

Experimental and Computational Methods in Linguistic Research

Spring 2025

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Week 5

Agenda

- Sentence processing
- Ambiguity and “illusion”
- Self-paced reading task

Review on word processing

- Lexical access
- Lexical access in context

Word processing

Prime

'butter'

Target

'shark'

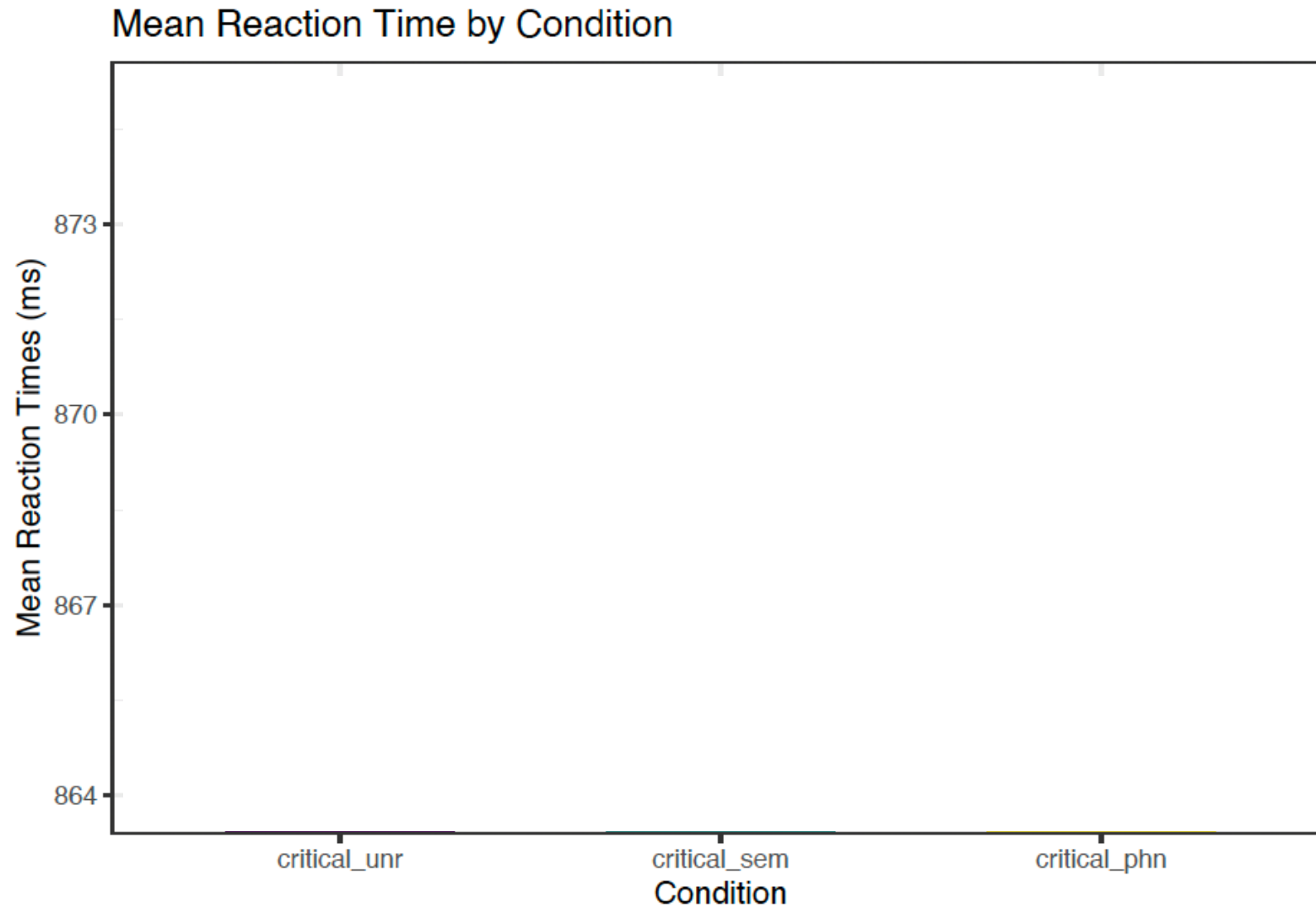
Reaction time (activation)

