Now you see it, now you don't:

What the specificity of two linguistic illusions can tell us about sentence processing

Hanna Muller

Answer the question

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The basic phenomenon

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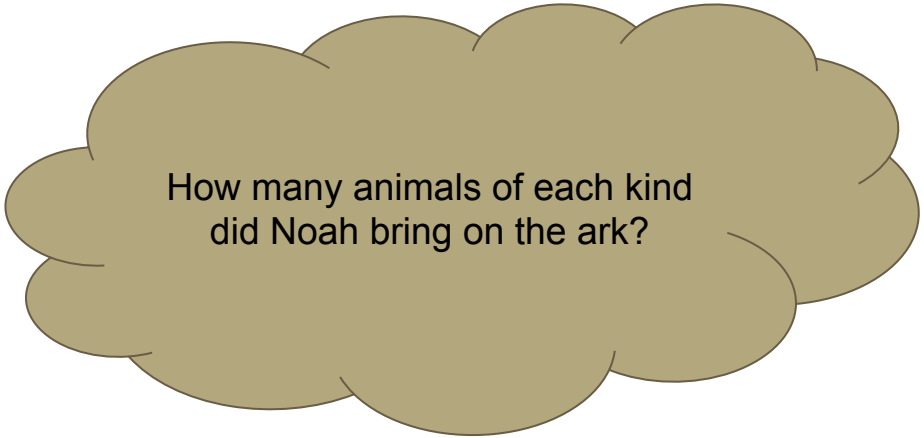

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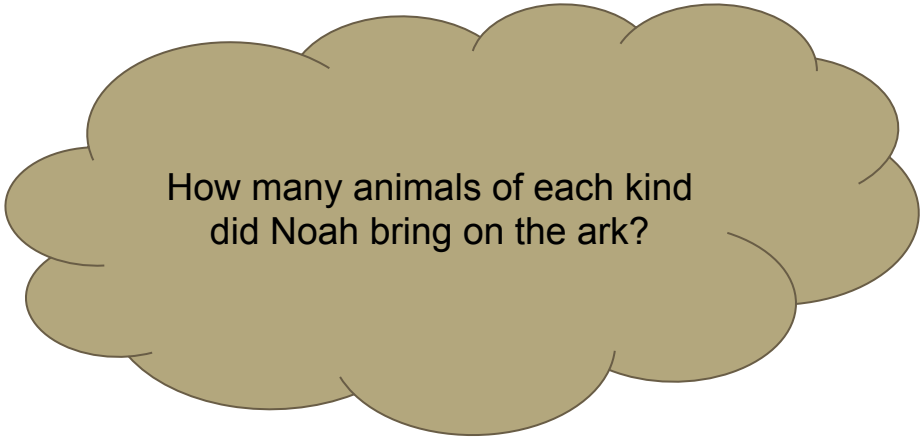
The basic phenomenon = The Moses Illusion



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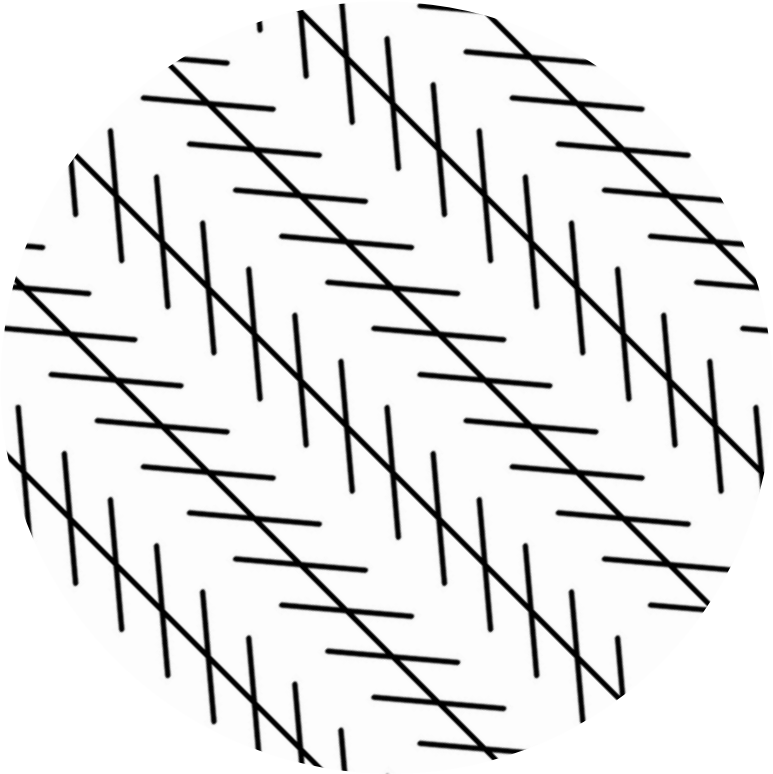
Illusions



Zöllner, 1860

The plan for today

1. Intro to linguistic illusions
2. Selective failures: the view from NPI illusions
    a. NPI illusion basics
    b. The licensor effect
    c. The distance effect
3. How can we “turn off” the Moses illusion?
    a. Item-wise variability
    b. Correlates of vulnerability
    c. Next steps

NPI illusions

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(1) a. I don't have a dog.

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Other words are more restricted, e.g. *ever*

(2) a. I haven't ever had a dog.

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(1) a. I don't have a dog.

