Today’s question: How (and when) does context (semantic, syntactic, bilingual) influence word recognition?
- **When does it happen?** Approximately ~200ms of a word is necessary to identify it in context.

- Linguistic input is analyzed *incrementally*, word by word.

- Analysis occurs at multiple levels in parallel.

- Lexical items compete for selection in comprehension: **Multiple candidates activated in parallel.**
I’ll wait for you by the port.
I’ll wait for you by the port.
I’ll wait for you by the port.
→ **Homophony** is when two words are pronounced the same (homographs if they are written the same). Homophones have distinct, unrelated meanings. Example: port (wine) vs port (docks), pitcher (baseball) vs pitcher (beer).
Ambiguity in context

Said at a liquor store:

I’ll wait for you by the port.
→ **Exhaustive access**: when hearing an ambiguous word, all possible meanings are activated, and then the context helps you decide among these.

Said at a liquor store:

I’ll wait for you by the **port**.
Ambiguity in context

→ **Exhaustive access**: when hearing an ambiguous word, all possible meanings are activated, and then the context helps you decide among these.

Said at a liquor store:

*I’ll wait for you by the port.*
→ **Selective access**: context has a very early influence on lexical access processes, and you immediately identify the contextually-appropriate meaning. The other meanings are not activated in context.

Said at a liquor store:

**I’ll wait for you by the port.**
Priming: The facilitation of the processing of a stimulus when it is preceded by a related stimulus in, for example, a lexical decision task:

Semantic priming (related meaning)

DOG → CAT

Form priming (related phonology)

HAT → CAT

No priming (no association)

PILL → CAT
→ **Cross-modal priming:** Task in which prime and target are presented in different modalities:
Rumor had it that the government building had been plagued with problems. The man was not surprised when he found several bugs in the corner of his room.
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Rumor had it that the government building had been plagued with problems. The man was not surprised when he found several spiders, roaches, and other bugs in the corner of his room.

This context biases towards the ‘insect’ meaning. Is the ‘spy’ meaning *still* facilitated?
Rumor had it that the government building had been plagued with problems. The man was not surprised when he found several spiders, roaches, and other bugs in the corner of his room.
The time course of priming

→ **At short SOAs (stimulus onset asynchronies):** Priming was observed for both contextually related (ANT) and contextually inappropriate words (SPY). This was not seen for unambiguous words.

→ **At long SOAs (three syllables following critical word):** Priming was observed only for contextually related (ANT) words, for both ambiguous and unambiguous words.

**Graph:**
- Short SOA: Both meanings prime
- Long SOA: Appropriate meaning primes
→ **Exhaustive access**: when hearing an ambiguous word, all possible meanings are activated, and then the context helps you decide among these.

Said at a liquor store:

I’ll wait for you by the port.
Eye-tracking-while-reading
Your eyes move across text by alternating between fixations and saccades. **Fixations** are points of relative stability, where the eye is located on one position in the text. A fixation typically lasts around 150-250 milliseconds. **Saccades** are rapid ballistic movements that last around 25-40 milliseconds, during which you are functionally blind (**saccadic suppression**).
The fovea is ~ 2° of visual angle on either side of the point you are fixated. This is where visual acuity is greatest. The parafovea extends to 5° on either side, with diminished acuity. Peripheral vision is beyond that, with much degraded acuity.

Linguistic processing can happen in fovea or parafovea.

Figures: Schotter et al., 2012; Abbott & Staub, 2015
The fovea is ~ 2° of visual angle on either side of the point you are fixated. This is where visual acuity is greatest. The parafovea extends to 5° on either side, with diminished acuity. Peripheral vision is beyond that, with much degraded acuity.

Linguistic processing can happen in fovea or parafovea.

Lexical access time is a strong determinant of how long the eyes remain fixated on a word.

Figures: Schotter et al., 2012; Abbott & Staub, 2015
Competition in context

→ **Biased** homophones have one meaning that is dominant, or more frequent

→ **Equibiased** homophones have meanings that are more balanced in terms of frequency

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**port**

**pitcher**
Duffy et al. (1988)

Equibiased homophones: Slower reading compared to control word (whiskey)

Of course the **pitcher** was forgotten because it was kept on the shelf.

