Computational Models of Lexical Access

Lecture 7 - Part II

Introduction to Psycholinguistics

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Models of word recognition

Search models (e.g., Forster, 1976) - serial comparison

- Similar to looking up a word in the dictionary

Direct Access models - parallel comparison

- Logogen Model (Morton, 1969), not domain specific
- Cohort Model (Marlsen-Wilson & Welsh, 1978), speech
- TRACE (McClelland and Elman, 1986), speech
- Shortlist/Merge (Norris, 1994), speech
- NAM (Neighborhood activation model; Luce, 1998)
- FLMP (Fuzzy logical model of perception; Massaro, 1998)

Lexical Search Theory (Forster, 1976)

A complete perceptual representation of the perceived stimulus is constructed.

The perceptual representation is compared with the representation of what words look like or sound like in the access files

There are three access files:

- Orthographic (reading)
- Phonological (listening)
- Syntactic/semantic (language production)

Lexical Search

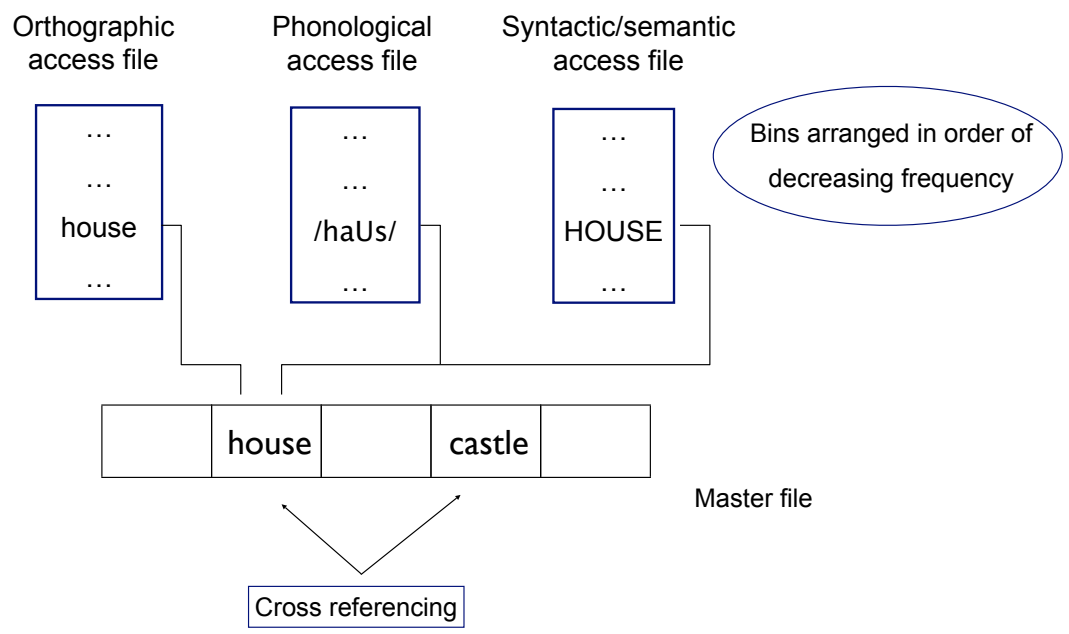
The access files are organized in a series of bins, and only one bin needs to be searched to find a match

Comparisons of the representation of the perceived stimulus are one by one against representations in the bins.

Serial position within a bin affects the speed with which it is accessed (i.e., ordered by lexical frequency)

Meaning of words is not stored within the access files, rather representations in the access files have a pointer to meaning information in a master file in semantic memory

Sketch of lexical search model



Lexical search model

In short, lexical access in the search model corresponds to going to the right access file and comparing stimulus with access code

Frequency effects can be explained by the ranking of the bins

But for example, repetition priming is more difficult to explain. Suggestion: Not lexical access, but memory trace which facilitates decision.