baseline

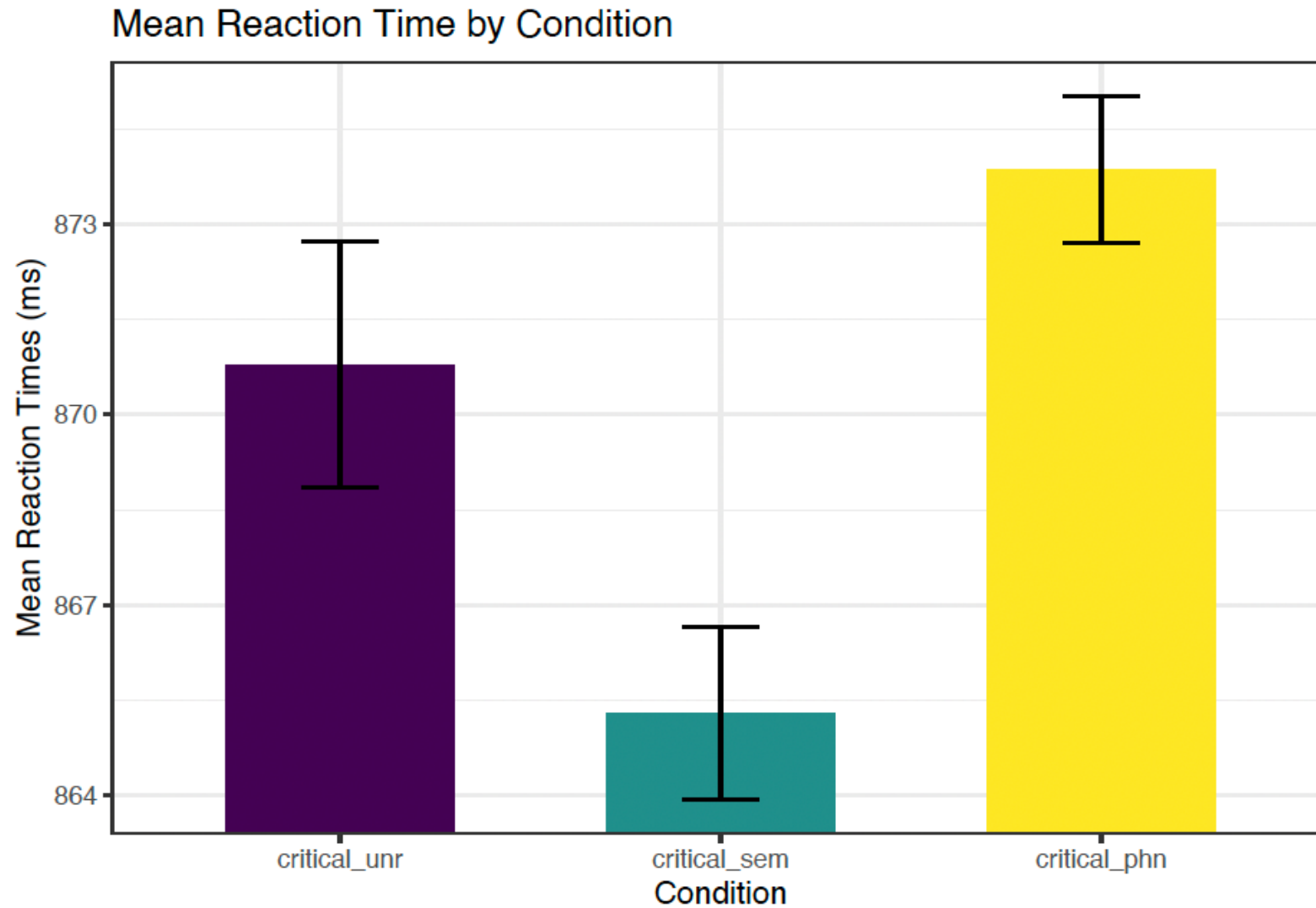
Word processing

<u>Prime</u>	<u>Target</u>	<u>Reaction time (activation)</u>
'butter'	'shark'	baseline
'whale'	'shark'	
'sharp'	'shark'	

Word processing



Word processing



Word processing

<u>Prime</u>	<u>Target</u>	<u>Reaction time (activation)</u>
'butter'	'shark'	baseline
'whale'	'shark'	faster than baseline (facilitation)
'sharp'	'shark'	slower than baseline (inhibition)

Word processing

- **Priming effect:** (roughly speaking) A facilitation or inhibition of mental representations due to recent exposure to certain inputs.

