LEXICAL ACCESS:
UNDERSTANDING AND SPEAKING WORDS

Cat!
Why studying speaking (production) is harder than studying understanding (comprehension)

• It is difficult to get participants to say specific things.

• Motion artifacts contaminate the electrophysiological signal.

➤ We know much more about the brain basis of lexical access in comprehension than in production.
THE CLASSIC MODEL OF LANGUAGE IN THE BRAIN

- Addressed the comprehension and production of words
- Aphasia = language impairment as a result of acquired brain damage (usually via stroke)
Paul Broca & Broca’s aphasia

- First localization of language function (1861).
- Patient could only produce a single syllable “tan”.
- Severe production problem.
  - Broca’s aphasia
- Lesion in the posterior part of the left inferior frontal gyrus
  - Broca’s area
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Production problems of Broca’s aphasia

- Slow, laborious, non-fluent speech. Output limited to short utterances of less than four words.
- Speech understanding and reading relatively intact, but writing is limited.

Broca’s aphasic writing sample.
Broca’s Aphasia
Wernicke’s aphasia

- A language problem distinct from Broca’s aphasia first described by Carl Wernicke (1874).
- Damage to the boundary of the temporal and parietal lobes --> Wernicke’s area.
- Fluent but disordered speech. Similar writing.
- Impaired understanding of speech. Impaired reading.
Wernicke’s aphasics
The classic model / Wernicke-Lichtheim model

Broca’s aphasia (non-fluent aphasia):
Ah ... Monday ... ah Dad and Paul [patient’s name] ... and Dad ... hospital. Two ... ah doctors ..., and ah ... thirty minutes ... and yes ... ah ... hospital. And, er Wednesday ... nine o’clock. And er Thursday, ten o’clock ... doctors. Two doctors ... and ah ... teeth. Yeah, ..., fine. (Goodglass, 1976)

Wernicke’s aphasia (fluent aphasia):
Examiner: What kind of work did you do before you came into the hospital?
Patient: Never, now mista oyge I wanna tell you this happened when happened when he rent. His - his kell come down here and is - he got ren something. It happened. In thesse ropiers were with him for hi - is friend - like was. And it just happened so I don’t know, he did not bring around anything. And he did not pay it. And he roden all o these arranjen from the pedis on from iss pescid. (Kertesz, 1981)
The classic model: Conduction aphasia

• Lesion to the arcuate fasciculus (= the bundle of nerves connecting Wernicke’s and Broca’s areas).
• Results in inability to repeat words, especially nonwords.
Lexical entry: the connection between sound and meaning

Question:
- What’s the nature of the connection? Is it something you could lose?
- I.e., is it possible to have both your sound representations and meaning representations intact but just not be able to connect them?
  - Aphasia evidence suggests yes.
Selective loss in linking sound to meaning in comprehension:

TRANSCORTICAL SENSORY APHASIA

Selective loss in linking meaning to sound in production:
ANOMIA
Transcortical sensory aphasia

- Auditory comprehension deficit in the absence of evidence of phonological impairment or semantic impairment.

- Word repetition is intact.
  - Requires accessing phonological representations but can be performed without access to semantic representations.

- Naming is intact (although this is debated).
  - Therefore:
    - Phonological representations are intact (as they can be used in production).
    - The route from meaning to sound is intact (but not vice versa).

- The sparing of repetition the main difference to Wernicke’s aphasia (where repetition is impaired).
Transcortical sensory aphasia

- Extremely rare form of aphasia; thus hard to study.
- However, has been successfully studied with so-called electrical interference
Inducing TSA with electrical interference

(Boatman et al. 2000)

- Stroke lesions typically involve multiple areas
- Focal, transient, lesions can be via induced electrical interference:
  - A low-level (10–15 mA) electrical current is generated for 5–10 s at a time, between pairs of electrodes located on the lateral surface of the cortex.
  - The current disrupts processing associated with the underlying brain tissue, causing a “functional” lesion for about 5 seconds.
- Downsides:
  - Invasive
  - Subject population limited to patients undergoing electrocortical mapping.
    - Electrical interference testing is routinely used to map speech and language functions in epilepsy patients implanted with subdural electrode arrays to assess their candidacy for focal resection surgery.
Inducing TSA with electrical interference
(Boatman et al. 2000, Transcortical sensory aphasia: revisited and revised, Brain)