Also we know by now, that activation of word candidates begin before a complete word has been presented

Direct Access models - The Logogen model

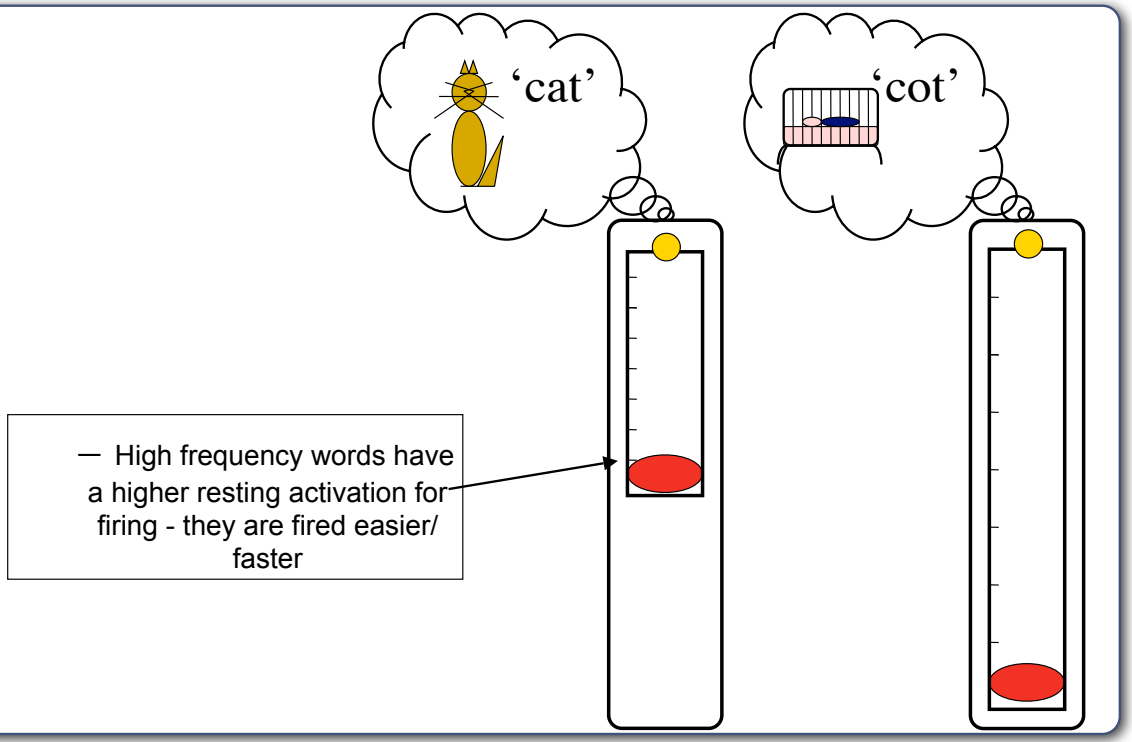
In Morton's Logogen model (1969), perceptual input feeds into feature counters called logogens

Each word is represented by a logogen (logos=word; genus=birth, origin, class)