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Other words are more restricted, e.g. *any*

(2) a. I don't have any dogs.

b. * I have any dogs.

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Most words can occur in positive or negative contexts, e.g. *dog*

(1) a. I don't have a dog.

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Other words/phrases are more restricted, e.g. *in years*

(2) a. I haven't adopted a dog in years.

b. * I have adopted a dog in years.

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Most words can occur in positive or negative contexts, e.g. *dog*

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Other words/phrases are more restricted, e.g. *lift a finger*

(2) a. I cleaned the house all afternoon and my dog didn't lift a finger.

b. * I cleaned the house all afternoon and my dog lifted a finger.

NPI background

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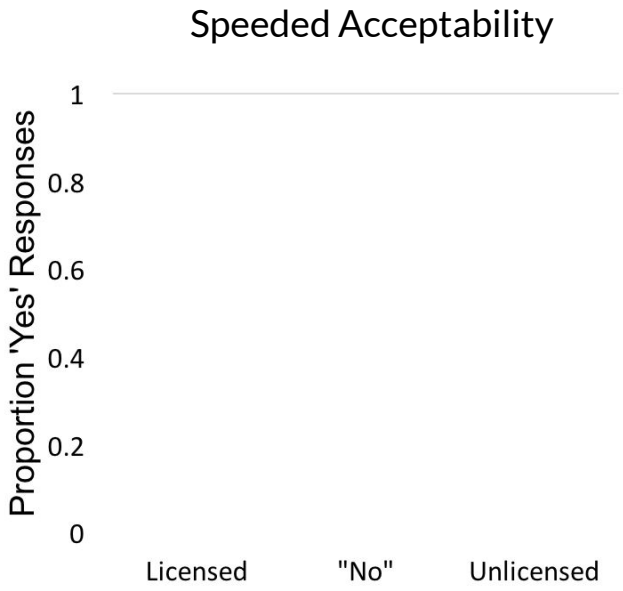

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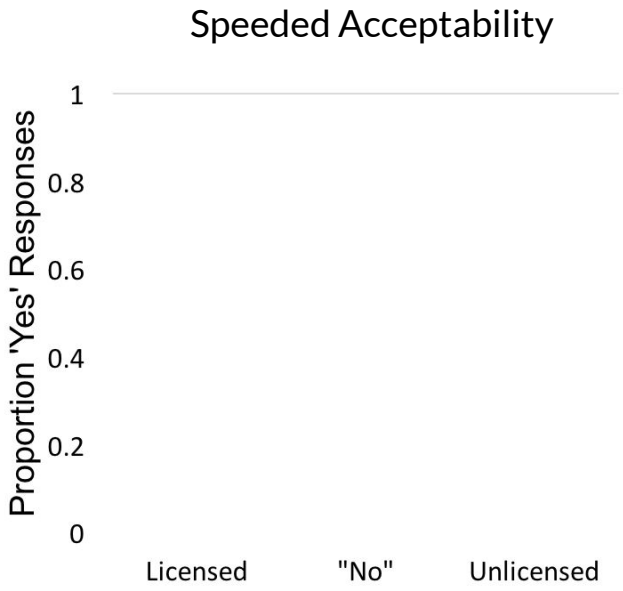

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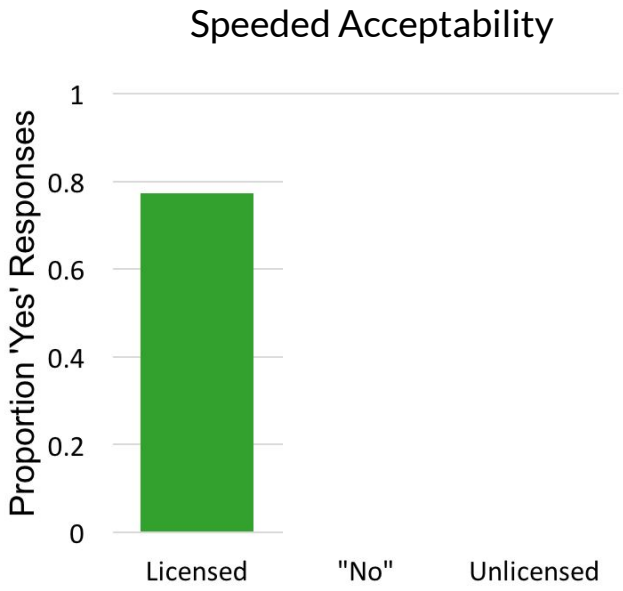

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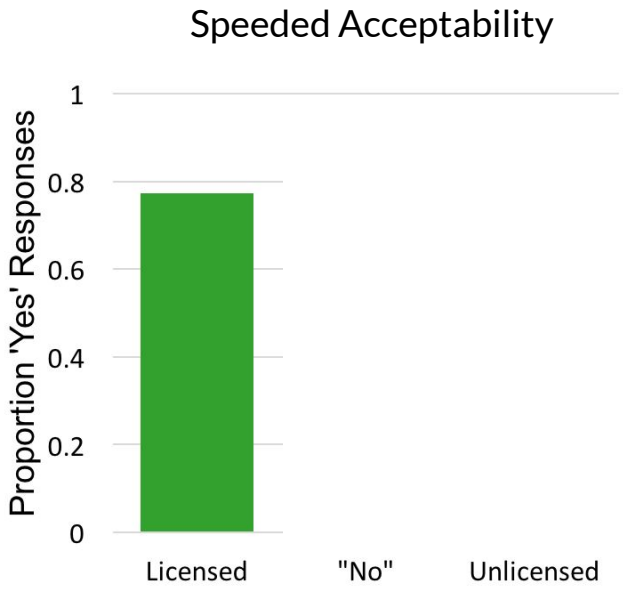