<u>Prime</u>	<u>Target</u>	<u>Reaction time (activation)</u>
'butter'	'shark'	baseline
'whale'	'shark'	faster than baseline (facilitation)
'sharp'	'shark'	slower than baseline (inhibition)

Word processing in context

- Ex: Federmeier & Kutas (1999)

prefix	expected	within_category	between_category
Ann wanted to treat her foreign guests to an all-American pie. She went out in the back yard and picked some	apples	oranges	carrots
Every morning, Jack makes himself a glass of fresh-squeezed juice. He keeps his refrigerator stocked with	oranges	apples	tomatoes
Sheila loves the taste of home-made spaghetti sauce. She decided to start growing her own	tomatoes	carrots	apples
They told the little boy it was Bugs Bunny's favorite food. But he still didn't want to eat his	carrots	tomatoes	oranges

A note on Assignment 4

- Tokenization
 - “carrots” doesn’t exist in the vocabulary?

```
from transformers import AutoTokenizer

tokenizer = AutoTokenizer.from_pretrained("bert-base-uncased")

word = "carrots"
tokens = tokenizer.tokenize(word)
print(tokens)

['carrot', '##s']
```

A note on Assignment 4

- Check out the Bonus section in `word-prediction.ipynb` if you want to avoid the tokenization problem.

```
[ ] from transformers import AutoTokenizer, AutoModelForMaskedLM
import torch

tokenizer = AutoTokenizer.from_pretrained('bert-base-uncased')
lang_model = AutoModelForMaskedLM.from_pretrained('bert-base-uncased')

def fill_mask_target(model_name, seq, target_words, tokenizer, lang_model):
    sequence = seq.replace('[MASK]', tokenizer.mask_token)
    inputs = tokenizer(sequence, return_tensors="pt")
    mask_token_index = torch.where(inputs["input_ids"] == tokenizer.mask_token_id)[1]
    token_logits = lang_model(**inputs).logits
    mask_token_logits = token_logits[0, mask_token_index, :]
    probs = mask_token_logits.softmax(dim=1)

    target_ids = dict()
    for word in target_words:
        if 'roberta' in model_name:
            target_ids[word] = tokenizer.encode(' ' + word)[1]
        else:
            target_ids[word] = tokenizer.encode(word)[1]

    target_probs = dict()
    for k, v in target_ids.items():
        target_probs[k] = round(probs[0, v].item(), 4)
    return target_probs

[ ] seq = df.loc[0]['prefix'] + " [MASK]."
print(seq)
fill_mask_target('bert-base-uncased', seq, ["apples", "oranges", "carrots"], tokenizer, lang_model)['apples']
```

Sentence processing

Language comprehension



Many Groups Promised Federal Aid Still Have No Funds and No Answers

Judicial rulings have unfrozen some grants awaited by nonprofits, states and companies, but the reprieve has been uneven and many fear the relief is only temporary.

Work to turn an old church into an emergency shelter in Jackson, Miss., is on hold after funding from the Environmental Protection Agency was frozen. Imani Khayyam for The New York Times

What happened when you read the title?

Why does this happen?

Why legal writing is so awful

Never attribute to malice what can be explained by mere convenience

"It is understood by lessees standing liable for violating obligations inter se, hereinbefore set forth in clause 3 of this real estate agreement, that lessors shall be exempt from liability for any damages, to the maximum extent not prohibited by law, unless lessors knew of the possibility of such damage and acted with scienter."

"Tenants understand that landlords will be exempt from liability for any damages to the extent allowed by law, unless landlords knew of the possibility of such damage and acted willfully."

Why are these difficult to understand?

These pictures of a one-day-old baby
orangutan with its mother is the cutest thing
you'll see today



