one frame profiles the entire event (corresponding to *the boy is walking to the girl*). Meanings use the same logic representation but include variables (indicated by a question mark), which are bound to their referent in interpretation. The function of a case system is to mark which variables refer to the same object, as illustrated here for German (with the meanings in italics under the words):

(3)

Der Junge	ging		**zu dem** Mädchen.
boy(?x)	*walk(?ev)*		*girl(?y)*
?x = ?a	*walker(?ev, ?a)*	*walk-destination(?ev, ?b)*	*?y = ?b*

The agents, however, start without such a grammar and only know lexical constructions for events and objects. They would describe the scene in Figure 1 as *boy walk girl*, an associative utterance with free word order. Because no relations between events and participants are marked, the listener has to *infer* from the situation that the boy was the walker (*?x = ?a*) and that the girl was the destination (*?y = ?b*). Each inference is counted as one unit of *cognitive effort*.

3. Self-Organization of a Morphosyntactic Case System

Agents are equipped with a *language strategy* for inventing, adopting and aligning a case system. This section compares two morphosyntactic case strategies: an idiosyncratic strategy and a coercion strategy.

3.1. *Two Morphosyntactic Strategies for Case*

The innovation and adoption components of a strategy include *diagnostics* and *repairs* for detecting and solving problems during processing. The case strategies involve a particular configuration of the following diagnostic and repairs:

- *Diagnostic (both strategies)*: Detect whether cognitive effort is minimal during interpretation. If not, report a problem.
- *Repair 1 (both strategies)*: Invent (speaker) or adopt (listener) a new case.
- *Repair 2 (only coercion strategy)*: Try to reuse an existing case through coercion.

Innovation is speaker-based: the speaker always parses his own utterance to estimate its effect on the listener, and may detect a problem of cognitive effort for interpretion (*diagnostic 1*). If so, one solution for the problem for both the idiosyncratic and coercion strategy is to invent a new case (*Repair 1*). First, the agent makes an argument structure construction that assigns case to the proper participant (e.g. the boy). The agent also extends the verb's valence (which is initially empty) with the new case, stating for example that a 'walker' can be categorized as 'case-1'. Valence plays a crucial role during the build-up of the utterance structure in processing because it makes the utterance structure compatible with the argument structure construction, as illustrated in the left of Figure 2. The agent also invents a case marker, which serves as the surface form of the new case. Another solution, only accessible to agents equipped with the coercion strategy, is to *reuse* an existing case through coercion (*Repair 2*, the right in Figure 2). Coercion is a domain-independent operation that enables a grammatical construction to impose its constraints even if it violates the conventions of a language. A famous example is *Pat sneezed the napkin off the table* (Goldberg, 1995), in which the intransitive verb *sneeze* is coerced into a Caused-Motion frame. In the experiments, agents can coerce a case if it *discriminatory*, that is, if it cannot already be used for marking another role in the same event.

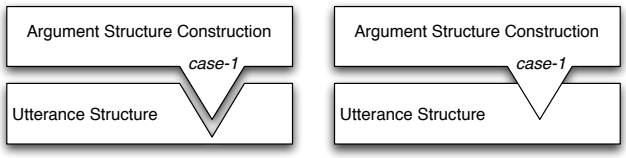

Figure 2. Left: routine processing of a case mapping. The utterance structure has been made compatible with a grammatical construction by the lexicon. Right: Despite a mismatch between the utterance structure and the grammatical construction, the construction can impose its structure through coercion.

Adopting a case is possible through the same diagnostic and repairs. The only difference is that the listener may observe an unknown case marker (*Repair 1*) that can be coupled to the problem of cognitive effort, or that he observes a known case marker in a new distribution (*Repair 2*). Technical details on processing and coercion can be found in Steels and van Trijp (2011).

Since variation is inevitable in a multi-agent population, the agents need a way to **align** their inventories with each other. Both strategies use a crude alignment strategy in which the listener always changes a verb's valence to be compatible with the last cases that the verb occurred with, thereby often overriding earlier, conflicting choices. The most frequent cases will thus be retained in the population, while the others are simply forgotten.

3.2. *Results for the Idiosyncratic Case Strategy*

Figure 3 shows the results for a population of 10 agents equipped with the idiosyncratic strategy. All values represent the mean of ten series of 10.000 language games; error bars indicate standard error. The X-axis shows the number of language games, the Y1-axis (left) shows variation and the running average of cognitive effort, and the Y2-axis (right) shows the number of cases.

The chart shows that the agents succeed in minimizing the **cognitive effort** they need for interpretation. Cognitive effort is calculated as a Simple Moving Average of the effort measured in the last 10 language games (see section 2.2). **Variation** measures whether all agents converge on the same meaning-to-form mappings. For example, if the most frequent case for a participant role is adopted by 40% of the population, variation for that meaning-to-form mapping is 60%. Population-wide variation averages over the individual variation scores. The chart shows that there is no variation in the beginning, as the agents all share the same lexical language. Variation then rises when the agents start inventing new cases and it reaches a maximum of about 50%, which means that only half of the agents have adopted the dominant cases in the population. However, variation then goes

