Nuts and bolts of language

- Language has an inventory of stored elements (=lexicon) and a generative mechanism that builds complex structures from the stored elements.

- Core question: What elements are stored and what are generated?
neuromagnetic investigation is fascinating
Lots of generation, little storage

Lexical entries:
- neuro
- magnet
- ic
- investigate
- is
- fascinate
- -ic
- -ion
- is
- -ing
Lots of storage, little generation

Lexical entries:
- neuromagnetic
- magnetic
- magnet
- investigation
- investigate
- fascinating
- fascinate etc…
Morphology

- The study of the internal structure of words.
  - What are the basic computational units of language?

- Do words such as *magnetic* and *magnetism* contain the same computational unit, *magnet*, or are these just two words that are similar in sound and in meaning?

  - Answer from Linguistics:
    - They uncontroversially contain the same unit.

  - Answer from Psychology/Psycholinguistics:
    - More controversial.
    - For example, it has been argued that what looks to be morpheme identity is just similarity at the extreme (Seidenberg & Gonnerman, 2000; Gonnerman and Plaut, 2000).
"Emergent" morphology

Figure 1. A connectionist framework for lexical processing. The large arrows depict inputs and outputs of the system.

Gonnerman and Plaut (2000)
How can we find out whether morphemes are the basic building blocks of language?

- It is uncontroversial that morphemes are the basic building blocks of language in some sense, since, for example, we have tacit knowledge about the properties of morphemes that allows us to create new complex words.

  - Sally is very blick today.
  - Did her blickness makes you happy?
    - As soon as you know that blick is an adjective, you can derive blickness.

  - Kim wugged the computer today.
  - So the computer must be pretty easily wuggable.
    - As soon as you know that wug is a verb, you can derive wuggable.

- But could it still be the case that once we’ve learned a complex word, we memorize it as a whole and don’t bother to split it up into its pieces anymore?
In language processing, do we decompose complex words like *neuromagnetism* into their constituent morphemes, or do we access them as whole?
Predictions

Decomposition theory

magnet

magnet ism

magnet ic

magnet ize
Predictions

Decomposition theory

All of these words contain the same morpheme magnet.

→ All of these words relate to each other via identity.

→ Any prime–target combination of these words should elicit repetition priming.
Predictions

All of these words are similar in sound.
→ They should compete with each other in recognition.

Some of these words are also similar in meaning.
→ They should semantically prime each other.

None of these words relate to each other via identity.
→ Any priming effect between magnet and magnetism, for example, should be explainable in terms of sound and meaning similarity alone.
Do morphologically related words elicit repetition priming effects or cumulative similarity effects?

- Rastle et al. (2000) tested for the priming effects of
  - Meaning similarity: cello - VIOLIN
  - Form/sound similarity: typhoid - TYPHOON
  - Meaning + form similarity: screech - SCREAM
  - Morphological relatedness: adapter - ADAPTABLE
  - Identity: church - CHURCH

- Lowercase visual prime followed by uppercase visual target.
- Lexical decisions to target only.
- Priming assessed with respect to unrelated controls.
Additional factor that was manipulated:

**Stimulus Onset Asynchrony (SOA)**

- The interval between the onset of the prime and the onset of the target.

![Diagram showing time and SOA](image)

**SOA = 200ms**

- Priming effects differ in how fast they develop and how long they last.
- Rastle et al. used 3 different SOA’s:
  - 43 msec
  - 73 msec
  - 230 msec
**Results** (Rastle et al. 2000)

How much faster or slower were subjects’ lexical decisions to the related than to the unrelated conditions?

Positive numbers = priming. Negative numbers = inhibition.

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### Priming (Unrelated - Related) / ms

![Graph of priming effects](image)

- **Identity**
  - church-CHURCH: Positive priming all around.
  - churc-CHURCH: Slowly developing priming effect.

- **Positive priming**
  - +Morph +Sem +Orth adapter-ADAPTABLE: Positive priming all around.
  - +Morph +Sem +Orth screech-SCREAM: Slowly developing priming effect.
  - -Morph +Sem -Orth cello-VIOLIN: Slowly developing priming effect.
  - -Morph -Sem +Orth typhoid-TYPHOON: No reliable effects.
Conclusions

- The effect of morphological relatedness is
  - Indistinguishable from the effect of identity.
  - Unexplainable in terms of combined form and meaning similarity.
- This follows straightforwardly from the decomposition theory but not from the storage theory.
Can we find evidence for decomposition in the brain?

- We saw that for simple words, the latency of the M350 tracks frequency.
- For complex words, would the M350 track the frequency of the whole word or the frequencies of the constituent parts?
  - If the constituent parts, evidence that complex words are indeed represented as complex.
Fiorentino & Poeppel (2007)

- Lexical decision on compound words (cowboy) vs. single words (basket).
- Sixty compound word - single word pairs where the whole word frequency of the compound was always matched to that of the single word, but the constituent frequency was not:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean Log. Freq.*</th>
<th>Mean no. letters</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound (CW)</td>
<td>0.451</td>
<td>7.82</td>
<td>flagship</td>
</tr>
<tr>
<td>CW 1st / 2nd constituents</td>
<td>1.96/1.98</td>
<td>3.82/4.0</td>
<td>flag/ship</td>
</tr>
<tr>
<td>Single word (SW)</td>
<td>0.459</td>
<td>7.78</td>
<td>crescent</td>
</tr>
</tbody>
</table>

- If the M350 peaks faster for flagship than for crescent, evidence that processing flagship involves accessing flag and ship.
Neurolinguistic evidence that processing *flagship* involves accessing *flag* and *ship*.

But when, and where, does the decomposition happen? Presumably before the M350 since at that stage the brain is already sensitive to the frequencies of the parts.
Behavioral evidence for across the board presemantic decomposition from masked priming

- The prime is sandwiched between a forward pattern mask and the target stimulus, which acts as a backward mask:
  E.g.,:  
  ```
  mask (500 ms) ######
  prime (40-50 ms) horse
  target (500 ms) HOUSE
  ```

- At such short SOAs, subjects are not consciously aware of the prime.
  - Nevertheless, form-based and repetition priming can be obtained.
  - No semantic priming (SOA too short).

- Masked priming demo: [http://www.u.arizona.edu/~kforster/priming/masked_priming_demo.htm](http://www.u.arizona.edu/~kforster/priming/masked_priming_demo.htm)
Behavioral evidence for across the board presemantic decomposition from masked priming

- Davis, Rastle, & New (2004):

  In a masked priming paradigm:
  - morphology: CLEANER - clean priming
  - apparent morphology: CORNER - corn equivalent priming
  - no morphology: BROTHEL - broth no priming

- All apparently morphologically complex words are decomposed in early stages of visual word perception.

- What are the brain correlates of such early decomposition?
What are the earliest effects of morphological complexity in MEG? (Zweig & Pylkkänen, 2008, LCP)

- Lexical decisions on
  - bimorphemic (teacher),
  - monomorphemic (switch), &
  - orthographic controls (winter)

- Larger M170 amplitudes for bimorphemic words:

- But surprisingly, the effect was right-lateral… (stay tuned)
Effects of low-level visual features such as size and luminance.

Letter-string effects “Visual word form area”

Form-based decomposition (anything that looks complex decomposes)

Lexical effects:
Frequency
(Morpheme repetition
(Pylkkänen et al., 2002; Stockall & Marantz, 2006, Mental Lexicon)
Morpheme frequency
(Fiorentino & Poeppel, in press, LCP; Pylkkänen et al., 2004, Cognition)
“Morpheme access”