Friday, September 04, 2015 - 06:47 PM

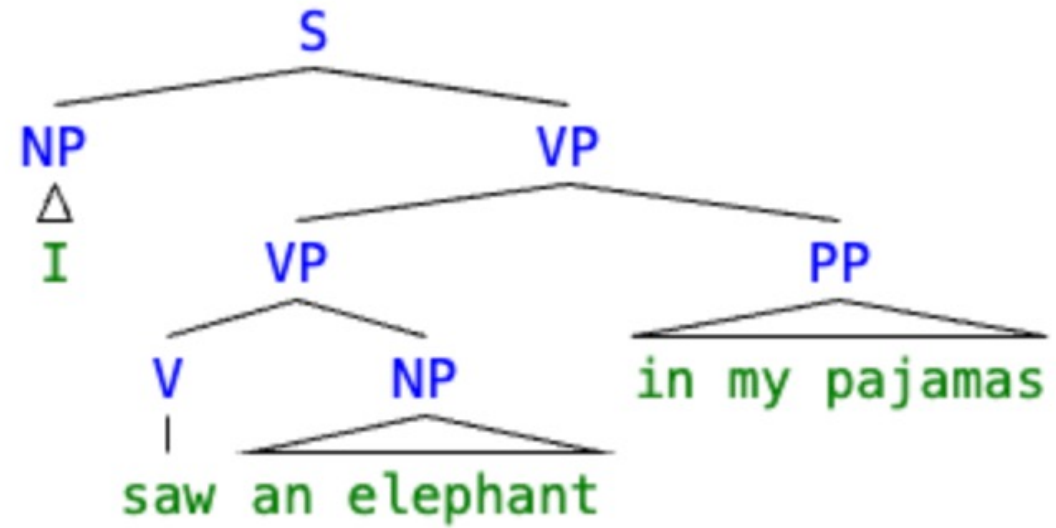
- (1) a. The glorks were in the bucket on the counter.
b. The glorks was in the bucket on the counter.

Is one sound better than the other? Why is that?

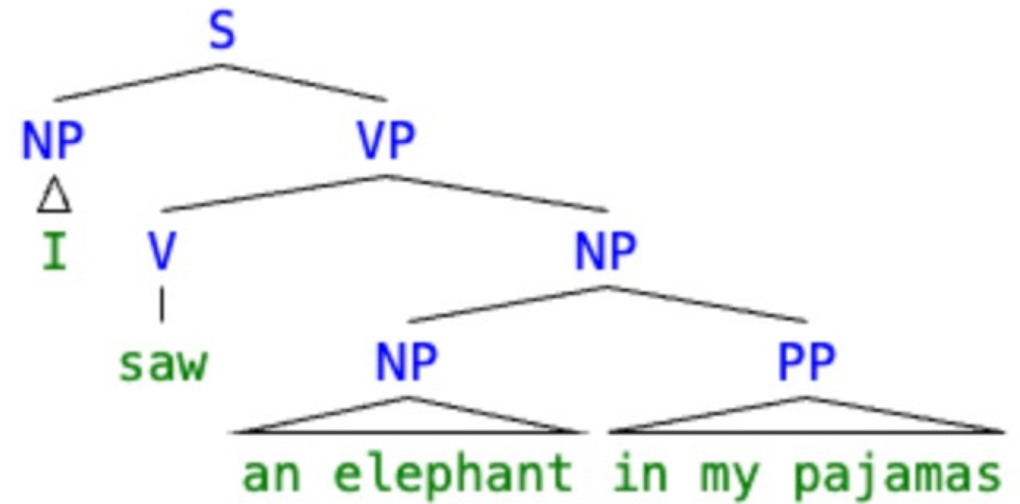
How do we have this judgment when we don't know what *glorks* mean?

- I saw an elephant in my pajamas!

- I saw an elephant in my pajamas!



- I saw an elephant in my pajamas!



Complexity, ambiguity, and error

- These phenomena have been used as a “window” to understand how the mind works in language comprehension.
- The way humans deal with linguistic ambiguity, errors, and complex structure has been useful for understanding how language is understood (i.e., comprehended) in real time.
- These phenomena are given unique names!

Some of psycholinguists' favorite phenomena

1. Long-distance dependencies (1960s –)
2. Garden-path phenomenon (1970s –)
3. Attachment ambiguity (1970s –)
4. Grammatical illusion (2000s –)

Science & technology | The language of the law

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These pictures of a one-day-old baby orangutan with its mother is the cutest thing you'll see today



Friday, September 04, 2015 - 06:47 PM

Long-distance dependency

- The landlord needs to be responsible.
- The landlord who owns the property needs to be responsible.
- The landlord who owns the property that violates safety codes needs to be responsible.

Long-distance dependency

- The landlord needs to be responsible.
- The landlord [who owns the property] needs to be responsible.
- The landlord [who owns the property [that violates safety codes]] needs to be responsible.

Garden-path sentences



*Many Groups Promised Federal Aid
Still Have No Funds and No Answers*

- Many groups (that was) promised federal aid still have no funds

Garden-path sentences



*Many Groups Promised Federal Aid
Still Have No Funds and No Answers*

- How do we study this phenomenon?
- What kind of reading study can we use?
- Where and what should we be measuring?

