(Theoretical) Linguistics

- in terms of the speaker’s subconscious knowledge about what constitutes a well-formed sound-meaning mapping

- and in terms of uncovering meaning from sound in real-time comprehension and executing the motor commands necessary to externalize meaning in language production.

Psycholinguistics

Focus of this course: the neural bases of real-time comprehension.
Neural bases of language comprehension

*mushrooms are an edible fungus*

- Studying the neural bases of the computations that build the mental representation of this sentence requires
  - an understanding of what the final representation is like
  - a cognitive model of the real-time nature of the computations (i.e., a non-neural characterization of the nature of the operation to give us hypotheses about what to look for in the brain.)

- Cognitive neuroscience of language crucially relies on results from Linguistics and Psycholinguistics.
Examples properties of linguistic representations
On the mental representation of sounds

- Speech sounds are grouped into categories, so-called *phonemes*.

- Each phoneme is characterized by a set of *features*.
  - For example, *bilabial* is a feature that characterizes all sounds that are produced by pressing the lips together.

- Languages differ in what features can make a difference in meaning.

- If a feature can make a difference in meaning, it is called a *distinctive feature* in the sound system of that particular language.
Length as a distinctive feature

- Three different Finnish words:
  - tuli = fire
  - tuuli = wind
  - tulli = customs

- You would never be able to find a triplet like this in English.
  (imagine different pronunciations of 'happy', varying the length of the first vowel or the 'p')
  - hapy
  - haapy
  - happy

- Changing the length of a sound has the potential of changing the meaning of a word in Finnish but not in English.
- Length is a distinctive feature in Finnish but not in English.
- /u/ and /uu/ (or /uː/) are different phonemes in Finnish but not in English.
A distinction made in English but not in Japanese

- [l] and [r] belong to different phonemes in English but not in Japanese.
  - So ‘lip’ and ‘rip’ could never be two different words in Japanese. A Japanese speaker has trouble hearing and producing this difference.
Neural bases of phonological categorization

- Equipped with a theory of distinctive features we can
  - manipulate them experimentally
  - and investigate what brain structures convert the variable speech signal into abstract categorical phoneme representations.

- But why do you need to convert the variable signal into abstract categorical representations?

- Because the mental representations of words are not plausibly encoded in terms of every possible pronunciation of the word.
Stored lexical representations must abstract away from a huge amount of physical variance in the signal

- **Loudness**
- **Pitch**
- **Gender**
- **Speaker identity**
- **Accent and other variance in pronunciation**
- **Etc...**
On the mental representation of “words”

- Words, in most cases, are complex entities.
- As a native speaker of your language, you have a huge amount of tacit knowledge about the possible internal structures of the words in your language.
Knowledge about the internal structure of words

$\text{right}_N$
Knowledge about the internal structure of words

copyright
Knowledge about the internal structure of words

copyright_{N}
Knowledge about the internal structure of words

copyright$_N$
Knowledge about the internal structure of words

copyrightable
Knowledge about the internal structure of words

uncopyrightable

What wrong with

- copyable
- rightable

- effortable
- eventable
- fortunable

-able attaches to verbs.

In order to make effortable sound OK, you need to be able to imagine a verbal use of effort.
Knowledge about the internal structure of words

- Covert vs. overt morphology
  - hard → harden
  - right → right
Knowledge about the internal structure of words

- Covert vs. overt morphology

  - teach → teacher
  - bake → baker
  - driver → driver
  - cook → cook∅ (NB the special meaning of ‘cooker’)

- What you see is not what you get -- much of your subconscious knowledge about language is knowledge about grammatical elements that aren’t even audible.
The neural bases of lexical access and morphology

Equipped with a theory about the internal structure of words we can manipulate the internal structure and investigate

- how the brain decomposes words into their constituent parts (i.e., morphemes)
- how the brain accesses the meanings of those constituents
- how the brain puts the parts back together.
MEG response to visual words

**Effects of low-level visual features** such as size and luminance.

“Visual feature analysis”

**Letter-string effects** “Visual word form area”

Form-based decomposition (anything that looks complex decomposes)

**Lexical effects:**
- Frequency
  (Embick et al., 2000, CBR)
- 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”
Knowledge about the internal structure of sentences

- Sentences are not word strings but are made up of constituents.