Last night the **port** was a great success when she served it.

Biased homophones: Not slower than control word (whiskey)
Of course the pitcher was forgotten because it was kept on the shelf
Last night the port was a great success when she served it

Slowdown reflects competition in meaning
Of course the **pitcher** was forgotten because it was kept on the shelf.

Last night the **port** was a great success when she served it.

Slowdown reflects competition in meaning.

Less of a competition here; no measurable slowdown.
Because it was kept on the back of a high shelf, the **pitcher** was ...

When she finally served it to her guests, the **port** was ...
Equibiated homophones: Not slower reading compared to control word (whiskey)

Because it was kept on the back of a high shelf, the *pitcher* was ...

When she finally served it to her guests, the *port* was ...

Biased homophones: Slower reading compared to control word (soup)
Context reinforces a highly accessible meaning. Competition is reduced because context + frequency both support ‘beer’ meaning.

Because it was kept on the back of a high shelf, the *pitcher* was …

When she finally served it to her guests, the *port* was …
Context reinforces a highly accessible meaning. Competition is reduced because context + frequency both support ‘beer’ meaning.

Because it was kept on the back of a high shelf, the *pitcher* was ...

When she finally served it to her guests, the *port* was ...

Context reinforces less accessible meaning. Competition is increased because context supports ‘liquor’ meaning while frequency supports ‘ship’ meaning.
Subordinate bias effect: If context supports a relatively infrequent meaning, processing time is slowed.

Because it was kept on the back of a high shelf, the *pitcher* was …

When she finally served it to her guests, the *port* was …
Reordered access:

→ All meanings of a homophonic word are activated, and ranked/activated based on their fit to the context and the frequency of the different meanings.

→ When there is a single highly activated candidate, processing is easy.

→ When many candidates are strongly activated, competition slows processing.

Because it was kept on the back of a high shelf, the **pitcher** was ...

When she finally served it to her guests, the **port** was ...
Syntax: A different type of context

noun

duck

verb
Is access exhaustive when the syntactic context rules out one lexical entry?

The game warden knew that the injured *duck* ...
The waiter spilled the **port** ...

Marcus asked the bartender for a bottle of **port** ...
The waiter spilled the **port** ...

Marcus asked the bartender for a bottle of **port** ...

The game warden knew that the injured **duck** ...

Eric went by the pond at the petting zoo to feed the **duck** ...

**Cross categorical noun-verb ambiguity:** No subordinate bias effect
Only the syntactically appropriate category was activated: Access may be exhaustive, but only within appropriate syntactic categories.

The game warden knew that the injured duck ...
Only the syntactically appropriate category was activated: *Access may be exhaustive, but only within appropriate syntactic categories*

The game warden knew that the injured *duck* ...
Since they really liked each other, they had a lovely **chat** that lasted all night.
Table 3
Sample Sentences Across Conditions

<table>
<thead>
<tr>
<th>Word type</th>
<th>Low-constraint sentence</th>
<th>High-constraint sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interlingual homographs</strong></td>
<td>Since they really liked each other, they had an extended chat that lasted all night.</td>
<td>Since they liked to gossip, they had an extended chat that lasted all night.</td>
</tr>
<tr>
<td>Target word</td>
<td>Since he was kind of bored, he made an extended tune that was very catchy.</td>
<td>Since he liked to compose songs, he made an extended tune that was very catchy.</td>
</tr>
<tr>
<td>Matched control</td>
<td>Because they owned a lot of property around the world, the expensive divorce was a disaster.</td>
<td>Because of the bitter custody battle over the kids, the expensive divorce was a disaster.</td>
</tr>
<tr>
<td>Matched control</td>
<td>Because her parents strongly disapproved of her decision, the expensive wedding was a disaster.</td>
<td>Because the maid of honor and best man were late, the expensive wedding was a disaster.</td>
</tr>
</tbody>
</table>

Table 8
Mean Values and Difference Scores for First Fixation Duration (FFD), First Pass Gaze Duration (GD), Skipping Proportion (Skip), Go-Past Time (GPT), and Total Reading Time (TRT) for Interlingual Homographs, Cognates, and Matched Control Words

