COGNITIVE MODELING FOR FORMAL SEMANTICS

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1. INTRODUCTION

We introduce an incremental, cognitively realistic semantic parser that:

- composes and integrates semantic representations (DRSs) on-line
- evaluates new semantic representations relative to a model (database of known facts) stored in memory
- can model RT data and predict the 'fan effect'

Details in forthcoming book *Computational Cognitive Modeling and Linguistic Theory*:
`https://www.springer.com/gp/book/9783030318444`
Short demo: `https://people.ucsc.edu/~abrsvn/demo_hippie_in_town_1.mp4`
Long demo: `https://people.ucsc.edu/~abrsvn/demo_hippie_in_town_2.mp4`

2. FAN EFFECT (ANDERSON, 1974)

Participants studied facts about person-location pairs. 10 examples:

a. A lawyer is in a cave.
b. A debutante is in a bank.
c. A doctor is in a bank.
d. A doctor is in a shop.
e. A captain is in a church.
f. A captain is in a park.
g. A fireman is in a park.
h. A hippie is in a park.
i. A hippie is in a church.
j. A hippie is in a town.

- Each person concept – used 1, 2 or 3 times (=fan of 1, 2 or 3)
- Each location concept – used 1, 2 or 3 times (=fan of 1, 2 or 3)

In the test phase, participants had to accept targets (learned facts) and reject foils (novel facts)

Target RTs		location fan **1**	**2**	**3**
person fan	**1**	1.11	1.17	1.15
	2	1.17	1.20	1.23
	3	1.22	1.22	1.36

Foil RTs		location fan **1**	**2**	**3**
person fan	**1**	1.20	1.25	1.26
	2	1.22	1.36	1.47
	3	1.26	1.29	1.47

(*i.*) the effect of 1-fan (intercept) is about 1.2s

(*ii.*) latency is a non-additive function of fan: (1, 3)/(3, 1) faster than (2, 2)

(*iii.*) the fan effects are approximately equal for targets and foils

3. BASIC ACCOUNT

DRS consists of three sub-DRSs:

$$1.\ \begin{bmatrix} \text{DREF}: & 1 \\ \text{PRED}: & \textit{hippie} \\ \text{ARG1}: & 1 \end{bmatrix}$$

$$2.\ \begin{bmatrix} \text{DREF}: & 2 \\ \text{PRED}: & \textit{town} \\ \text{ARG1}: & 2 \end{bmatrix}$$

$$3.\ \begin{bmatrix} \text{PRED}: & \textit{in} \\ \text{ARG1}: & 1 \\ \text{ARG2}: & 2 \end{bmatrix}$$

After constructing the DRS, the parser checks whether a matching fact is present in the model (learned facts in declarative memory).
Recall of fact i from declarative memory: parallel search driven by activation A_i. A_i modulated by spreading activation from sub-DRSs j. (Free params are in red below.)

$$A_i \approx \sum_j W_j S_{ji} \tag{1}$$

$$S_{ji} = S - \log(\text{fan}_j) \tag{2}$$

$$\begin{aligned} T &= I + Fe^{-A_i} \\ &= I + F' \textstyle\prod_j \text{fan}_j^{W_j} \\ &\quad (F' = Fe^{-\sum W_j S}) \end{aligned} \tag{3}$$

(*i.*) follows by I in (3)

(*ii.*) follows by $\prod_j \text{fan}_j^{W_j}$ in (3)

(*iii.*) follows by parallel search

4. INCREMENTAL DRS CONSTRUCTION AND SEMANTIC EVALUATION

DRS construction as a set of production rules in ACT-R

Production rules: conditionalized actions

Left-corner parser interspersed with DRS construction; syntax and semantics built side by side

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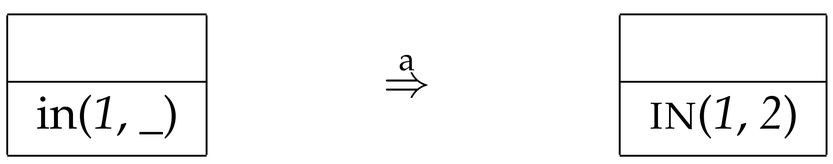
- 

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Evaluation as a recall from declarative memory.
Fan effect due to sub-DRSs built during incremental interpretation.
Parameter estimates obtained by embedding the parser in a Bayesian model.