A Network Model of Homograph Disambiguation

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Does priming one meaning of an ambiguous word lead to the suppression of an alternative meaning?

Set me as a seal upon thine heart.

Set me as a seal upon a rock.
According to the standard view, the non-selected meaning is suppressed or inhibited.
The Cognitive Inhibition Paradigm

A popular view in the field of lexical ambiguity processing (Gernsbacher & St. John, 2001; Norman, Newman, & Detre, 2007; Simpson & Adamopoulous, 2001; is that some type of *cognitive inhibition* between meaning representations is involved in selecting the meaning of an ambiguous word.

How does *cognitive inhibition* differ from *neural inhibition*?
Nobody doubts that about 20% of cortical connections are inhibitory

But cognitive inhibition is an additional claim. As defined by MacLeod et al. (2003) in opposition to the claim:

- Cognitive inhibition is composed of suppression, restraint, and blocking.
  - *Suppression* is prevention of a process from beginning or from continuing once begun.
  - *Restraint* is a mental state in which behavior is difficult to initiate or is curtailed.
  - *Blocking* is keeping a concept from coming into consciousness.
Alternative theory (Gorfein & Brown, 2007)

**Activation-selection model (ASM):**

The context in which a word appears activates a small number of the word’s attributes to the extent that the context is related to one of the word’s meanings. This has the effect of producing a short-term bias in favor of one of the meanings of an ambiguous word.

Weights between these attributes and the meaning are increased, and the increase lasts through the experiment.
Activation-Selection Model

Words are represented by a weighted set of attributes.

For modeling purposes “attributes” are just abstract features, but presumably they constitute the visual, phonological, and semantic aspects of a word’s representation.

Dominant Attributes
seal (animal)

Secondary Attributes
seal (shut)
Activation-Selection Model

Processing a word “activates” a subset of attributes.

Attributes are activated in proportion to their current weight. Baseline weights for dominant-meaning attributes are higher than baseline weights for secondary-meaning attributes.

The number of attributes activated is determined by task constraints, such as the type of response required and the processing time available.
Activation-Selection Model

The meaning of a word is assigned based on the majority of its active attributes.

Activation of an attribute decays fairly quickly to a resting level. That is, activation is a short-term property of an attribute.
Activation-Selection Model

Each time a meaning is selected, the weights of active attributes associated with that meaning are increased.

Incrementing the weight of an attribute has the effect of increasing the likelihood the attribute will be activated on subsequent encounters with the word.

Thus, the weights are a long-term (but not permanent) property of an attribute.

Dominant attributes are reweighted when the dominant meaning is selected. Secondary attributes are not reweighted when the dominant meaning is selected.
Shunting neural network version of ASM (Levine & Brown, 2007)

The network includes representations of sound (for a homophone) or spelling (for a homograph); both meanings; attributes of both meanings; choices of each meaning.

Weights between meanings and their associated attributes are modifiable.

Lateral inhibition occurs between choice representations but not between meaning representations.
Relatedness data (Gorfein, Brown, & Amster, 2005)

Participants judged relatedness of word pairs. In this experiment, the homograph was presented twice.

Some homographs were paired with a word related to one meaning of the homograph on both presentations, and for others, the word paired with the homograph was related to alternative meanings on each presentation (e.g., seal/glue followed by seal/walrus).
Also, word order on first presentation was manipulated.

The related (to one meaning) word either preceded the homograph \((\text{glue/seal})\) or followed it \((\text{seal/glue})\).

Prediction of suppression theory (Simpson & Adamopoulos, 2001): when the disambiguating context precedes the ambiguous word in a sentence little or no inhibition is necessary and therefore little or no cost should be observed. So bias toward one meaning will be stronger when the related word follows the homograph.
Prediction of the Standard View

When meaning context is changed on the second occurrence of a homograph, performance should be better for homographs which had preceded by a related word the first time they were presented than homographs which followed a related word during their first occurrence.
But the opposite happened!

