What’s in a Sentence?

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Why study sentence processing?
Enraged Cow Injures Farmer With Ax

Why study sentence processing?
• We constantly process sentences.
• We ask our patients with aphasia to do it.
• It’s a complex process that involves many aspects of language and cognition.
• For some, study of processing is a means to a different end for computer programs, AI, AAC, etc.

Two Worlds
• Research vs. clinical
• Ideally (EBP) these are not completely separated.
• But research doesn’t generally use a lot of real world tasks.
• Will discuss implications.
Several different tasks we ask people to do in the “clinical” world.

• Follow directions
• Respond “yes” or “no.”
• Point to pictures
• Complete a sentence.

• But note that our BDAE/WAB tasks ALSO are not the same tasks we do as comprehenders outside the clinic.

How do we process sentences?

• There are structural theories and process theories.
• One theory suggested that we process syntax first, then semantics; that we process clauses separately.
• Others suggest that we access both syntax and semantics simultaneously, more of an interactive type of model.

How do researchers study sentence processing?

• Often with ambiguity – shows the use of strategies when there is a problem.
• The horse raced past the barn fell. (Garden Path)
  – The horse runs past the barn
  – The horse fell down (and it was the horse that someone put in a race)
• The old man the boat.
  – The old who happens to be old....
  – The boat is manned by the old.
• Buffalo....

Studies with these types of sentences shows that do create both representations when processing the sentence.
Buffalo who live in Buffalo (e.g., at the Buffalo Zoo, which does, indeed, have buffalo), and who are buffalized by other buffalo from Buffalo, themselves buffalo still other buffalo from Buffalo.

How do researchers study sentence processing?
• Also with ungrammaticalism.

• What kinds of behavioral or other observations are made when an individual is confronted with either a “good” sentence or a sentence that has errors?

• Methods of study show differences in processing.... Focus today.

Several different ways we can present a sentence
• Auditory versus visual
• Whole sentence
• Word by word
• Several other means that we’ll discuss.

• Real world:
• Auditory: We hear sentences in real time; does not remain available to us
• Reading: We employ our own strategies but the sentence remains available to us.
Syntax and Semantics: Actives and Passives: Reversibility

1. *The woman read the book.*
2. *The book read the woman.*
   - Only one is capable of being the agent. Animacy of the subject matters... we know #2 is incorrect even before we get to the word “woman.”
3. *The dog chased the cat.*
4. *The cat chased the dog.*
   - Either one is capable of being the agent.

Syntax and Semantics: Actives and Passives: Reversibility

1. The mouse ate the cheese
2. The cheese was eaten by the mouse.
3. *The mouse was eaten by the cheese*
4. The girl chased the boy
5. The boy was chased by the girl.
6. *The girl was chased by the cheese*
   - Can interpret #2 without utilizing syntax.
   - Obvious issues with #3
   - MUST use syntax to comprehend #(4), 5, 6.

Can there be ONLY semantic errors?
(of course there can.)

• John ate hot dogs and popcorn at the ball game.
• *John ate hot dogs and trees at the ball game.*

• Semantic plausibility is part of our judgment as we derive meaning in sentence processing.
• Semantic aspects (e.g. reversibility) can impact processing speed/accuracy.
Complex interplay

- Syntax—word order
- Semantics—word selection and meaning.

- As noted, we use both to comprehend.

- Different modalities may complicate things further.
  - Auditory: Adds prosodic features, which helps.
  - Reading: Less memory demand, which helps.

Purpose today

- Review some of the different tasks we use to study sentence processing
- What do they actually involve?
- What "hidden" skills can be examined?
- What technology is used to examine this?

- So if my patient can’t do my sentence task… where might the problem actually BE?
“Skeleton”

Tasks
• Picture pointing
• Object manipulation
• Grammaticality judgment
• Whole Sentence Comprehension
• Self Paced Reading
• Rapid Serial Visual Presentation
• Monitor for unrelated event.

Responses and Technology
• Eye gaze/movement
• Pupillometry
• ERP
• fMRI

Tasks
• Picture pointing.
• Can vary:
  — Length of utterance
  — Content of utterance
  — Number in field
  — Frequency of items in sentence
• Often the task is primarily LEXICAL until it gets more complex.