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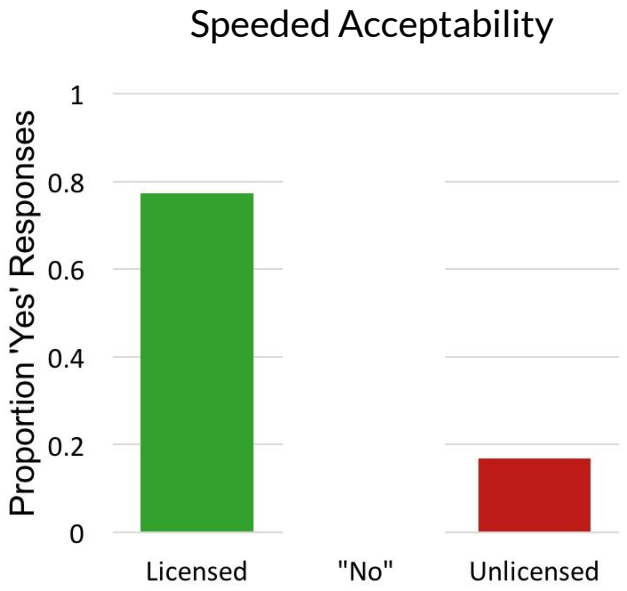

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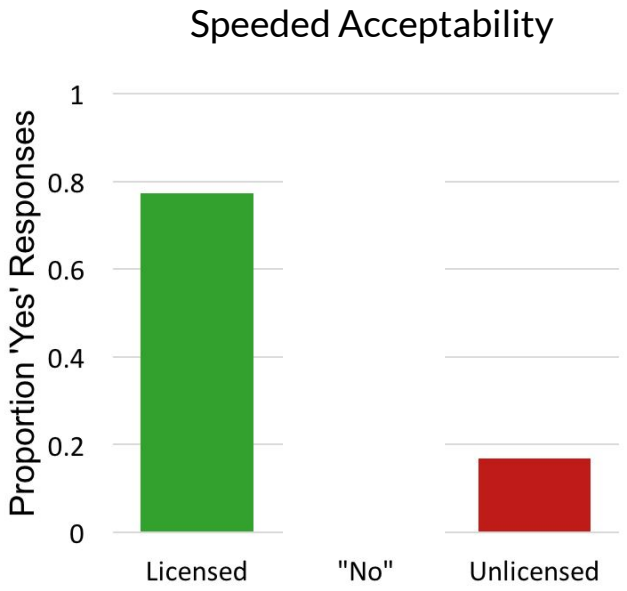

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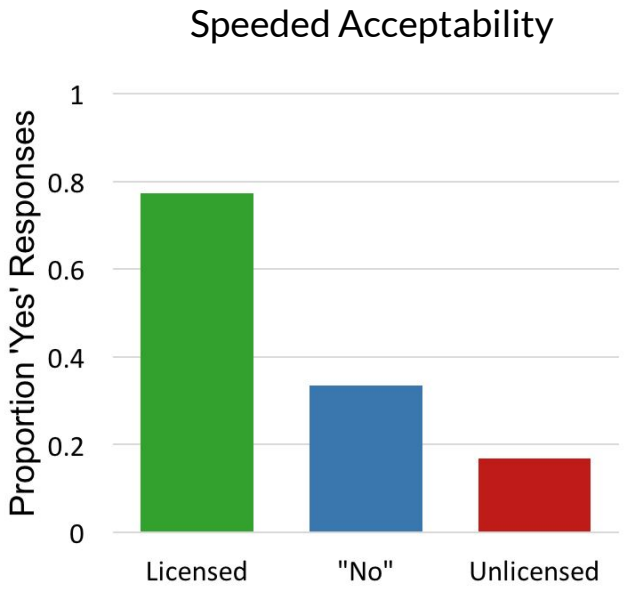

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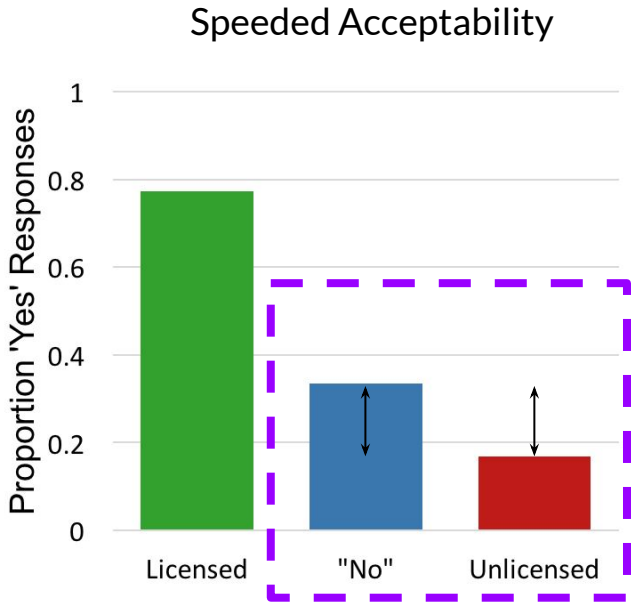