*What did the boys eat _? Burgers and fries.
*What did the boys eat _ and fries? Burgers
Burgers and fries the boys ate __.
*Burgers and the boys ate _ fries.
*Burgers the boys ate _ and fries. (bad with a flat intonation)
The famous Broca’s area

- When the structure of sentences is difficult, Broca’s area “lights up.”

  Consider

  *The juice that the child spilled stained the rug.* vs. *The child spilled the juice that stained the rug.*

- Due to this finding, Broca’s area is commonly thought of as the primary syntax related region in the brain.

- This popular notion is, however, in many ways problematic, as we will see later.
Knowledge about the internal structure of sentences

- Content morphemes: cat, dog, love, boy
- Function morphemes: the, for, -er, un-, ...

The **boy**'s **pick**ed up a **blender** from the **store**.

* The ___'s _____ing up a ______er from the _____.

- Grammaticality depends on function morphemes.
- We can detect ungrammaticality without understanding the content words of a sentence.
- The structure of a sentence depends on the function morphemes.
A finding from EEG

Wrong content morpheme: the brain responds around 400ms after the onset of the offending element

- Das Hemd wurde bebügelt.  
  *The shirt was 'ironed'.*

- Das Gewitter wurde gebügelt.  
  *The thunderstorm was ironed.*

Wrong function morpheme: the brain responds already at 130ms after the onset of the offending element

- Das Hemd wurde bebügelt.  
  *The shirt was 'ironed'.*

- Die Bluse wurde am gebügelt  
  *The blouse was on ironed.*
Knowledge about the meanings of sentences

Since humans are able to effortlessly understand and produce sentences that they’ve never encountered before, there must be some systematic way to predict the meanings of sentences from the meanings of their parts.

Frege’s Principle of Compositionality:

- The meaning of an expression is a function of the meanings of its parts and the way the part are syntactically combined.
The neural bases of semantic interpretation

- If the semantic interpretation of a sentence is so intimately intertwined with its syntactic structure, how can we ever design experiments that identify the neural bases of complex meaning construction, without confounding that with complex structure construction?

- An approach: try to find cases where the relationship between structure and meaning is not quite so tight.
Varying the transparency of semantic compositionality

<table>
<thead>
<tr>
<th></th>
<th>Transparent</th>
<th>Less transparent</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1a)</td>
<td>The author wrote a book.</td>
<td>The author began a book. ‘the author began reading/writing a book’</td>
</tr>
<tr>
<td>(1b)</td>
<td></td>
<td>‘the author began reading/writing a book’</td>
</tr>
<tr>
<td>(2a)</td>
<td>At 3 o’clock, the clown jumped.</td>
<td>For 3 hours, the clown jumped. ‘for 3 hours, the clown jumped over and over again’.</td>
</tr>
<tr>
<td>(2b)</td>
<td></td>
<td>‘for 3 hours, the clown jumped over and over again’.</td>
</tr>
<tr>
<td>(3a)</td>
<td>Bill was asleep.</td>
<td>In two minutes, Bill was asleep. ‘in two minutes, Bill came to be asleep.’</td>
</tr>
<tr>
<td>(3b)</td>
<td></td>
<td>‘in two minutes, Bill came to be asleep.’</td>
</tr>
</tbody>
</table>

Manipulating the transparency of compositionality is a way to vary the interpretation of a sentence while keeping its structure constant.
Ventromedial prefrontal cortex and Compositionality

- Expressions with less transparent meanings systematically elicit increased activity in ventromedial prefrontal cortex (vmPFC).

- The vmPFC is currently our best candidate for a region that computes complex semantic representations.
Are the mental representations and computations specific to language, or shared with other cognitive abilities?

- Can language be selectively impaired via brain damage?
  - Aphasias

- Can language be selective spared or impaired in genetic disorders?
  - Specific language impairment
  - Williams Syndrome (relative sparing of language)