Examples of stimuli
• Show me the carrot
• Point to the rutabaga
• Point to the dog
• Show me the boxer
• Before you point to the dog, point to the car.
• Before you point to the rutabaga, point to the dromedary.
• Point to the one that we eat.
• Show me the one in the living room.
• The cat is in the box.
Requirements

• Task is AFTER THE FACT
  – Memory
  – Processing vs Retention

• Task involves SEMANTICS
  – Can patient do task without even using syntax?
  – Does semantic knowledge influence accuracy?
  – Foils can be set up to vary semantics.

• Revised BDAE, CAT

The shonk was eating the prate.

The shonk was ooking the prate.
The shonk was ooking the prate.

Caramazza and Zurif, 1976

- Found that patients with aphasia made more errors in matching sentences to pictures when the sentences were semantically plausible despite syntactic misinterpretation (reversible) or improbable, and far fewer errors when the sentence could be interpreted via semantic analysis alone.

- This study was one of the first to describe the importance of semantics AND syntax on sentence comprehension in patients with aphasia.

- Problem: Limited foils.
Task: Object manipulation

- Use of toy animals or small models to manipulate in response to questions
- “The elephant kissed the lion.”
- Participant makes his own foils, essentially.
- Increases the number of possible errors as compared to picture pointing.
- Not worried about the verb but more focus on the agent-object/agent-theme assignment.
- Still requires retention vs comprehension

Relevant research – Object manipulation

Used a wide variety of sentence types and asked patients with varying sites of lesion to “demonstrate” what was happening in the sentence.

Active – 2-place
   The frog hit the monkey.
Active – 3-place
   The rabbit passed the cow to the goat.
Cleft object
   It was the cow that the rabbit kissed.
Passive
   The elephant was given to the monkey by the frog.

Caplan et al. (1996)

- Using this object manipulation task, they found no relationship between lesion site and comprehension ability.
- (Did find high level of agreement in performance in object manipulation task with picture-pointing task.)
- Perhaps site of lesion wasn’t so important to comprehension as previously thought.
Other ways to measure whole sentence processing

- Grammaticality judgment
- Can the person correctly indicate if a sentence is “good” or “bad?”
- Historically a task used by linguists
- Task used for study of patients with aphasia (Linebarger, Schwartz and Saffran) among others.
- Patients with aphasia can often indicate grammaticality of sentence structures that they cannot comprehend.
- Suggested that multiple levels of syntactic analysis must exist.

  
  A whole-sentence grammaticality judgment task where patients were asked to indicate if a sentence presented auditorily was good (point to happy face) or bad (point to sad face).
  - Untimed.
  - Found that patients with aphasia were able to judge grammaticality of sentence structures that they could not comprehend.
  - Suggested that there were multiple levels of processing in these patients and that the problem with aphasic comprehension was in “mapping” syntactic structures to thematic roles.

Modality of presentation matters

GJ is an off-line task, but if RTs are measured, there is less conscious reflection.

- Differences in reaction times to a GJ task can inform us about the cognitive and linguistic load of various types of sentences.
- Reading whole sentences ≠ word by word ≠ phrase by phrase ≠ auditory. Different modalities ≠ different task requirements.
- Normals often show LONGER GJ times with ungrammaticality in auditory GJ and SHORTER GJ times with ungrammatical sentences in whole sentence reading task (proofreading).
Whole Sentence GJ

- Whether timed or not... it is after the fact – like picture pointing and object manipulation
- Still reflective—not the same kind of processing as in real time sentence processing.
  - Ss is asked to make a judgment, not simply read/listen.
- “Off Line” as opposed to “On Line” processing

- “Postinterpretive Processing” versus “Interpretive Processing” (Caplan & Waters, 1999)

Whole Sentence GJ task

Passive sentences in quiet and two distraction environments: Cafeteria noise and Narrative

Compared RTs with regard to semantic variable (reversibility), memory manipulation (location of padding) and attention (distraction)

Whole Sentence GJ

- The truck was driven by the woman. (nonrever)
- The photographer was noticed by the actor. (rever)
  - (Processing of these two is already different)

- Added extra words ... Inside and outside. “Padding”
  - On the old country road, the truck was driven by the woman.
  - The photographer was quietly but still quickly noticed by the actor.
  - Location changes memory requirements.
  - Half good, half bad; 1/3 padding in, 1/3 padding out.
  - Half reversible, half not.
Faster RTs in Talk distraction, especially for Nonreversible sentences.

Slowest RTs in Quiet for Good Reversible sentences.