<table>
<thead>
<tr>
<th>Word type</th>
<th>FFD</th>
<th>GD</th>
<th>Skip</th>
<th>GPT</th>
<th>TRT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High constraint</td>
<td>Low constraint</td>
<td>High constraint</td>
<td>Low constraint</td>
<td>High constraint</td>
</tr>
<tr>
<td><strong>Interlingual homographs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target</td>
<td>279</td>
<td>341</td>
<td>304</td>
<td>376</td>
<td>0.09</td>
</tr>
<tr>
<td>Control</td>
<td>262</td>
<td>320</td>
<td>282</td>
<td>339</td>
<td>0.11</td>
</tr>
<tr>
<td>Difference</td>
<td>17</td>
<td>21*</td>
<td>22*</td>
<td>37**</td>
<td>−0.02</td>
</tr>
<tr>
<td><strong>Cognate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target</td>
<td>229</td>
<td>307</td>
<td>261</td>
<td>329</td>
<td>0.06</td>
</tr>
<tr>
<td>Control</td>
<td>263</td>
<td>326</td>
<td>300</td>
<td>365</td>
<td>0.03</td>
</tr>
<tr>
<td>Difference</td>
<td>−34**</td>
<td>−19**</td>
<td>−39**</td>
<td>−36**</td>
<td>0.03*</td>
</tr>
</tbody>
</table>

* Planned comparison significant at the .05 level. ** Planned comparison significant at the .01 level.
Selective vs. non-selective lexical access

- **Semantic context**: Lexical access is initially non-selective. Multiple candidates consistent with input are activated, and can compete. Context can modulate this competition.

- **Syntactic context**: Lexical access may be selective: If true, only candidates consistent with syntactic input are activated, and can compete.

- **Language context**: Lexical access is initially non-selective for bilingual lexical access: Lexical items are initially activated regardless of whether they belong to a single language.
I like my coffee with cream and ...
I like my coffee with cream and ...  
sugar  
salt
→ **Cloze probability**: Proportion of respondents who continue a context with a given word.

→ **High cloze** probability words are easier to process as measured by EEG/ERPs, lexical decision tasks, *eye-movements during reading*....

I like my coffee with cream and ...

<table>
<thead>
<tr>
<th>sugar</th>
<th>High cloze probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>salt</td>
<td>Low cloze probability</td>
</tr>
</tbody>
</table>
He saw the black fin slice through the water and the image of sharks’ teeth came quickly to his mind. He turned quickly toward the shore and swam for his life. The coast guard had warned that someone had seen a shark ...

The young couple were delighted by the special attention they were getting. The zookeeper explained that the life span of a shark ...

High constraint context

Low constraint context
He saw the black fin slice through the water and the image of sharks’ teeth came quickly to his mind. He turned quickly toward the shore and swam for his life. The coast guard had warned that someone had seen a shark...

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<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>Average Fixation Duration (msec) on the Target Word as a Function of Context and Whether or Not There Was a Misspelling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High constraint</td>
</tr>
<tr>
<td>Control</td>
<td>221 (248)</td>
</tr>
<tr>
<td>Misspelling</td>
<td>315 (476)</td>
</tr>
</tbody>
</table>

Note. Values in parentheses indicate total reading time for the target word.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Probability of Fixating on the Target Word as a Function of Context and Whether or Not There Was a Misspelling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High constraint</td>
</tr>
<tr>
<td>Control</td>
<td>.51 (.54)</td>
</tr>
<tr>
<td>Misspelling</td>
<td>.50 (.75)</td>
</tr>
</tbody>
</table>

Note. Values in parentheses include regressions.
→ **Discrete guessing**: Guess a single highly probable word and expect that word.

I like my coffee with cream and ... 

sugar
I like my coffee with cream and ... 

splenda
biscuits sugar
agave
honey
cinnamon
→ **Discrete guessing**: Guess a single highly probable word and expect that word.

\[\text{Proposed relationships between predictability and reading time} \]

→ If a single word is predicted in proportion to its cloze probability, then the probability of being surprised should be a simple linear function of probability.
→ **Gradient activation:** Activate many words that are compatible with input, as a function of how much the context supports them.