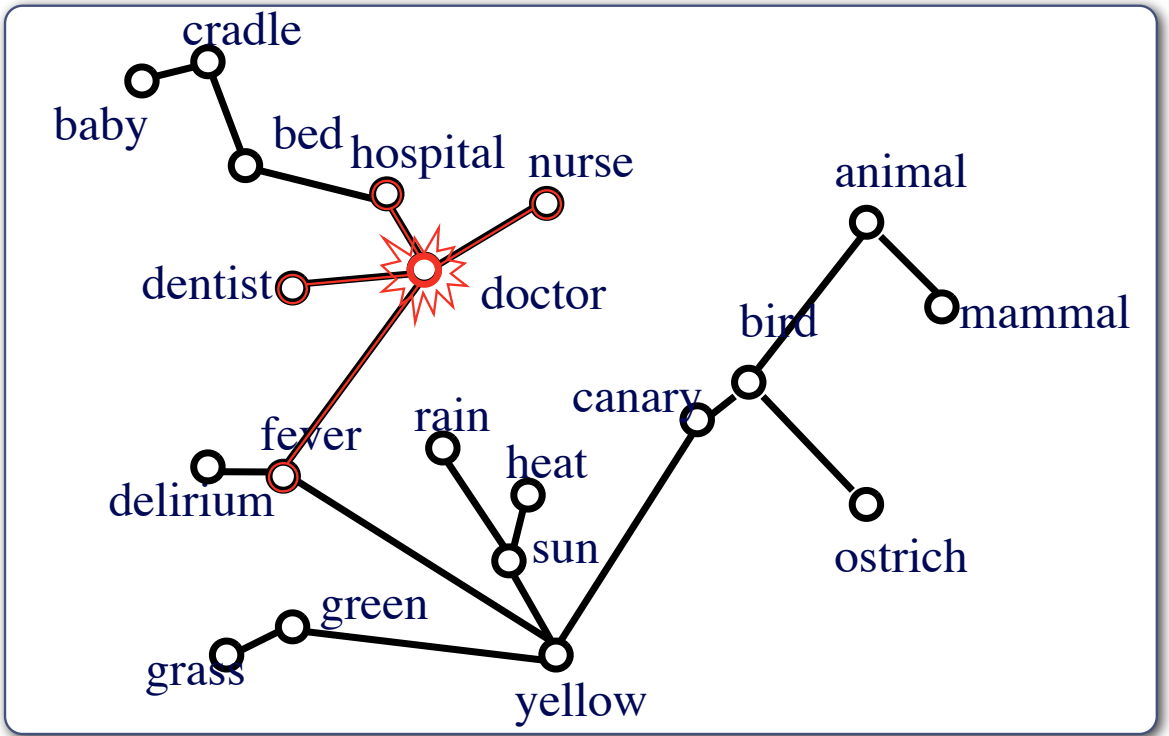
If the perceptual input contains a feature of a particular word, then the feature count of its logogen increases. Features can be visual or auditory (vertical stem in a letter or plosive air release in stop consonants)

Each logogen has a threshold at which it fires - when it fires, the word is said to have been identified and its meaning becomes available

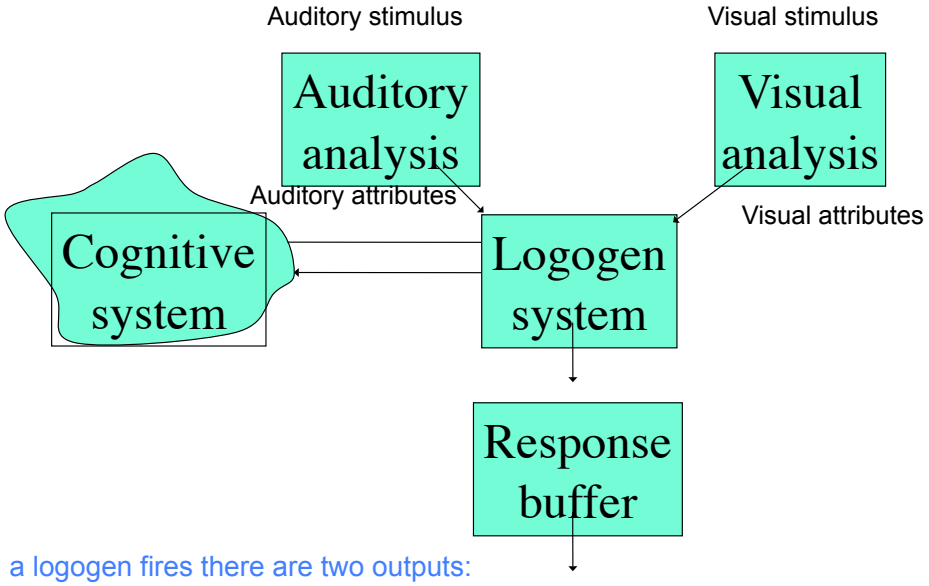
Frequency effect in Logogen



Spreading activation in semantic network



Sketch of Logogen model



When a logogen fires there are two outputs:
- One to the response buffer for speech
- One to the cognitive system for comprehension