Self-paced reading task

- <https://farm.pcibex.net/p/plaBFD/>

Self-paced reading task

- **Reading times** (RTs) spent at each “**word region**” are measured.
- Longer RTs commonly indicate cognitive load and processing costs (e.g., complex structures, ungrammatical sentences, etc.).

Self-paced reading task

- When Susan tripped the singer stopped and picked her up.
- Where is the “**critical region**” (i.e., the word region you will be able to observe the ambiguity effect)?
- ‘stopped’

Self-paced reading task

- When Susan tripped the singer stopped and picked her up.
- How do we design this experiment? What type of structures do we need?

Self-paced reading task

- Condition A1:

When Susan tripped the singer stopped and picked her up.

- Condition B1:

When Susan fell the singer stopped and picked her up.

- ‘fell’: Always an intransitive verb; no object is expected; ‘the singer’ is expected to be the subject of a new clause; hence, seeing ‘stopped’ is not so surprising.

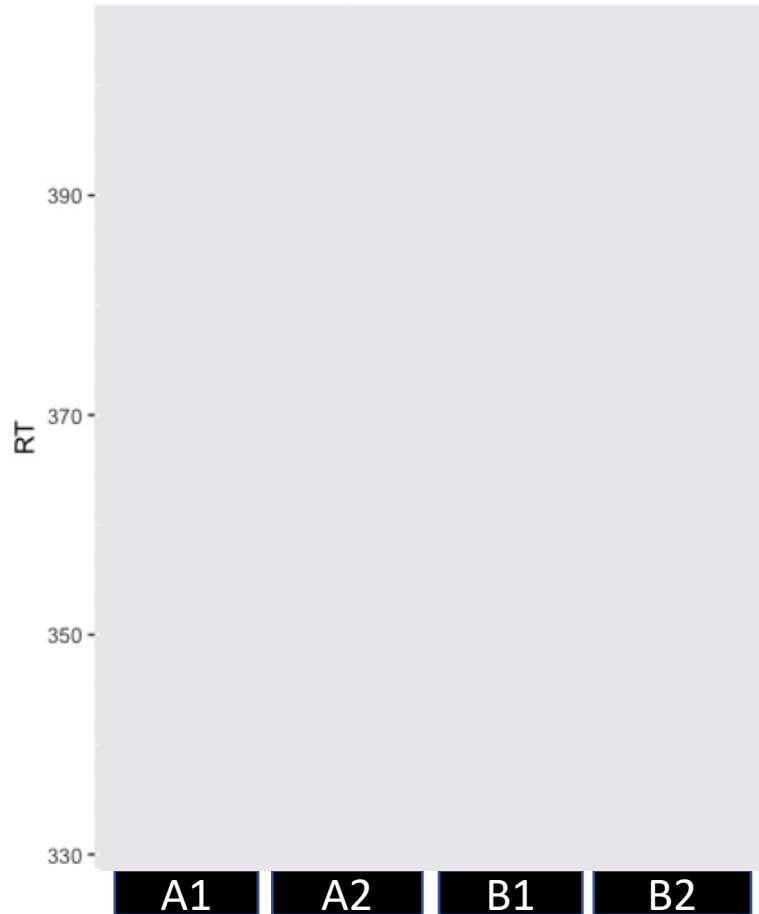
Self-paced reading task

- Condition A2:
When Susan tripped, the singer stopped and picked her up.
- Condition B2:
When Susan fell, the singer stopped and picked her up.
- Comma leads to an intransitive reading for 'tripped'; no ambiguity is expected.