![Proposed relationships between predictability and reading time](image)

→ If multiple words are preactivated as a function of their probability, then we should be sensitive to probability differences even at very low ends of the probability scale.

→ **For example:** Probabilities of 0.0001 and 0.00001 are both **very unlikely**, but one is still 10x likelier than the other.
Surprisal

→ **Surprisal:** \(-\log_2(w_i | w_1, \ldots w_{i-1} - 1)\)

→ Surprisal is a measure of the amount of ‘surprise’ associated with an event, such as a word in context.

→ **Low probability** words have high surprisal, high probability words have low surprisal.

→ Can be quantified with a language model that assigns a probability to a word in context.
→ Log probability linearly predicts gaze duration **over size orders of magnitude**.

→ Readers are sensitive to proportionally large probability differences even for very improbable words.

→ Consistent with gradient preactivation of words in context as a function of how likely they are to appear in context.
Syntactic expectations: Relative clauses

**Surprisal:**
- General index of information conveyed by an individual word, related to its log probability in context.
- Is estimated by a **language model:** Any probabilistic model that defines a probability distribution over a word in context. Can be...
  - **Structured:** Probabilistic Context Free Grammars (e.g. Levy, 2008)
  - **Neural:** LSTM / Transformer based neural architectures.

That’s the cat that the dog **likes**.

Difficulty $\propto -\log p(w_i | w_1, w_2, \ldots, w_{i-1})$
→ **Subject relative clauses:** Distance between filler and gap is short (both syntactically and linearly).

* I know **the cat** that __ attacked the terrier.*

→ **Object relative clauses:** Distance between filler and gap is longer (both syntactically and linearly).

* I know **the cat** that the terrier attacked __ .*
Object relative clauses are relatively infrequent in English: ~13% of all RCs in Brown Corpus (Hale, 2001).

Surprisal of a noun phrase after who is therefore high.

Figure 8: Object relative clause
Object relative clauses are relatively infrequent in English: ~13% of all RCs in Brown Corpus (Hale, 2001).

Surprisal of a noun phrase after who is therefore high.

Subject relative clauses are relatively frequent in English: ~86% of all RCs in Brown Corpus (Hale, 2001).

Surprisal of a verb after who is therefore (relatively) low.

Figure 7: Subject relative clause

Figure 8: Object relative clause
Syntactic expectations: Relative clauses

*I know the cat that the terrier attacked.*

→ Readers already encounter difficulty when they see the embedded subject in an object relative clause (data from Staub et al. 2017)
→ **Exhaustive access...**: All meanings with a word, even contextually inappropriate ones, are activated...

→ **... constrained by syntax**: ... if they are syntactically legal.

→ **Rapid effect of context**: Context rapidly modulates how activated word senses are in context.

→ **Active prediction / preactivation**: Context allows comprehenders to preactivate a wide range of probabilistically likely completions, conditioned by syntactic structure.
Frisson et al. (2017)

High constraint context

The young nervous paratrooper jumped out of the plane/chair ...

Low constraint context

The tired movie maker was sleeping in the plane/chair ...

→ In reading there we see no prediction error: a highly plausible continuation (chair) is read the same regardless of whether there is a highly predictable continuation.

→ Suggests that we reactivate possible continuations but we do not commit to them.

→ The debate continues, however: Cevoli et al. (2022) suggest that it is possible to see prediction error costs in some highly constraining contexts.
→ **Homophony** is when two words are pronounced the same (homographs if they are written the same). Homophones have distinct, unrelated meanings. Example: port (wine) vs port (docks), pitcher (baseball) vs pitcher (beer).

→ **Polysemy** is when a word has multiple distinct, but semantically related, senses. For example, a newspaper could be the printed form of the Hampshire Gazette, or it could be the organization that publishes the Hampshire Gazette.
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The **school** is made of brick. The **school** is taking a field trip.
Polysemy

Polysemous words can have dominant or balanced senses as well.

\[ \text{lamb} \quad \text{school} \]
Neither slower than the other. **No subordinate bias effect.**

After being a favorite for decades, the *film* didn’t seem very good now.

After being repeatedly exposed to light, the *film* didn’t seem very good now.