02.11.19: Lexical Access
Words are (at least) a pairing of Sound and Meaning

[k æ t] = the word “cat”

A fancier word for “meaning” is **semantics**, and when it comes to words, we call their meaning their **lexical semantics**.
Where is the meaning in the speech signal?

When you listen to speech, you certainly perceive a meaning. But where is it in the signal?

Here is a waveform of speech. Where is the meaning?

From Natasha Warner’s website:
The answer is it comes from your memory!

There is no way to actually transmit meaning in an acoustic signal. Therefore it must be the case that we have the meaning stored somewhere in our memory, paired with sound, and we look up the sound in our memory to find the meaning that is paired with it!

The physical signal does not contain any meaning.
What is the organization of the words stored in our memory?
We need to store words in memory

Human memory is complex. There are multiple different components to human memory, and it is an active area of research all on its own:

- **sensory** (< 1s)
- **short-term** (< 1min)
- **long-term** (indefinite)

*lexicon*: the section of long-term memory dedicated to storing words

- **declarative**
  - **episodic** (events)
  - **semantic** (concepts)
- **procedural** (skills)
Memory must be organized

Just like books in a library, the items stored in memory must be organized in order to be retrieved effectively.

Words are no different (they are items stored in memory). One major question for us then is **How are words organized in the lexicon?**
Thought experiment!

Imagine that you were asked to figure out the organizational system of books in the library. In other words, you need to figure out where each book is stored inside the library.

Now let’s make it difficult. Imagine that you aren’t allowed to physically go inside the library yourself.

You have to figure out how the books are organized without ever stepping foot inside!

Think about this for a moment. How can you figure out the organizational system of the library if you can’t see it for yourself?
This is exactly the problem we face when studying the lexicon.

Just like the library thought experiment, we can’t look inside the lexicon to see the organization of the lexical representations.

One solution you probably already thought of is to ask somebody else to go into the library for us.

If we send that person in to the library over and over again to get different books, and time how long it takes them to retrieve each book, we will get a rough idea as to the location of each book based on the time it takes to retrieve it.
Timing the retrieval of words: The Lexical Decision Task
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The lexical decision task: Stare at this cross. When it changes to letters, tell me whether the letters form a “word” or not.
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The Lexical Decision Task

**The lexical decision task:** Stare at this cross. When it changes to letters, tell me whether the letters form a “word” or not.

**The idea behind the task:** In order to say “yes” or “no”, you need to access the stored word. This means that the task will engage the processes necessary for lexical access.

If we measure the amount of time it takes to respond to a word (the reaction time), we can use it to make inferences about the processes that occurred during lexical access.
The logic of reaction times

Imagine a lexical decision experiment where we compare two words. All we can measure directly is how long it takes to say “yes” to each word. In the plots below, word 1 is recognized faster than word 2.

**word 1:**

```
start --+-- time --+-- button press
```

**Word 1 is recognized faster than word 2.**

**word 2:**

```
start --+-- time --+-- button press
```
The logic of reaction times

Even though the only thing we can directly measure is the button press, we can use logic to make inferences about the processes underlying the recognition of the two words.

If the two words differ in timing, then there must either be a quantitative or qualitative difference in processes.

**word 1:**

```
start  | process 1 | process 2 | process 3 |
```

**word 2:**

```
start  | process 1 | process 2 | process 3 | process 4 |
```
The logic of reaction times

Even though the only thing we can directly measure is the button press, we can use **logic** to make inferences about the processes underlying the recognition of the two words.

If the two words differ in timing, then there must either be a **quantitative** or **qualitative** difference in processes.

**word 1:**

```
start          time
process 1  process 2  process 3
```

**word 2:**

```
start          time
process 1  process 2  process 4
```

Difference in **quality** of processes
Organizational principle 1: Frequency
Word Frequency

The **frequency of occurrence** of a word is the number of times that a word occurs.

How do we calculate frequency?

A **corpus** is a collection of text that was written or spoken by people. It could be a set of phone conversations, a set of newspaper articles, or even a set of webpages.