Self-paced reading task

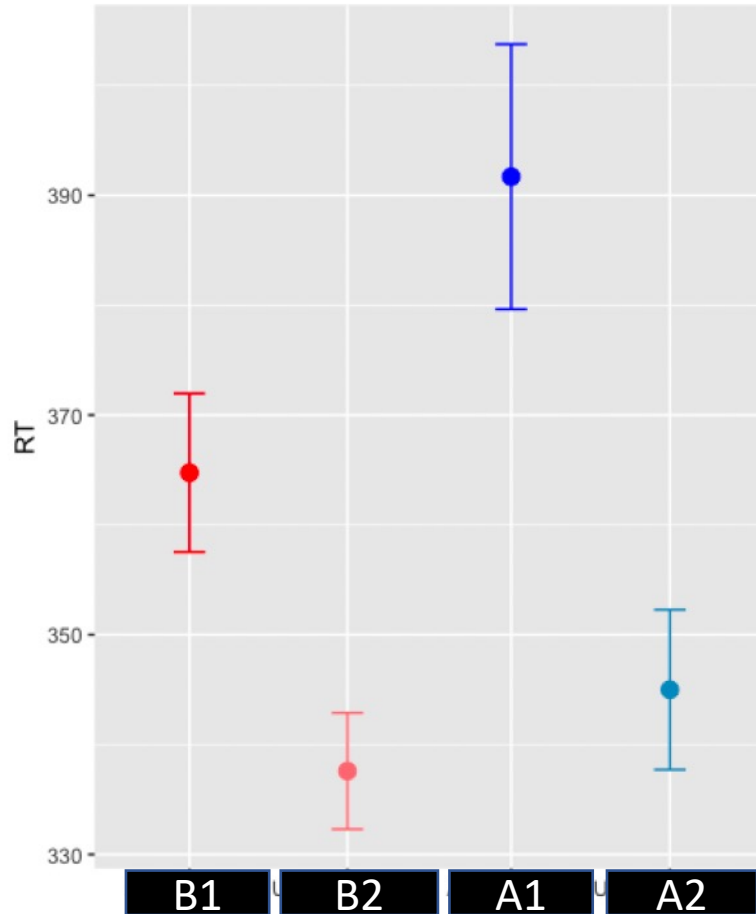
- Condition A1 (without comma):
When Susan tripped the singer stopped and picked her up.
- Condition A2 (with a comma):
When Susan tripped, the singer stopped and picked her up.
- Condition B1 (without comma):
When Susan fell the singer stopped and picked her up.
- Condition B2 (with a comma):
When Susan fell, the singer stopped and picked her up.

Self-paced reading task ('stopped')



- Condition A1 (without comma):
When Susan tripped the singer stopped and picked her up.
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When Susan tripped, the singer stopped and picked her up.
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Self-paced reading task ('stopped')



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When Susan tripped, the singer stopped and picked her up.
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When Susan fell the singer stopped and picked her up.
- Condition B2 (with a comma):
When Susan fell, the singer stopped and picked her up.

Sentence comprehension

- Identify the question
- Choose a method, e.g., a self-paced reading task
- Identify the “critical region”
- Design (baseline vs. control conditions)
- Compare reading times

Grammatical illusions

- Empirical cases summarized in Phillips et al. (2011):
 - **Number agreement attraction effect**
 - Case marking
 - Pronoun
 - Negative polarity items
 - Comparatives
 - Etc.

Number agreement attraction effect

- (a) The key to the cabinet was rusty.
- (b) The key to the cabinets was rusty.
- (c) The key to the cabinet were rusty.
- (d) The key to the cabinets were rusty.

Number agreement attraction effect

- Prediction on the reading time @was/were (+1)?

- (a) **The key** to the cabinet **was** rusty.
- (b) **The key** to the cabinets **was** rusty.
- (c) ***The key** to the cabinet **were** rusty.
- (d) ***The key** to the cabinets **were** rusty.

- (The most common pattern:) (c) > (d) > (a) ≈ (b)

Number agreement attraction effect

- Prediction on the reading time @was/were (+1)?

(c) ***The key** to the cabinet **were** rusty.

(d) ***The key** to the cabinets **were** rusty.



Number agreement

Number agreement attraction effect

- Prediction on the reading time @was/were (+1)?

(c) ***The key** to the cabinet **were** rusty.

(d) ***The key** to the cabinets **were** rusty.

“attractor” (also called as the “distractor”)

Number agreement attraction effect

How is this designed?

- (a) **The key** to the cabinet **was** rusty.
- (b) **The key** to the cabinets **was** rusty.
- (c) ***The key** to the cabinet **were** rusty.
- (d) ***The key** to the cabinets **were** rusty.

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A full account of the attraction effect should address (at least) the two following observations:

- (The most common pattern:) (c) > (d) > (a) \approx (b)

Number agreement attraction effect

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- (The most common pattern:) $(c) > (d) > (a) \approx (b)$

Number agreement attraction effect

- Wagers et al. (2009) (also (16 & 18) in Phillips et al. (2011)):

(a) The key to the cabinet unsurprisingly were on the table.

(b) The key to the cabinets unsurprisingly were on the table.

Self-paced reading task, reading time @'were' (+1): (a) > (b).

Experimental design and stimuli creation

- **The waitress who sat near the girl was happy.**
- What kind of design and material can we use to test the number agreement attraction effect?

Demo & Assignment 5