Issues in Implementing Three-Level Semantics with ACT-R

Sebastian Lohmeier (sl@monochromata.de) Nele Russwinkel (nele.russwinkel@tu-berlin.de)

Technische Universität Berlin

Keywords: Text Understanding, Spreading Activation, Representation

Three-Level Semantics

Three-level semantics (Schwarz, 1992) is a cognitive theory of how readers construct context-specific meaning from text by activating linguistic and world knowledge at following levels:

1. **Conceptual schemata** $[t, [a_1, ..., a_n]]$ represent amodal information, with

   type t e.g. individual, kind, property, relation or event (CT-... in Figure 1), and

   primitives a_i e.g. substances, structures, functions or causal relations (CP-... in Figure 1).

2. The **lexicon** relates language-specific syntactic, phonetic and graphemic information to sets of those primitives of a schema that are necessary features of the concept, irregardless of context. Figure 1 shows the LE-CAR lexicon entry sharing primitives with its concept.

3. Nodes with context-specific **current meanings** that are constructed from lexicon entries through **selection** and **specification** processes are represented at the third level. Activation spreading determines both processes.

A reader's top-down strategies establish **reference** to nodes of current meaning (Schwarz-Friesel, 2007) – to referents of Peter and his car in Figure 1.

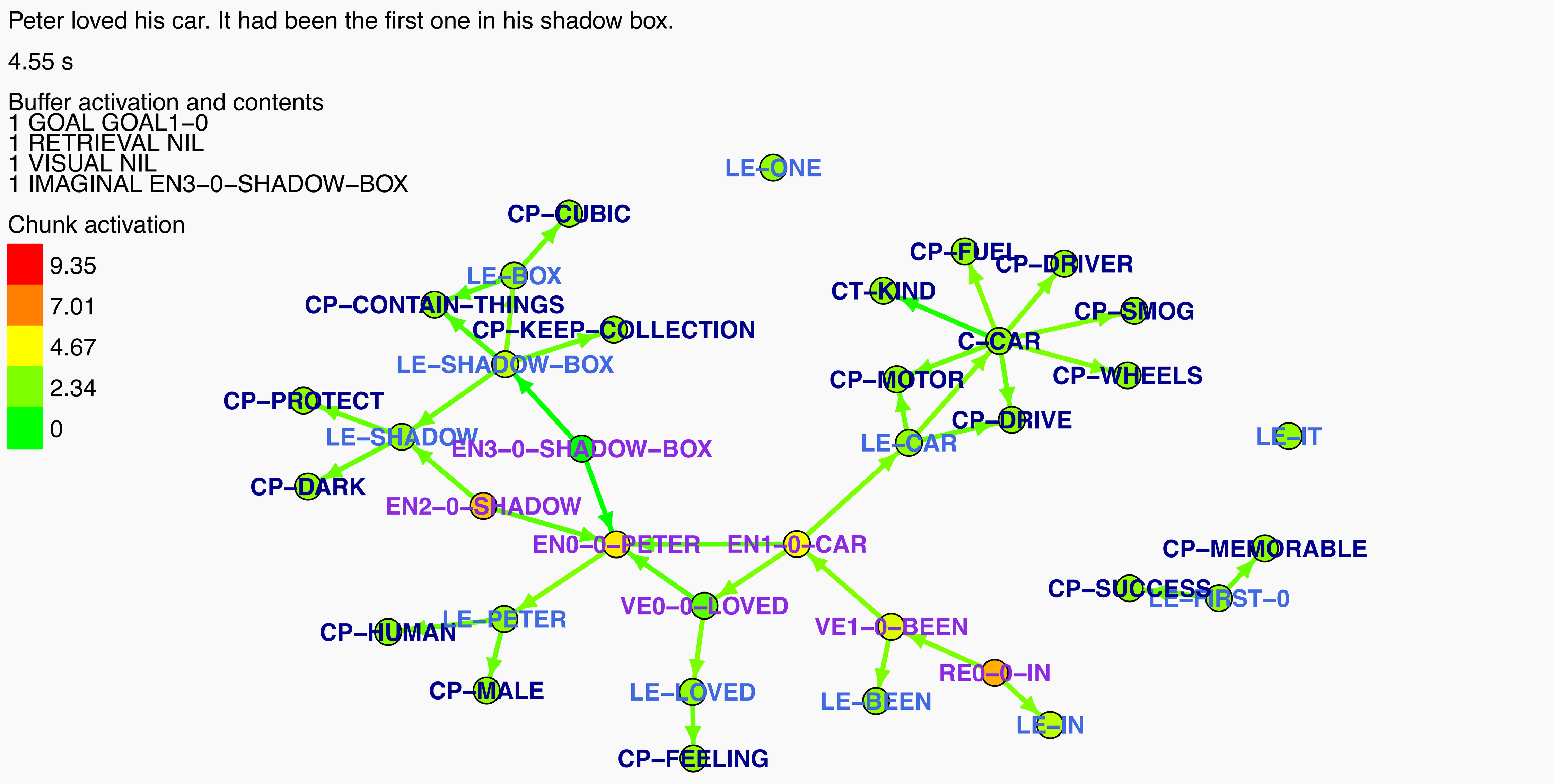

Figure 1: Selected chunks in memory after reading the sentence given in Figure 2 for 4.55 sec. At this point, a node for the current meaning of "shadow box" has been created in the imaginal buffer. Node colors indicate chunk activation. Node names are chunk names. The image visualizes an early implementation of three-level semantics for resolving noun-phrase reference without selection and specification of current meanings. An implementation of the specification process would at this point in time need to modify the current meaning EN1-0-CAR to turn it from a real into a model car.

