The role of pro- and anti-unification in insight grammar learning

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1. Introduction

Human cognition is remarkably robust and shows an impressive capacity to cope with open-ended situations. A case in point is language processing, which not only has to deal with fragmented, ungrammatical or ill-pronounced sentences, but also with true innovations, falling outside of established convention and introduced by the speaker to express new meanings or to optimize the production or comprehension of complex phrases. There is no doubt that the acquisition of grammar is partly based on statistical inductive learning, which makes abstraction over patterns observed in a large number of examples, so that these patterns can be reused when producing or comprehending utterances. But robust and open-ended processing requires an additional, complementary learning approach. We propose an approach based on insight learning, implementing abductive inference.

From a mechanistic point of view, insight learning can be achieved through meta-cognition based on diagnostics, repairs, and consolidation (Laird, 2012). The diagnostics monitor routine processing and become active when there is an impasse (Ohlsson, 1984), which means in this case missing grammatical rules, or an anomaly, e.g. a semantic structure that is incompatible with the current situation model. Repairs try to deal with these so that processing can continue. They may involve a shift in representation, ignoring some existing constraints, the abduction of new rules, coercion of words into new functions or the adaptation of grammatical categories. The outcome of a repair may get consolidated into long-term changes to the learner's language inventory when their enactment has lead to a successful interaction. There is substantial psychological evidence that such diagnostics and repairs are abundantly employed in human language interactions in order to cope with ungrammaticalities or errors and novel phrasings (Garrod & Anderson, 1987; Dingemanse, 2015). Quite a few prior experiments on how to integrate meta-level problem solving exist within the context of grammar learning (Beuls et al., 2012; Garcia-Casademont & Steels, 2016), but so far the repairs are ad hoc with respect to the diagnosed problem and the nature of the repair. Here we seek to find a minimal set of general and powerful operators that operationalize insight grammar learning from a mechanistic point of view.

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2. Anti- and pro-unification

The core of many computational grammar formalisms today is unification (Plotkin, 1971). It is a symbolic computing process that seeks to find out whether a transient structure, which represents all known information about an utterance being processed, fits with a grammatical construction schema, assuming a particular set of bindings. Unification is the operator that is used in routine processing.

When a problem is diagnosed during routine processing, e.g. because of a deviant word order, the system switches to its meta-level. A first operator that is applied at this meta-level is anti-unification of the transient structure with the relevant construction. Anti-unification is the opposite of unification. It seeks to find out how one expression (the construction), which is not yet unifiable with another expression (the transient structure), can be made to unify by proposing a minimal generalization of the pattern, called the *least general generalization*. Anti-unification therefore im-

plements abductive inference, as originally proposed by Charles Peirce. This generalised construction can then apply to the transient structure by means of unification and processing can continue.

An utterance that could not be processed using routine processing could be a downright error. In this case, the anti-unification step is sufficient and the problem is just solved once. The solution to the problem is not stored and does not affect the hearer's linguistic inventory. But in other cases, the utterance could have contained a true innovation by the speaker, or an other grammatical phenomenon that was previously unknown by the hearer. In this case, the hearer may want to store the solution to this problem. However, storing the generalised (anti-unified) construction might not be a good choice. It is often too general and might apply too often, or to problems it is not a solution to. To accommodate for this, we introduce a second operator, pro-unification, which constrains the generalised construction again towards the observation it was constructed for.

Pro-unification is a key mechanism for building novel construction schemas to be stored for later use. It takes a construction schema that was generalized through anti-unification and constrains it again based on the particular transient structure that could not be processed before. The constraining happens by making variables in the construction, that are bound to the same values in the transient structure, equal to each other. This level of constraining strikes a good balance between generality, such that the construction is applicable to other cases and specificity, such that it does not apply to too many cases.

The integration of anti-unification and pro-unification in FCG's meta level provides elegant and powerful mechanisms to solve processing problems and to store the solutions for later use on similar cases. In this presentation, we will show examples of the application of these mechanisms to learn new constructions for dealing with gender mismatches, word order deviation and missing words.

3. Conclusion

Human cognition in general and the language processing system in particular are robust and open-ended. In order to achieve this robustness and open-endedness, powerful insight mechanisms need to be available during language processing. We have proposed two general learning operators, anti-unification and pro-unification, to operationalise insight problem solving and insight learning for grammars. The operators are fully operational and implemented in Fluid Construction Grammar and our presentation at BENELEARN will include a live demonstration.

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References

Beuls, K., van Trijp, R., & Wellens, P. (2012). Diagnostics and repairs in fluid construction grammar. In L. Steels and M. Hild (Eds.), *Language grounding in robots*, 215–234. New York: Springer Verlag.

Dingemanse, M. e. a. (2015). Universal principles in the repair of communication problems. *Plos One*, *10(9*, e0136100.

Garcia-Casademont, E., & Steels, L. (2016). Grammar learning as insight problem solving. *The Journal of Cognitive Science*, *5(7)*, 27–62.

Garrod, S., & Anderson, A. (1987). Saying what you mean in dialogue: A study in conceptual and semantic coordination. *Cognition*, *27*, 181–218.

Laird, J. (2012). *The soar cognitive architecture*. Cambridge Ma: The MIT Press.

Ohlsson, S. (1984). Restructuring revisited: Ii. an information processing theory of restructuring and insight. *Scandinavian Journal of Psychology*, *25*, 117–129.

Plotkin, G. (1971). A further note on inductive generalization. In B. Melzer and D. Michie (Eds.), *Machine intelligence 6*, 101–124. Edinburgh: Edinburgh University Press.