All electrode locations (81 electrode pairs, range: 6-18 pairs per patient)

- Patients tested on:
  - Repetition
  - Picture naming
  - Auditory comprehension (‘move the green square’)
  - Word and paragraph reading
  - Spontaneous speech
  - Syllable discrimination
Inducing TSA with electrical interference
(Boatman et al. 2000, Transcortical sensory aphasia: revisited and revised, Brain)

Location of electrode sites where TSA was induced (auditory comprehension is impaired).

Intact: Repetition, syllable discrimination, speech, naming and word reading.
Sound-meaning interface in the Hickok & Poeppel (TiCS, 2004) model

Main argument: Transcortical sensory aphasia
Loss of naming: ANOMIA
Loss of naming: ANOMIA
Loss of naming: ANOMIA

- Comprehension:
  - In anomia, activation of meaning on the basis of sound is intact.
Loss of naming: ANOMIA

- Comprehension:
  - In anomia, activation of meaning on the basis of sound is intact.

- Production:
  - But activation of sound on the basis of meaning is impaired.
Lesion site most commonly left anterior temporal lobe (including the Ashcraft case report), although this is not a very strong generalization.

The impairment is often limited to specific semantic domains (e.g., fruits and vegetables).

**Loss of naming: ANOMIA**
Making sense of category specific naming deficits

- Category specific naming deficits suggest that different types of meanings are stored in different parts of the brain such that it is possible to lose the connection to sound from certain types of meanings but not others.

- This actually makes some sense given when we know about lexical access from psycholinguistics.
Lexical Decision Task

- Most common task in studies of lexical access
- Present string; is it a word or a nonword?
- Nonword foils must be plausible
  - Use “pseudowords”
  - Pronounceable
  - Conform to English orthographic rules (blicket)
Lexical Decision Task

- Encoding
- Lexical Access
- Decision
- Response
Semantic priming

Time

+ doctor +
+ +
+ nurse +

“yes”

“yes”
Semantic priming

Response Time

- Related: doctor-nurse
- Neutral: xxxx-nurse
- Unrelated: table-nurse
Spreading Activation Model

cradle
baby
bed
hospital
nurse
dentist
doctor
fever
rain
heat
sun
canary
bird
animal
mammal
ostrich
green
yellow
grass
Spreading Activation Model

cradle
baby
bed
hospital
nurse
dentist
doctor
delirium
fever
green
grass
rain
heat
sun
yellow
canary
bird
animal
mammal
ostrich
Semantic priming is highly automatic and occurs even in a mediated form:
LION primes STRIPES
(mediated by TIGER)

Evidence that the mental lexicon is organized into semantic fields.
So, each word activates not only its own representation, but also the representations of semantically related words.

The same holds for sound: each word activates a family of similar-sounding words.
Lexical access

Activation  Competition  Selection/Recognition

Stimulus: TURN

level of activation vs time

resting level
Lexical access in MEG

- If we manipulate the factors that affect lexical access during an MEG measurement, we see effects at ~300-350ms after word onset in left middle temporal cortex.

- This activity is known as M350 activity.
  - For example, the M350 peaks faster for repeated words, phonologically easy words and for frequent words (Pylkkänen et al., 2000, 2002; Embick et al., 2001).
Effect of frequency on lexical decision (Embick et al. 2000)

Reaction Time (ms)

Frequency Category (Frequent -- Infrequent)

1: number
2: ask
3: wheel
4: candle
5: clam
6: snarl
M350 data collected during the same experiment:

- Frequency Category (Frequent -- Infrequent)
  - 1: number
  - 2: ask
  - 3: wheel
  - 4: candle
  - 5: clam
  - 6: snarl

Latency (ms):
- 1: 700
- 2: 140
- 3: 30
- 4: 6
- 5: 1
- 6: 0.2

![Latency Chart](chart.png)
Auditory Production

These processing stages can be studied millisecond by millisecond with a technique like MEG or EEG.