But a whole sentence task doesn’t tell us much about what happens DURING actual processing.

Word Monitoring

- Best used for auditory. On-line as opposed to off-line.
- Present a word... participant listens for the word during presentation of the sentence and presses a key when the word is detected.
- Ungrammaticality disrupts normal processing, as long as the Ss perceives the ungrammaticality.
- We do not comprehend sentences after the fact = interpretive vs. postinterpretive processing.
- We comprehend them AS THEY UNFOLD.
• Baum, SR (1989) On-line sensitivity to local and long-distance syntactic dependencies in Broca's aphasia. *Brain and Language, 37:2, 327-338*

• Experiment involved patients with aphasia as well as normal controls. They monitored for a word in simple and complex sentences, where half of the sentences had errors.

• Complex sentences: Errors crossed clausal boundaries, such as:
  - *Old.* The dog that the cat chased down the hall were chewing the *old* baseball.
  - *Sweet.* The chef in the fancy restaurant were baking *sweet* cookies.

• Baum, SR (1989) On-line sensitivity to local and long-distance syntactic dependencies in Broca's aphasia. *Brain and Language, 37:2, 327-338*

• Normals’ word-monitoring RTs were *slower to target words in ungrammatical sentences* for both types of sentences.
  – The ungrammaticality disrupted processing, which was then reflected in the word monitoring reaction time.
  – Ungrammaticality disrupts on-line processing.

• Aphasic subjects had slower RTS to words in the simple sentences, but not in the complex sentences.
  – Processing for the more complex sentences not disrupted... they could not comprehend/process the more complex structures.

Using a word monitoring task, they examined the effects of stress and word class (open or closed) on word monitoring in normal and aphasic individuals. (n = 8, n = 8)
Created two tape recordings – paired sentences with one in each. Identical sentences with high stress and low stress productions of identified words... half the time the to-be-monitored-for word was high stress, and the other half it was low stress.

Normal subjects’ word monitoring was faster in words with higher stress; no differences in word class.

Patients with aphasia responded faster to stressed as well, but also to open class words, regardless of stress.

**Self Paced Reading**

- Participant is in charge of the rate of presentation of words.
- Press a key and more of the sentence appears.
  - Words may disappear
  - Words may remain
- Measure RTs to keypresses to make judgments about processing time for the word involved.
- Allows measures of processing time throughout the sentence.
- **Example**

  Relevant research
  • Participants completed self-paced reading of garden-path sentences.
  • Selected contextually/grammatically inappropriate words... increased reading time.
  • Paired musical chords with segments of self paced task.
  • When harmonically unexpected chords were presented with structurally unexpected words, RTs were much slower.
  • Showed similarity in underlying processing for both music and syntax.
Rapid serial visual presentation

• Computer program presents words to the participant.
• Each word for a given interval (it then disappears).
• More closely represents auditory—the words do disappear.
• Participant does not control the pacing.
• Removal of prosodic features which would affect processing (if the task were auditory).
• Often paired with another task.

Monitoring for an unrelated event.

• Usually added to another task.
• Example: Add some kind of linguistic or nonlinguistic task DURING another processing task.
  — Shape identification
  — Shape discrimination
  — Lexical decision
• Differences in RTs to the unrelated event provide insights into the cognitive/processing demand of the stimulus sentence.
• RSVP example

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• Used RSVP and a shape discrimination task to compare processing times for good and bad sentences of the following structures.
• In quiet and in normal and disordered narrative.
• Anomaly
  — Trees, families and neighbors were cooking * on the patio.
  — The necklace, earrings and bracelet were sitting * on the dresser.
• Auxiliary
  — Frank is reading * the newspaper
  — Frank are reading * the newspaper
• Copula
  – Nancy is a * gourmet cook
  – Nancy are a * gourmet cook

• Regular plural
  – The doctors are examining * the patient
  – The doctors is examining * the patient

• Irregular plurals
  – The children are opening * the holiday candy
  – The children is opening * the holiday candy

• Passive
  – The musicians were impressed by the singers * in the choir
  – The musicians were impressed the singers * in the choir

Same or Different

Distraction  Grammaticality
Eye tracking/eye movement

- Response method.
- Utilizes equipment that is calibrated to measure eye gaze in terms of timing and degree.
- Technology used in advertising – what do customers look at and for how long?
- Also used to measure attention to visual field – either for selection of objects or for measuring timing for reading.
- Advertising demo
Eye tracking/eye movement