Logogen Model

Frequency effects:

- increased experience of a word resulting in a higher resting activation for high frequency relative to low frequency words. (also how repetition priming works)

Semantic priming:

- Activation from one logogen spreads (indirectly) to those for related words.
- Activated logogens do not return to their resting level immediately: the primed target will require less perceptual input to be activated to its individual threshold

Neighbourhood effects: original model proposed before such findings were discovered, therefore no account for this finding

The Cohort Model (continuous activation)

First version appeared in 1978 by Marslen-Wilson and Welsh

Cohort: A group of words that are in a common candidate set during lexical selection

Continuous mapping of acoustic-phonetic information to the lexicon

Example "rabbit":

- Cohort 1: all words with [r]
- Cohort 2: all words with [rae]
- Cohort 3: all words with [raeb]

…

Cohort (cont'd)

Onset of next word can be anticipated (uniqueness point)

The model has still a strong emphasis on word onsets

3 levels of word recognition

- Contact with acoustic-phonetic representation of speech input (activation of cohorts based on feature overlap)
- Selection process (sensitive to syntactic/ semantic constraints)
- Integration with discourse

The Cohort model

The emphasis on word onset is potentially problematic (how to recover from early errors in perception)

Many words do not have a uniqueness point, but how to recognize then the onset of a word in a speech stream

- „stay cool" /stelk…/ the /k/ could still be part of the first word and until we hear the next sound /u/, we don't know that /k/ must be a word onset

TRACE (interactive continuous model)

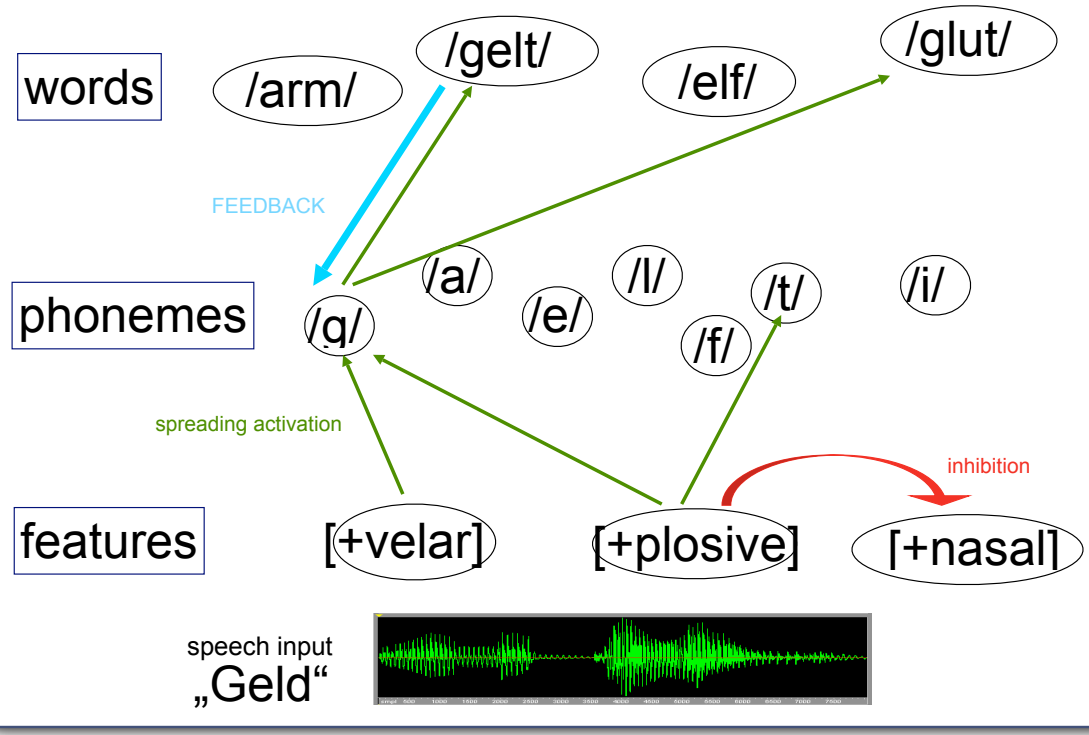
TRACE is a fully implemented connectionist model