German: Drenhaus et al. 2005; *English*: de-Dios-Flores et al. 2017; Hildebrandt & Husband 2019; Muller et al. 2019; Orth et al. 2020a; Parker & Phillips 2016; Xiang et al. 2006; *Korean*: Yun et al. 2018

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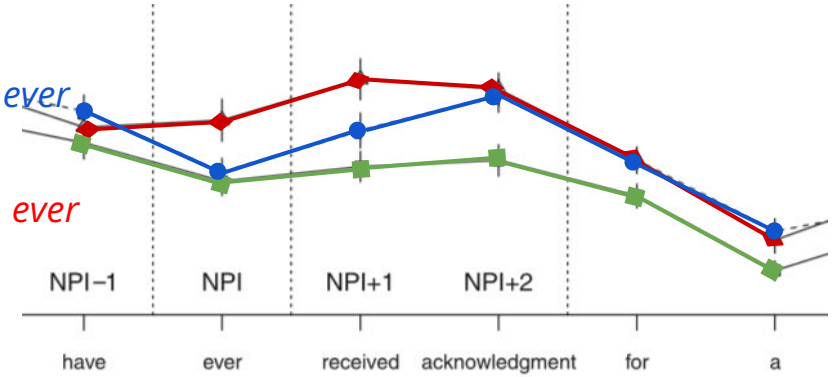

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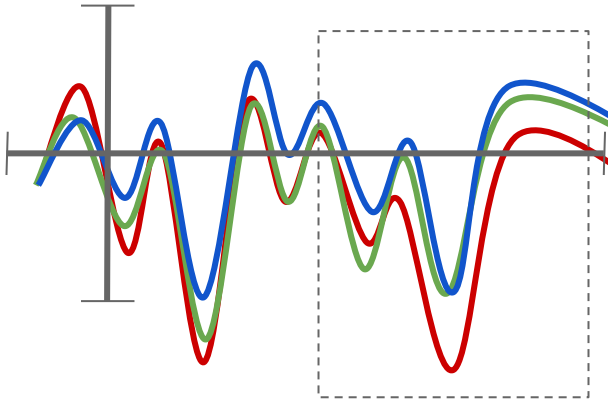

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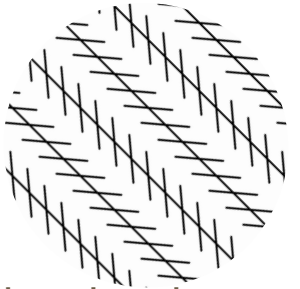

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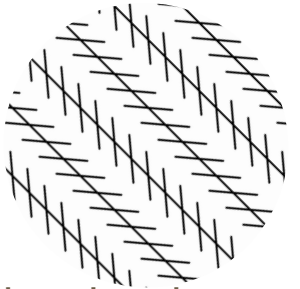

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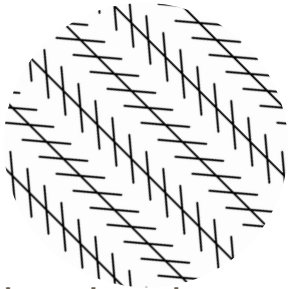

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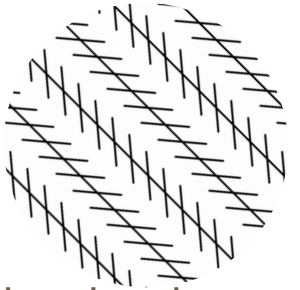

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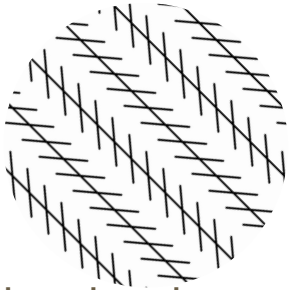

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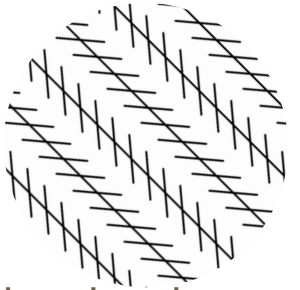

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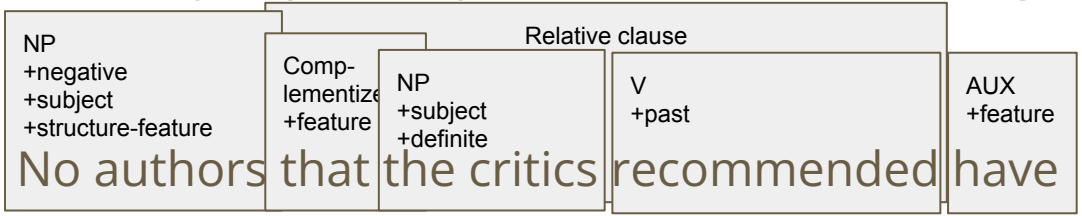