### The First Hundred

| 1. the | 21. at | 41. there | 61. some | 81. my |
| 2. of | 22. be | 42. use | 62. her | 82. than |
| 3. and | 23. this | 43. an | 63. would | 83. first |
| 4. a | 24. have | 44. each | 64. make | 84. water |
| 5. to | 25. from | 45. which | 65. like | 85. been |
| 6. in | 26. or | 46. she | 66. him | 86. call |
| 7. is | 27. one | 47. do | 67. into | 87. who |
| 8. you | 28. had | 48. how | 68. time | 88. oil |
| 9. that | 29. by | 49. their | 69. has | 89. its |
| 10. it | 30. word | 50. if | 70. look | 90. now |
| 11. he | 31. but | 51. will | 71. two | 91. find |
| 12. was | 32. not | 52. up | 72. more | 92. long |
| 13. for | 33. what | 53. other | 73. write | 93. down |
| 14. on | 34. all | 54. about | 74. go | 94. day |
| 15. are | 35. were | 55. out | 75. see | 95. did |
| 16. as | 36. we | 56. many | 76. number | 96. get |
| 17. with | 37. when | 57. then | 77. no | 97. come |
| 18. his | 38. your | 58. them | 78. way | 98. made |
| 19. they | 39. can | 59. these | 79. could | 99. may |
| 20. I | 40. said | 60. so | 80. people | 100. part |
One of the earliest properties that was discovered to affect lexical access is **frequency of occurrence**: the number of times that a word appears.

**The frequency effect:**

- **High frequency** words have faster lexical decision times.
- **Low frequency** words have slower lexical decision times.
Here’s another way to graph it

As the **frequency** of a word **increases** (x-axis), **recognition time decreases** (y-axis)

In other words, you are **faster** at recognizing **higher frequency** words.

This graph is from the 1951 paper (Howes and Solomon) that first proposed frequency as a predictor of lexical decision time.

The frequency effect is robust, and seems to hold for every language. However, you have to be sure that frequency is the only property of the words that varies. If other properties vary (e.g., length), the frequency effect can be washed out.
The advantage of frequency as an organizing principle

Databases like phonebooks and dictionaries are organized alphabetically. But our personal dictionary (the lexicon) appears to be organized by frequency. Why?

It actually makes some sense. If you have to retrieve items often (e.g., words), then you will want the items that are used the most often to be the easiest to retrieve.

Phonebooks and dictionaries are created so that every entry can be accessed equally easily. But we don’t need all words to be equal. There are some that we never use (e.g., defenestrate). The lexicon appears to be organized to maximize efficiency, not equality.
Organizational Principle 2: Semantics/Meaning
What’s up with word-association?

**Word Association Task:**

I’ll say a word, and you tell me the *first* word that pops in your head.

You can look this up yourself at: http://www.eat.rl.ac.uk/
What about Taboo?

Play It!
A semantic network is simply the idea that words (or concepts) are connected based on their semantic relatedness.
A semantic network

street

vehicle

car

bus

ambulance

fire engine

blue

red

fire

house

fire engine

truck
A semantic network
A semantic network

- street
- truck
- fire engine
- bus
- car
- ambulance
- fire
- blue
- red
- house
A semantic network
A semantic network

street

vehicle

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fire
A semantic network

- street
- vehicle
- car
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- bus
- ambulance
- fire engine
- house
- blue
- red
- fire
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- street
- vehicle
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- fire
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- street
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- bus
- truck
- ambulance
- fire engine
- house
- blue
- red
- fire
Spreading Activation is a process by which nodes in the network activate nodes that they are connected to.
Spreading Activation

- street
- vehicle
- car
- truck
- bus
- ambulance
- fire engine
- house
- blue
- red
- fire
At each step, the activation decreases, because the concept is not as strongly associated.
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Explaining Taboo with Semantic Networks and Spreading Activation

The difficulty lies in the number of steps necessary to get from legal words to the target word!
We can show this formally with Semantic Priming

**Semantic Priming:** Words that are semantically related to each other make each other faster during lexical decision!

No relationship: this is the normal recognition time for **truck**

Semantically related: **truck** is recognized faster here!
Semantic Priming

Bus primes truck, because accessing bus activates truck, making truck easier to access.
Chair does not prime truck, because truck and chair are not closely related.
Some Conclusions

Words are (at least) a pairing of sound and meaning.

The speech signal only contains sound, so the sound/meaning pair must be stored in your memory!

The lexicon is the section of long-term memory dedicated to storing words.

**Organizational Principle 1:** The frequency effect suggests that the lexicon is organized according to the frequency of words.

**Organizational Principle 2:** Semantic priming suggests that the lexicon is organized according to the semantics/meaning of words.