When the related word preceded the homograph, it served as a prime, and thus meaning selection was influenced to elicit a greater number of attributes in the primed direction. This resulted in greater benefits (compared with the homograph/related-word order) when the same meaning was paired with the homograph on both occurrences, and greater costs when the homograph was paired with a different meaning on second occurrence.
Experimental results on relatedness judgments

Conditions Ordered by Accuracy
Dominant Meaning

Proportion Correct

<table>
<thead>
<tr>
<th></th>
<th>rel/HOM</th>
<th>hom/REL</th>
<th>Control</th>
<th>hom/REL</th>
<th>rel/HOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Meaning</td>
<td>0.91</td>
<td>0.93</td>
<td>0.88</td>
<td>0.86</td>
<td>0.91</td>
</tr>
<tr>
<td>Different Meaning</td>
<td>0.83</td>
<td>0.82</td>
<td>0.85</td>
<td>0.86</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Graph showing the proportion correct for conditions with same and different meanings.
Experimental results on relatedness judgments

Conditions Ordered by Accuracy

Secondary Meaning

Proportion Correct

Same Meaning

Different Meaning

rel/HOM hom/REL Control hom/REL rel/HOM
Neural network simulation of relatedness judgments

Proportion judged as related

- Rel first
- Dom/Dom
- Hom first
- Sec/Dom
Neural network simulation of relatedness judgments

Proportion judged as related

Rel first
Hom first
Sec/Sec

Hom first
Rel first
Dom/Sec
Lateral inhibition in neural network models dating from the 1960s and 1970s (Sperling & Sondhi, 1968; Wilson & Cowan, 1972; Grossberg, 1973; Amari, 1977) has many cognitive uses. The next slide shows how its implications differ from those of the suppression theories of some cognitive psychologists.
Effects arising from inhibition networks

• Selective attention between stimuli
• Selective attention between attributes
• Response selection
• Contrast enhancement
• Stabilization of network activity

Effects not arising from inhibition networks

• Total suppression of inhibited representations
• Executive with inhibition as its primary function
• Stronger inhibition of stronger representations ("punishing competitors")
Suppression suggests opponent processing

Opponent processing (Grossberg, 1972; Solomon & Corbit, 1974): the most active mental representations are selectively deactivated after these representations are found not to be useful for the current task. Deactivation leads to rebound of a suppressed competing representation.

But rebounds are not typically seen in meaning selection, where facilitatory priming is the norm. Our studies suggest that our ASM Model and its neural network version, which does not include opponent processing, can account for many meaning selection data.
Homophone data our network can partially simulate

Gorfein, Brown, & DeBiasi (2007):

Phase 1: Participants were oriented towards the secondary meaning of a homophone (e.g., son vs. sun) by being asked to remember the location of the accompanying picture or word. The more difficult picture orienting task was assumed to lead to activation of more attributes of the secondary meaning. Control items were not primed.
“sun”
“hair”
“none”
“tail”
Phase 2: **Dominant meaning is primed**

Phase 3: **Neither meaning is primed**

Both phases: participants are asked either to write down the spelling of the homophone or to say a word associated with that homophone. These two types of responses are combined in the graphs.
Results: % choices of dominant meaning on each phase

Homophones primed for their secondary meaning in phase 1, showed fewer dominant responses in neutral phase 3 (despite having been primed for their dominant meaning in phase 2). This is a primacy effect.

In addition the primacy effect is greater for homophones primed with pictures than for homophones primed with words in phase 1.
Phase 1 Orienting Task

Proportion of Dominant Response

Phase 1 (secondary orienting)  
Phase 2 (dominant prime)  
Phase 3 (neutral prime)  

Phase 1 Orienting Task
Why do the Gorfein-Brown-DeBiasi data refute inhibition/suppression theories?

Suppression theories would predict:

More priming of secondary meaning on Phase 1 would lead to
More “need” to inhibit secondary meaning, therefore
Less activation of secondary meaning on Phase 3.

But just the opposite happened: more priming of secondary on Phase 1 led to MORE activation of secondary (less of dominant) on Phase 3.