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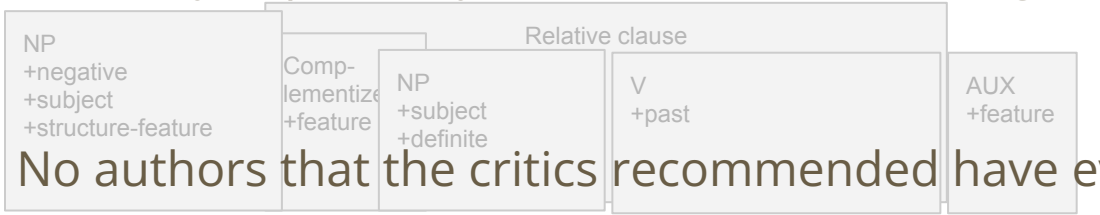

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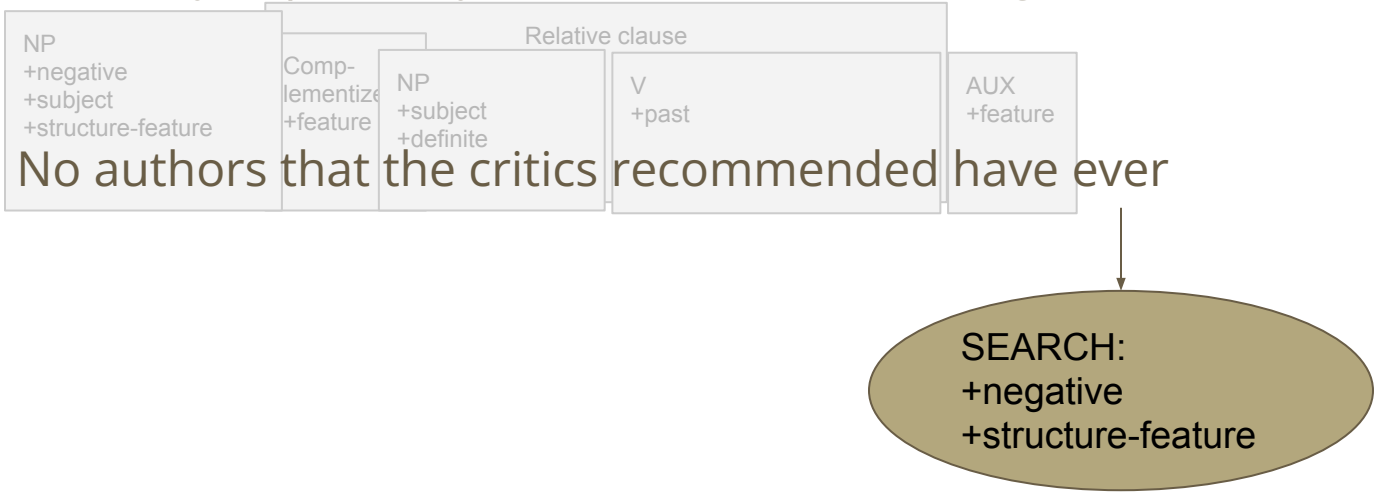

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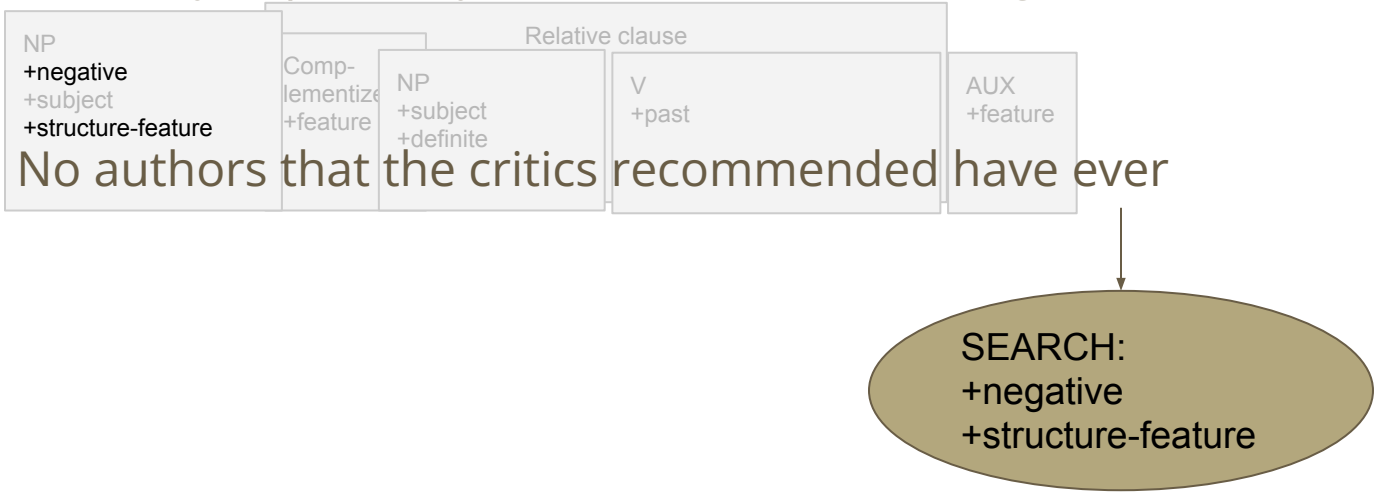