At this point motion artifacts ruin the electrophysiological signal.

http://www.waseda.jp/wias/researchers/monthly/spot_r_verdonschot.html
Auditory Production

- When speaking, we plan ahead roughly two words at a time.
- Therefore, with electrophysiology, we can capture the activity associated with the planning of roughly two words in a relatively artifact-free manner.
- Your course project takes advantage of this fact.
“lemma” = the word in a syntactic and semantic sense (minus phonology)

“lexeme” = the actual phonological form of the word

[Note that linguists do not use the lemma/lexeme terminology but just talk about morphemes which map meanings to forms]
A meta-analysis of 58 neuroimaging studies of word production.

Willem J. M. Levelt PNAS 2001;98:13464-13471
Co-activation of related concepts
Similarity: priming and interference

- Interference occurs when there are multiple representation that could fit the stimulus.
- Comprehension:
  - Representations that sound or look like the stimulus compete for recognition: hearing “spinach” will activate SPIN and therefore SPIN interferes with the recognition of SPINACH.
- Production:
  - Semantically related concepts compete at the conceptual preparation/lexical section stage.
- Semantic similarity to a previous word is typically facilitory in comprehension and inhibitory in production.

Comprehension:
“horse” (activates COW so if you then hear) “cow” (it is responded to faster)

Production:
The concept horse is selected and related ones inhibited
Oops, I just inhibited cow but now I need to retrieve it ➔ slower
What about the bilingual brain?
What about the bilingual brain?

• It is intuitive that in a bilingual context (like the NYUAD campus where you speak a lot of English but then perhaps also your native language with some friends), each new social interaction forces you to choose one language and inhibit the other.

  - The degree to which you’ll inhibit the other language will depend on the details of the situation: if you are both fluent in both languages, you may switch back and forth pretty freely.

• But once a language has been chosen for a particular context, to what extent is the other language still active?
Brain potentials reveal unconscious translation during foreign-language comprehension

Guillaume Thierry*†‡ and Yan Jing Wu† PNAS, 2007

Whether the native language of bilingual individuals is active during second-language comprehension is the subject of lively debate. Studies of bilingualism have often used a mix of first- and second-language words, thereby creating an artificial “dual-language” context. Here, using event-related brain potentials, we demonstrate implicit access to the first language when bilinguals read words exclusively in their second language. Chinese–English bilinguals were required to decide whether English words presented in pairs were related in meaning or not; they were unaware of the fact that half of the words concealed a character repetition when translated into Chinese. Whereas the hidden factor failed to affect behavioral performance, it significantly modulated brain potentials in the expected direction, establishing that English words were automatically and unconsciously translated into Chinese. Critically, the same modulation was found in Chinese monolinguals reading the same words in Chinese, i.e., when Chinese character repetition was evident. Finally, we replicated this pattern of results in the auditory modality by using a listening comprehension task. These findings demonstrate that native-language activation is an unconscious correlate of second-language comprehension.
Experimental Design

Related in Meaning
Wood – Carpenter
木头 – 木匠
mu tou – mu jiang

Unrelated in Meaning
Ham – Train
火腿 – 火车
huo tui – huo che

Form related in Chinese

Unrelated in Chinese

Doctor – Nurse
医生 – 病人
yi sheng – bing ren

Rabbit – Pencil
兔子 – 钢笔
tu zi – gang bi

Indicate whether word pairs are related in meaning

Thierry and Wu, PNAS, 2007
Results

Semantics

Amplitude (µV)

Form in Chinese

English Natives
Chinese-English Bilinguals
Chinese Natives

Thierry & Wu PNAS, 2007  |  Wu & Thierry, J Neurosci, 2010
A follow-up study clarified that the form related effect was driven by the SOUNDS, not the CHARACTERS/orthography of the activated Chinese words.

In general, evidence largely supports the conclusion that both languages of a bi-lingual brain are to some extent active at all times.