- Connectionist systems rely on parallel processing of sub-systems, using statistical properties instead of logical rules to transform information (they are assumed to reflect functional properties of the brain)
- First version appeared in 1986 McClelland & Elman

3 levels of processing elements (nodes) with resting activation values

- Features (e.g., [+voice], [+nasal])
- Phonemes (e.g., /d/, /g/)
- Lexical entries (words)

Sketch of TRACE



TRACE model

Frequency effects are explained by frequently occurring units being weighted higher

Phonological priming is explained by weights being temporarily changed before returning to normal

Semantic priming is explained by words activating related words

Lexical processing can constrain phonetic processing in TRACE (feedback)

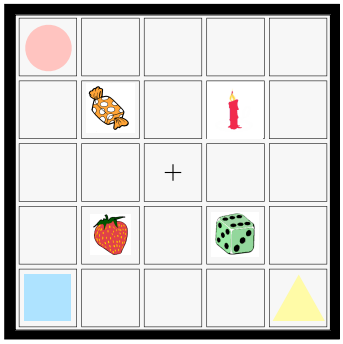
TRACE model

This makes it, however, hard to identify nature of mispronunciations.

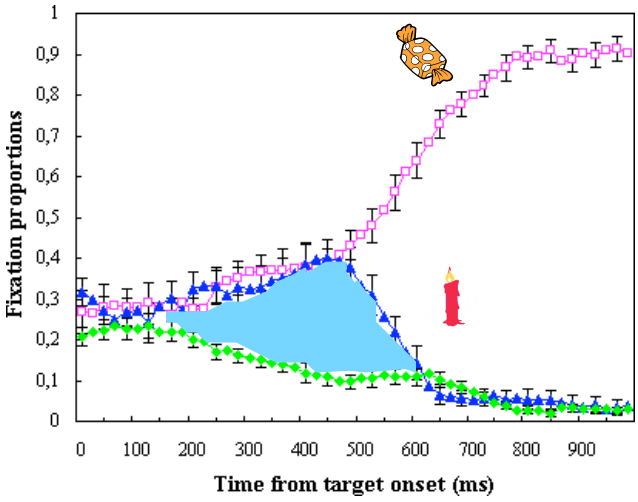
- Although a mispronounced word activates the wrong set of phonemes, TRACE will be unable to tell at lexical level which phoneme was mispronounced because top-down feedback will correct the errorful information at the phoneme level

TRACE predicts that lexical involvement in phonetic categorization should build up over time (as a word becomes more activated, it will send stronger feedback to phoneme nodes); however, empirical evidence shows that the bias to label ambiguous sounds so as to form a word decreases with time

Fixations over time, Tanenhaus et al. (1996)



"Pick up the *candle*"



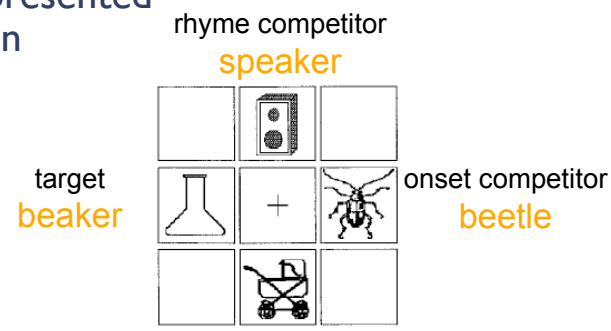
Allopena et al. (1998)