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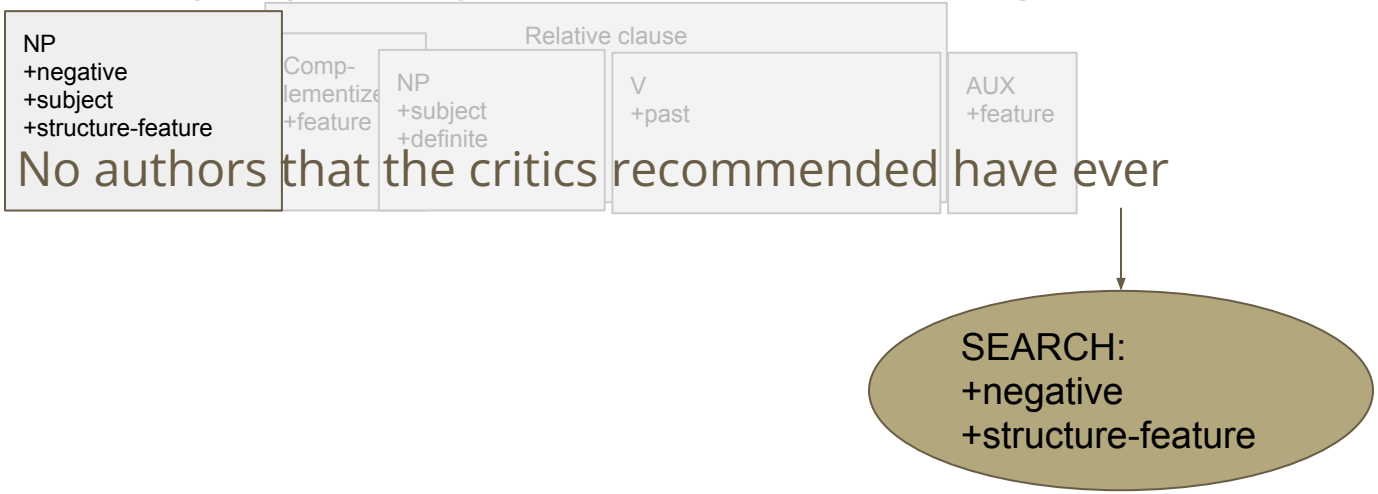

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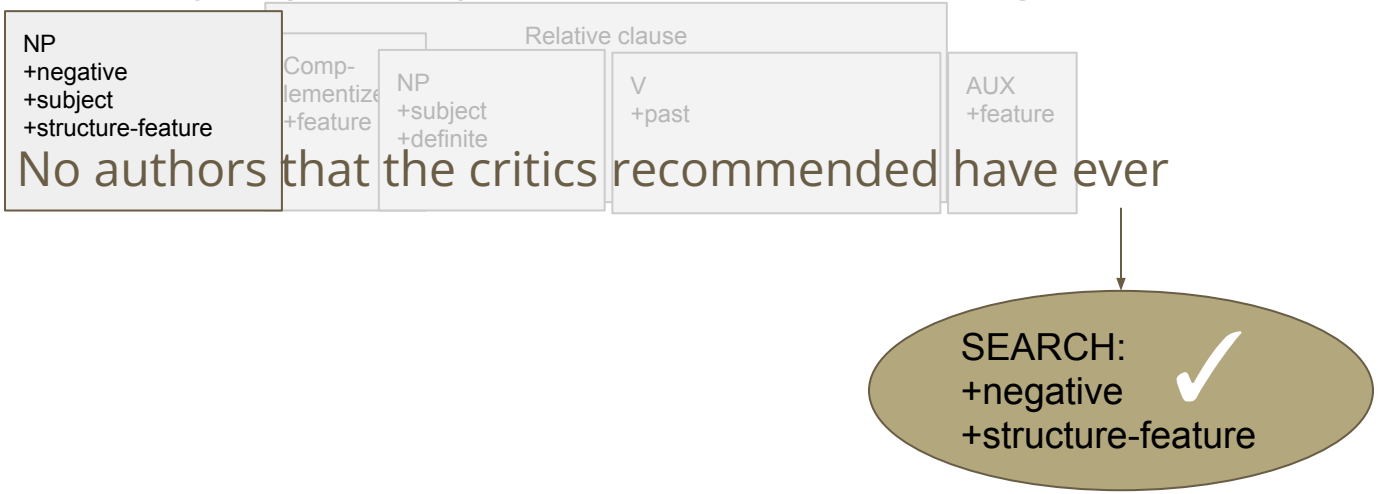

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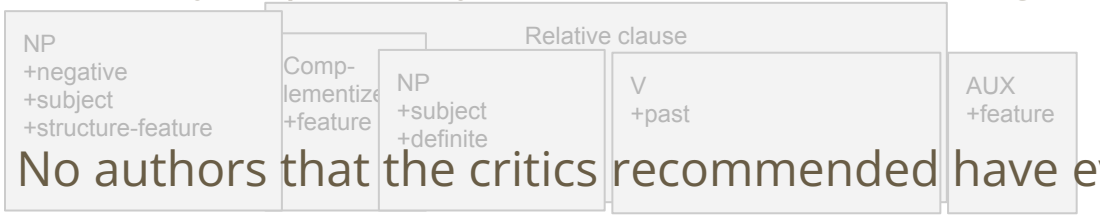

