

## Connectionism

An alternative architecture for modeling cognitive processes

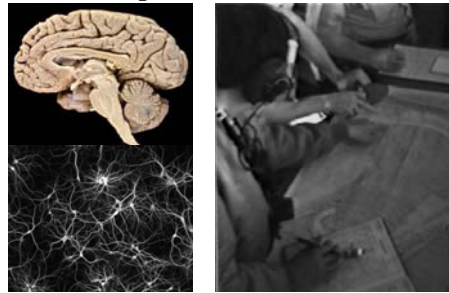
## Alternative to what?

- Physical Symbol System Hypothesis
  - Internal representations are symbolic
  - Transformations are syntactic
  - Single CPU
- PSSH strength's
  - It can model many “intelligent” processes: logic, theorem proving, game playing, etc.
  - One can see how it does what it does.

## Weaknesses of PSSH

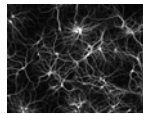
- People are better than PSSH-based programs at:
  - Perception
  - Language
  - Context relevant remembering
  - Planning
  - Learning through experience!
  - Interacting with a dynamic world

## Not obvious how a brain can implement a PSSH



## Neurally inspired computing

- Massively parallel
  - Composed of many very simple processors
- Parallel Distributed Processing
  - Distributed representation
  - Processing by passing activation among the simple processors

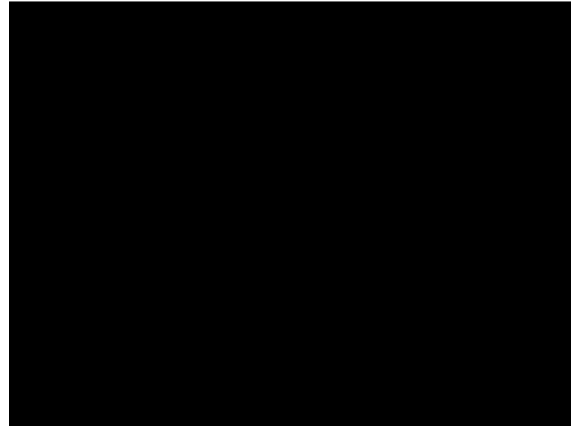


## Hopes

Computationally sufficient,  
psychologically accurate,  
mechanistic accounts,  
of human cognition.

## General approach

- Units
- Representation in patterns of activation across units
- Connections
- Knowledge in patterns of connection strength
- Learning by adjusting connection strengths



## Advantages of Connectionism

- Content addressable memory
- Graceful degradation (contrast with brittle)
- Spontaneous generalization
- Natural learning
- Learn functions where analytic solutions are not known

## Learning the past tense of English Verbs (Rumelhart and McClelland)

- Regular verbs - form past tense by adding "ed" e.g. look, open, twist
- Irregular verbs - form past tense by phonetic transformation. Go, get, sing, find...
- A typical early past tense verb lexicon:  
*came, got, gave, looked, needed, took, went.*

## The phenomenon

- Three stages of learning:
  1. Small number of verbs, past tense for those verbs is formed correctly
  2. Larger number of verbs. Many regular. Can generalize to novel verbs (e.g., rick/ricked), but make errors on verbs they handled correctly in stage 1. (e.g., come/comed/camed)
  3. Correct performance on regular and irregular verbs.

## Is the child learning a rule?

"If a child knows that the plural of witch is witches, he may simply have memorized the plural form. If however, he tells us that the plural of gutch is gutches, we have evidence that he actually knows, albeit unconsciously, one of those rules which the descriptive linguist, too, would set forth in his grammar." (Berko, 1958:151)

## A PSSH approach

- Language acquisition device (LAD).
- LAD discovers explicit inaccessible rules.
- Hypotheses are rejected and replaced when they fail to account for the utterances the learner hears.
- LAD is presumed to have innate knowledge of the possible range of human languages and, therefore, only considers hypotheses within the constraints imposed by a set of linguistic universals.

## A connectionist model

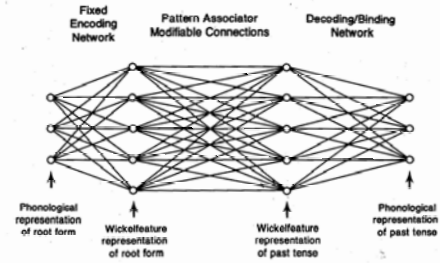


FIGURE 1. The basic structure of the model.

## Results

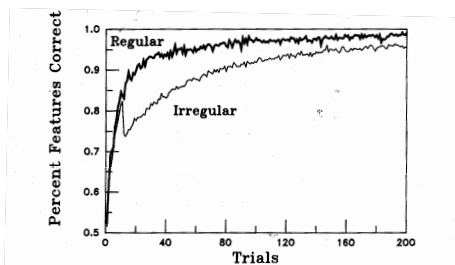


FIGURE 4. The percentage of correct features for regular and irregular high-frequency verbs as a function of trials.

## What the model does

- Generates the U-shaped learning curve for the past tense forms of irregular verbs.
- Over-generalizes like children do.
  - Most regularization in forms like *know/knew* and least with pairs like *feel/felt*.
- Can generate regular past tense for unfamiliar forms.
- Different past tense forms for the same verb can coexist. (e.g., *cring/crang/crung*).

## So What?

- A working alternative to the idea that children learn explicit rules.
  - Rule described versus rule governed behavior.
- The child need not figure out what the rules are, or even that there are rules!
- No need to decide that a verb is regular or irregular.
- All of this comes “for free” from normal processing.
- If this works for verbs, what else might work this way?

## Later breakthroughs...

- Limits of pattern associators, more layers, back-propagation learning rule. First generation connectionism.
- Recurrent connections, dynamics. Second generation connectionism.
- More biologically realistic, more dynamics, more complex connectivity, more realistic timing, deliberate use of noise.

### A viable alternative to PSSH?

- Representing the microstructure of cognition
- More accurate than PSSH
- Lots of nice features come “for free”: generalization, learning, feature extraction...

### Unknown

- Will it scale up?
- How can nets interact with a real-world?
- How does higher-level organization arise?
- How are symbols processed?
- Where do symbols come from?

### Ok, But....

- The time course of real-world action
- There are many levels of software. Are there also levels of mindware?
- Are games good representatives of cognitive tasks?
- Is the Turing test a good representative?

### OK, But...(continued)

- Engineering A/I vs Research A/I
- Consciousness (the C word) and qualia
- Language and Searle’s Chinese Room