Implementation Issues

ACT-R (Anderson et al., 2004) provides an encouraging basis for three-level semantics: productions and chunks can model strategies and structures of three-level semantics as follows.

Verification of implementation choices by reproducing empirical data will need to be **incremental**: e.g. reproducing significant differences in reference resolution will require, but not be hindered by, an unverified implementation of lexical access.

Long-term base-level activation values

- for lexicon entries can be derived from **word frequencies**, but **lack reader-specificity** and are
- unavailable for parts that make up a lexicon entry.
- Modeling **learning by reading** might incorporate activation spread by reading processes.

Multi-level spreading activation will avoid redundant representations and select contextually relevant conceptual primitives in three-level semantics.

Four kinds of memory are known in three-level semantics: sensory, short-term (STM), working (WM) and long-term memory (LTM).

- ACT-R's aural- and visual-location buffers implement sensory memory,
- the imaginal buffer may implement consciousness of stimuli in STM after 250ms,
- WM and LTM are implemented as levels of chunk activation in the declarative module of ACT-R.

Peter loved his car. It had been the first one in his shadow box.

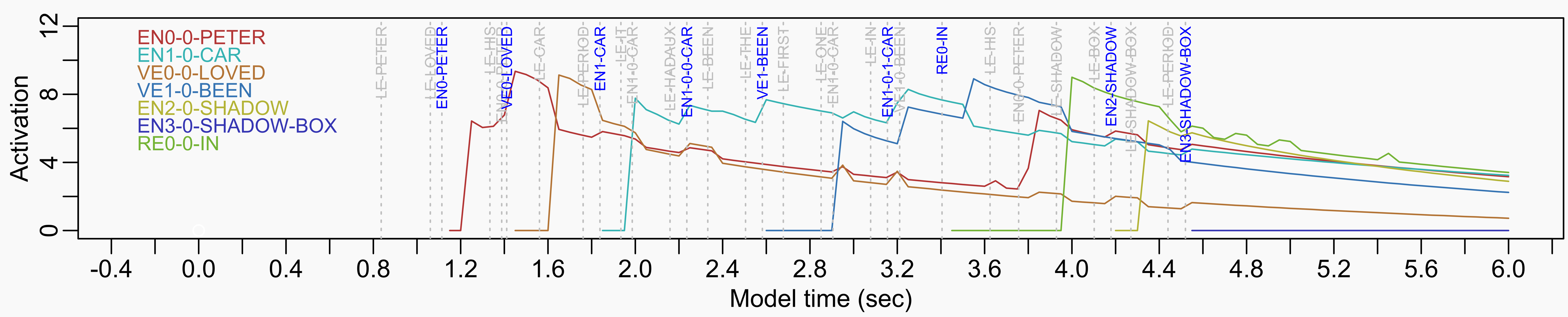

Figure 2: Activation of selected chunks representing current meaning during reading. Chunks in retrieval buffer are given in gray, chunks in imaginal buffer are given in blue. Instead of multi-level spreading, an activation of $y = 5 \cdot 0.7^x$ is added to ACT-R's base level activation (decay=0.5) to simulate textual context during reading that speeds up retrieval. It also enables re-activation of previously mentioned referents like EN0-PETER activated by "his" after 3.7 sec.

Conceptual schemata can be modeled in ACT-R as chunks with slots for their

- conceptual type and
- individually-activated conceptual primitives.

Sourcing schema contents is an open issue:

- schemata encoded by the modeler need to be validated in a pre-study,
- schema sources like Cyc might lack application-specific knowledge.

The mental lexicon is created using

- chunk types for each part of speech, with
- slots for syntactic, graphemic and phonetic information, as well as conceptual primitives.

Morphological processes need to be implemented that derive regular word forms not stored in the mental lexicon.

Contents of the mental lexicon could be derived from databases like WordNet and FrameNet.

Current meanings can be implemented by

- chunk types for e.g. entity and verb nodes, with
- slots for conceptual primitives, as well as conscious graphemic and phonetic information.

The selection process requires spreading activation that is sensitive to sentences read previously.

For specification to work, lexicon entries must be prototypes whose default conceptual primitives can be replaced by contextually adequate ones.

References

Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S., Lebiere, C., & Qin, Y. (2004). An integrated theory of mind. *Psychological Review*, *111*(4), 1036–1060.

Schwarz, M. (1992). *Kognitive Semantiktheorie und neuropsychologische Realität: repräsentationale und prozedurale Aspekte der semantischen Kompetenz*. Tübingen: Niemeyer.

Schwarz-Friesel, M. (2007). Indirect anaphora in text: A cognitive account. In M. Schwarz-Friesel, M. Consten, & M. Knees (Eds.), *Anaphors in text : cognitive, formal and applied approaches to anaphoric reference* (pp. 3–20). Amsterdam: Benjamins.

Authors

Sebastian Lohmeier
sl@monochromata.de
Technische Universität Berlin
MSc Informatik degree course

Nele Russwinkel
nele.russwinkel@tu-berlin.de
Technische Universität Berlin
FG Kognitive Modellierung in dynamischen MMS