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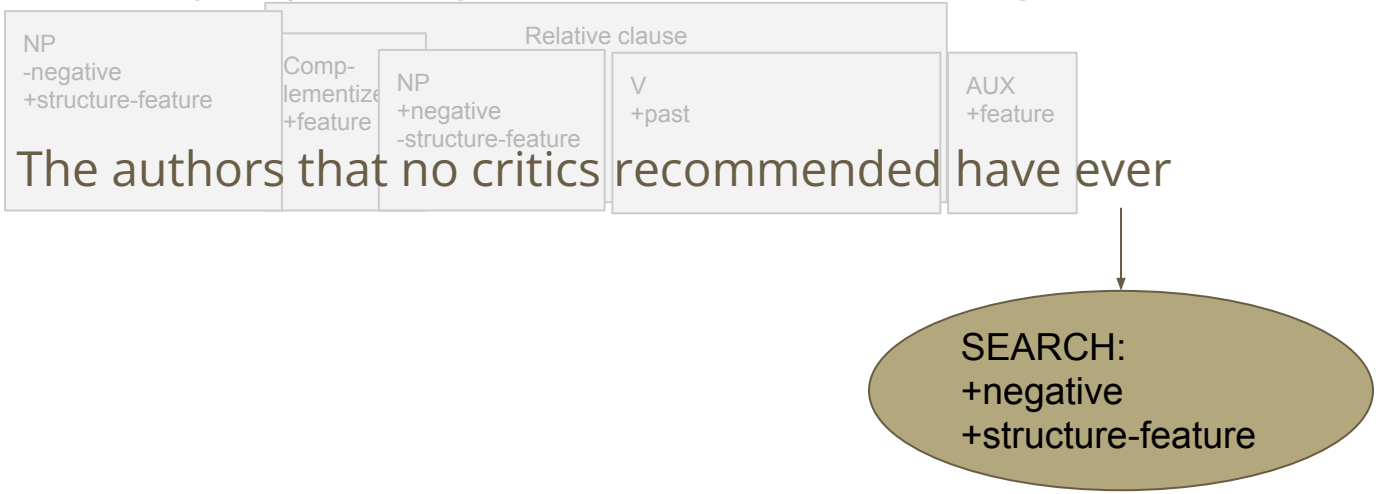

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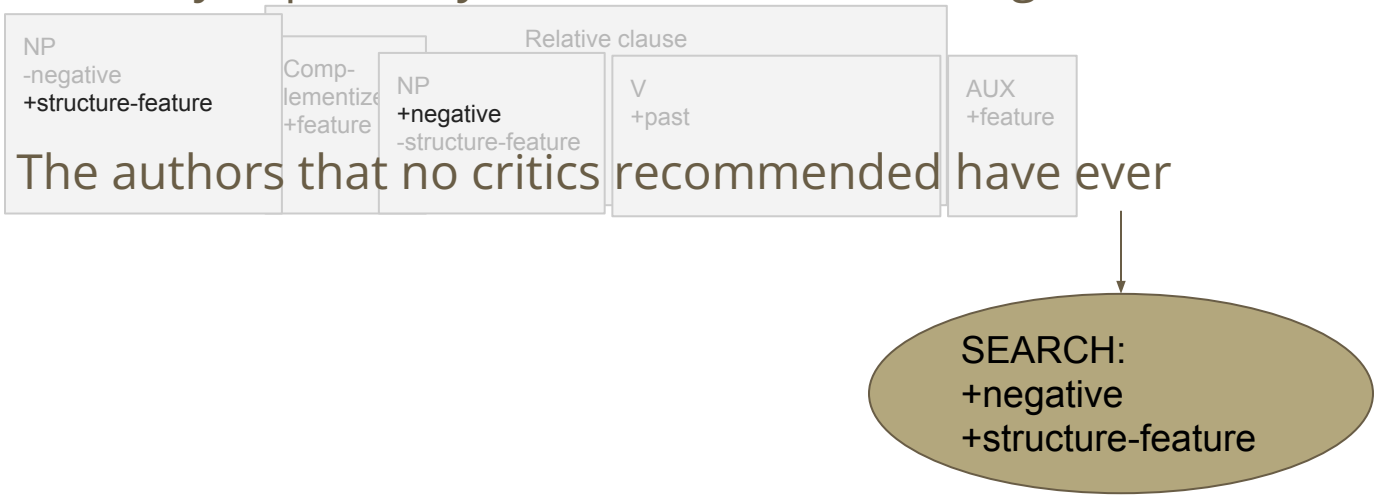

Vasishth et al. 2008

The licensor effect

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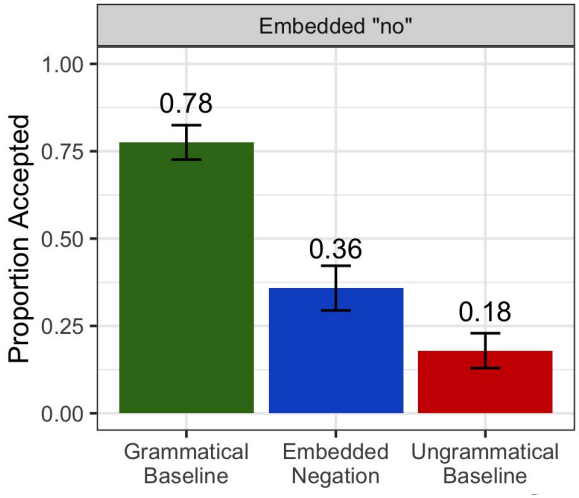