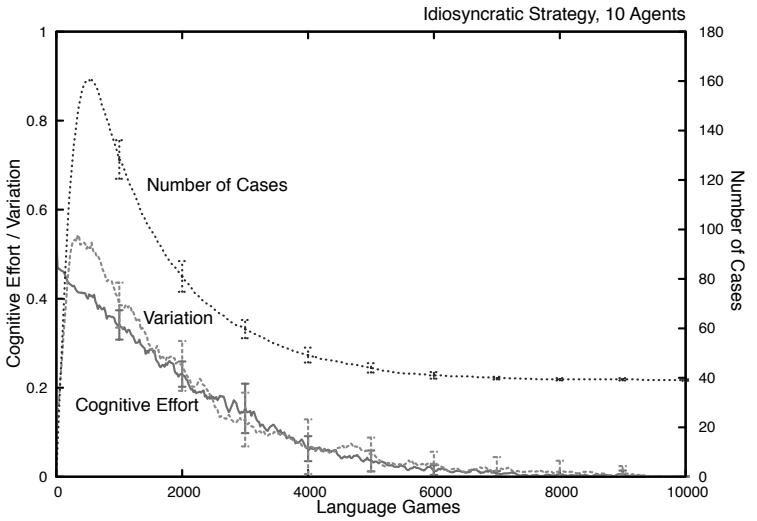

Figure 3. This chart shows that the agents with the idiosyncratic case strategy succeed in reducing the cognitive effort needed for interpretation (full line) as they develop a coherent case system. However, each case is verb-specific hence the emergent case system is not expressive.

down to a minimum, which means that the agents successfully align their inventories with each other. The **number of cases** shows the average amount of cases that are actively used in the population. At its maximum, the agents need to cope with 160 competing cases, but the alignment strategy allows them to converge to a shared set of 39 idiosyncratic cases for 39 participant roles. This one-to-one mapping however means that the emergent case system is not productive, and that the number of cases grows linearly if new event meanings need to be expressed.

3.3. *Results for the Coercion Case Strategy*

Figure 4 shows the same measures for a population that uses coercion. The agents succeed in reducing the cognitive effort they require to a minimum. Variation shows similar results as well, rising to 45% early on and then gradually sloping down to almost zero. A spectacular difference is however observed in the number of cases that circulate in the population: the maximum never exceeds 8 cases (so not all agents innovated) and the final systems count 4 to 7 cases. The 'redundancy' of more than 3 markers is due to the effect of frequency on conventionalization. In comparison, case systems in natural languages vary between two (e.g. Mapudungun) and more than twenty cases (e.g. Hungarian; Iggesen, 2005).

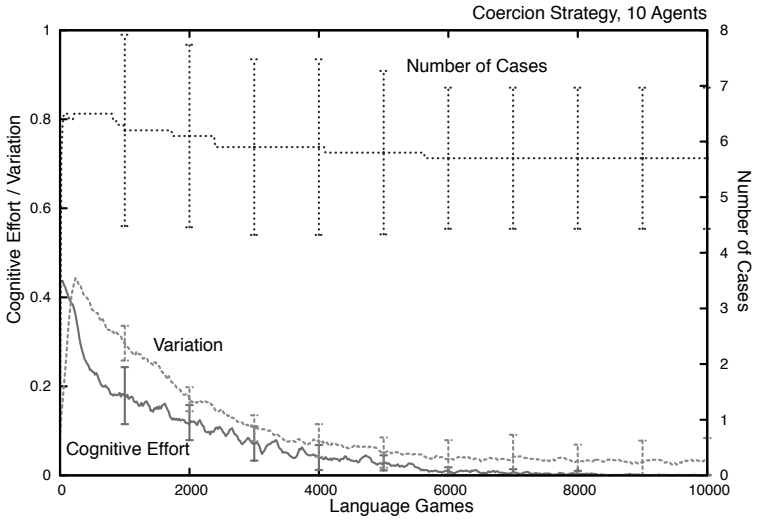

Figure 4. When exploiting coercion, the agents drastically reduce the number of cases in their case system while at the same time minimizing cognitive effort.

Coercion thus allows the agents to develop a more economical case system in terms of inventory size, which also entails that the system is more expressive than the idiosyncratic one. However, whereas case markers in natural languages are often semantically motivated, the cases developed here are entirely arbitrary: a case that marks an agent-like participant in one event may be reused for marking location in another event. Without any clear system that motivates *how* the agents can expand their case system, they constantly introduce conflicting solutions.

4. Discussion and Conclusion

This paper addressed two of the shortcomings of earlier work on the evolution of case. First, whereas previous studies focused solely on semantics, this paper explored a syntactic route in order to reveal which formal pressures may steer an emergent case system towards a more economical paradigm. Secondly, by operationalizing those formal pressures through the general cognitive function of coercion rather than a domain-specific learning bias, the experiments take a promising step towards explaining how a population can develop a case *strategy* from scratch.

However, the results also show mismatches with case systems found in natural languages. Innovation in such systems are not random, but functionally motivated, whereas the mappings between meaning and form in the experiments are entirely

arbitrary. The results therefore reveal that theories that predict that case systems evolve to become more economical and learnable (e.g. Tallerman, 2008) only tell part of the story: case also evolves in a way that language users can maximize their chances of being immediately understood when they need to expand their system to accommodate for novel situations. Future research therefore needs to show how the semantic and syntactic routes to the origins of case can intersect to explain how functionally motivated, yet abstract case systems may evolve.

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