Implemented models of spoken-word recognition are based on empirical observations

Can be used to simulate and quantitatively predict human behavior during spoken-word recognition

- TRACE was used to calculate predictions of response probabilities for a certain set of items
- The same items were presented to participants during an eye-tracking study

"Click on the *beaker*"



TRACE simulations

Simulation conducted with 230+38=268 words:

- Each input word was run for 90 cycles
- New phonemes introduced every 6 cycles
- Input for each successive phoneme active for 11 cycles

TRACE activations converted to fixation probabilities:

- Based on the *Luce Choice Rule*
- 1 cycle = 11ms of "real time"
- 200ms delay to launch saccade

TRACE predictions, Allopenna et al. (1998)

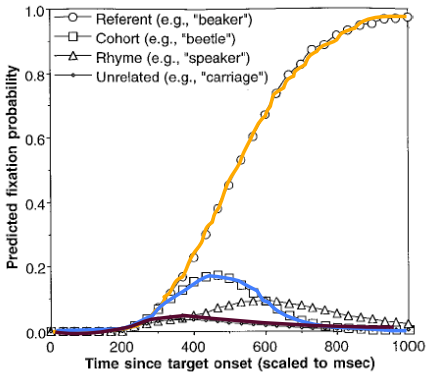


FIG. 2. Predicted response probabilities converted from TRACE using the scaled Luce choice rule.

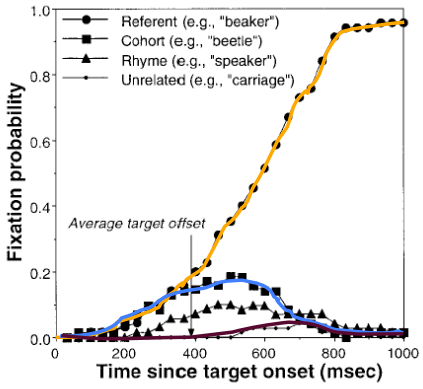


FIG. 4. Probability of fixating each item type over time in the full competitor condition in Experiment 1. The data are averaged over all stimulus sets given in Table 1; the words given in the figure are examples of one set.

Linking hypothesis

The close match between predicted and observed fixation patterns allowed the following linking hypothesis (link between lexical activation and eye movements):

- The activation of the name of a picture determines the probability that a subject will shift attention to that picture and thus make a saccadic eye movement to fixate it.

Shortlist (autonomous continuous model)

Shortlist is a fully implemented connectionist model

Two distinct stages:

- Bottom-up information determines set of candidate words for shortlist (may span different proportions of input)
- Only short-listed candidates compete with each other

Similar to TRACE but:

- No influence from higher levels on lower levels
- Activation only spreads from phoneme level to word level
- Bi-directional connections (inhibition and facilitation) between nodes within a level but not at adjacent levels

Models of word recognition

Search models (e.g., Forster, 1976) - serial comparison

- Perceptual input has no direct access to lexical entries
  - a complete perceptual representation of the stimulus is constructed
- Forster's model is for both reading and listening

Direct Access models - parallel comparison

- Logogen Model (Morton, 1969), not domain specific
- Cohort Model (Marlsen-Wilson and Welsh, 1978), speech
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Main similarities and differences

COHORT puts emphasis on word onsets

- limits the competitor set to
  - *beaker* and *beetle* but not *speaker*
- not very robust to noise and continuous speech

TRACE and ShortList allow all perceptual features to activate competitors ... e.g. predicts rhyme competition

  - *beaker* and *beetle* and *speaker*
- TRACE allows top-down feedback
- ShortList does not