- Does not rely upon limb movement.
- Eye movement often the best preserved movement pattern – can assess comprehension in patients who otherwise cannot indicate.
- Participants don’t have to “do” anything special – just read.
- Technology used to evaluate effectiveness of advertisements, etc. What do people look at and for how long?
- Differences in gaze duration indicative of longer processing time.

http://arts.ucalgary.ca/lrc/research/equipment-and-facilities

http://www.ecu.edu/cs-hhp/exss/VML.cfm

http://www.massgeneral.org/psychiatry/research/neuroimaging_equipment.aspx

- Discussed the eye fixations and movements and how they can be used to determine processing.
- Eye movements are different in silent versus oral reading
- Multiple measures available, multiple variables and substantial debate in the literature.
- Modifications of stimuli to reduce some of these variables.
Examined eye movements in reading of sentences with low and high probability word combinations ("transitional probability") as rated by an independent group of similar participants.

One way to avoid confusion is to make the changes during vacation. (High)
One way to avoid discovery is to make the changes during vacation. (Low)

Longer fixation times in low probability combinations. A word’s predictability influences how quickly it is processed.

**Pupillometry**

- Changes in pupil size occur with task demand.
- Technology has been available for > 40 years.
  - Sensitive to memory demand, syntactic complexity
  - No volitional motor response required.
  - Participant does not have to “do” anything except attend to task while pupils are monitored for changes.

[Image of a head with a device on it]

[Website link: http://www.lfe.mw.tum.de/en/research/labs/pupil]
Examined pupil reactions in older and younger subjects hearing and repeating sentences like:

- The gambler who signaled the dealer revealed the card. (subj rel)
- The gambler who the dealer signaled revealed the card. (obj rel)
- Also in a digit recall task

Both age groups showed pupillary changes with increased memory load in the digit task.

- Only the younger group showed longer pupillary response times to more syntactically difficult sentences.
- Could not be attributed to differences in older pupils, but thought to reflect a dissociation between the two types of memory (lists vs syntax)

**ERP**

Event Related Brain Potential

- Uses EEG technology to examine brain functions.
- Evoked response potential.
- Simpler stimuli best... more complex will invoke more brain responses.
- Put on a pretty cap and listen to or read sentences... EEG pattern is generated and analyzed.
Measured ERPs in sentences where the final word was contextually appropriate or not.

- Expected, same category; unexpected, same category, or different category.
- Would there be differences in aging?

Authors state that it is difficult to classify ERP results in connected speech due to uncertainty of specific time of word onset and multiple analyses are required.

Note pattern of “negativity” (reduction in activity) between 250 and 600 ms.

However, there was less negativity (or reduction in activity) in expected completions, with more negativity in unexpected within-category, and more negativity in those outside the category (younger SS).
fMRI

- MRI measures oxygenation of tissue
- fMRI pairs traditional MRI with tasks in real time.
- Measures of volumes of tissue involves
- Data management complex and time dependent.
- Simple stimuli necessary...more complex will invoke more brain responses.

Used fMRI to examine different brain responses to form and content, by measuring responses to sentences such as the following:

Trees can grow. Trees can grew. Trees can eat.
Analysis involves subtraction of common activation from processing of auditory stimuli and attention to task... commonalities across all stimuli.

Necessary to determine what underlying brain functions were responsible for any differences in response to these specific stimuli.

Found that syntactic anomaly triggered reaction around Broca’s area...

Semantic anomaly triggered reaction among multiple sites, including Wernicke’s area.

Who cares? So what?

- Different stimulus paradigms
  - “unnatural” presentations
    - Compare precise aspects of sentence processing to specific measures.

- Increasingly sophisticated technology
  - “unconventional” measures
    - What really goes on inside people’s brains while they are comprehending language?

- By necessity, research limits context and task, so that measures can be made.
- By necessity, administration of a BDAE/WAB also limits context and task, so that measures can be made.

“The patient comprehends everything I say to him.”

- He very well may NOT, if comprehension is limited to syntactic decoding alone.
- He probably uses strategies (semantics, intonation) to make up for that which is difficult (syntax).

- Typical adults also show variations in performance even when they are unimpaired.
- Insights regarding the relationship between cognitive demand and language processing.
An appreciation of the complexity involved in sentence processing leads to greater appreciation of the complexity of what we do every day when we comprehend.

Thank You.
Questions?
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