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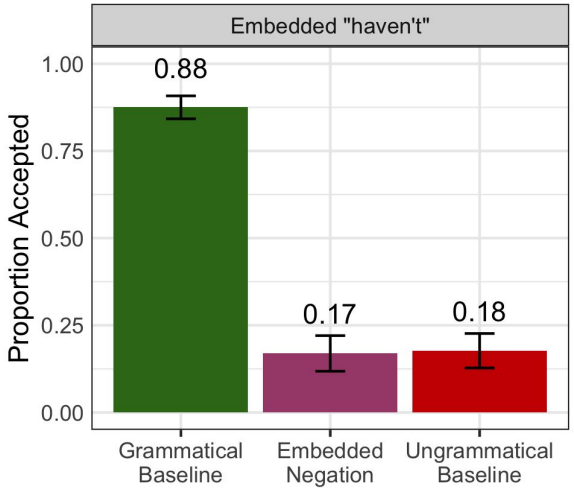

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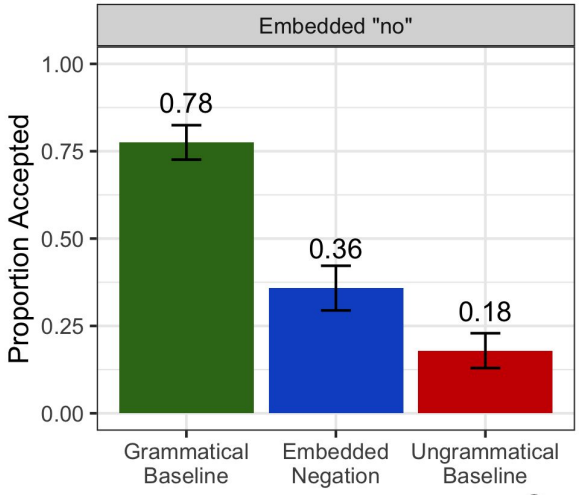

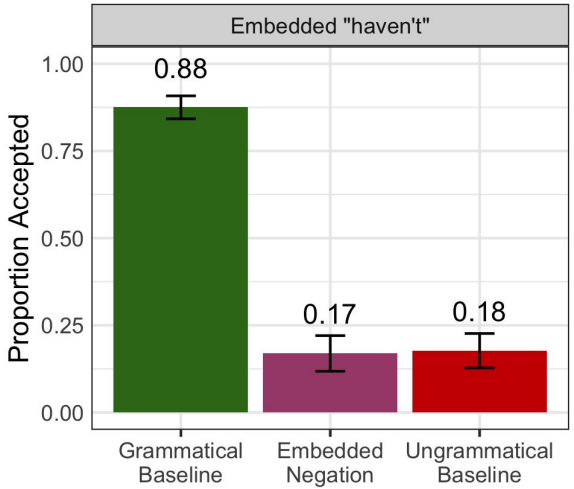

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Mary hasn’t ever been to Paris.

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Mary hasn't been to Paris in the last month.

Mary hasn't been to Paris in the last year.

Mary hasn't been to Paris in the last 5 years.

Mary hasn't been to Paris in the last 10 years.

Mary hasn't ever been to Paris.

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Prior to the NPI - processing negation

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Prior to the NPI - processing negation

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The authors [that many critics recommended] have...
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The authors [that **few** critics recommended] have...

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negation!

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negation!

Harper Lee
Stephenie Meyer
E.L. James
J.D. Salinger
J.K. Rowling
Ernest Hemingway
William Faulkner

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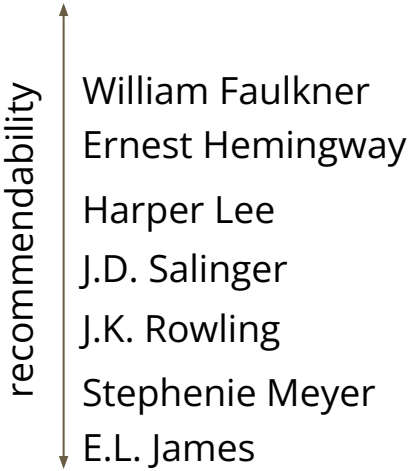

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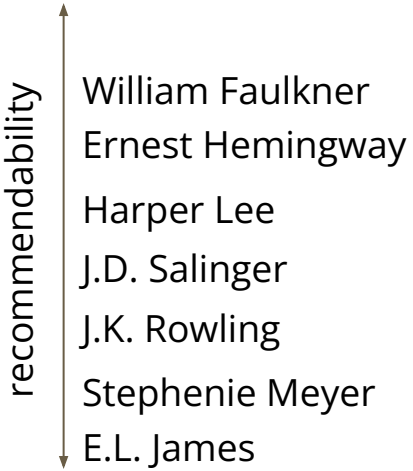

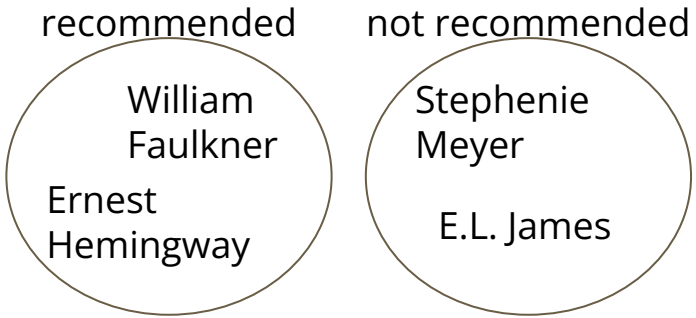

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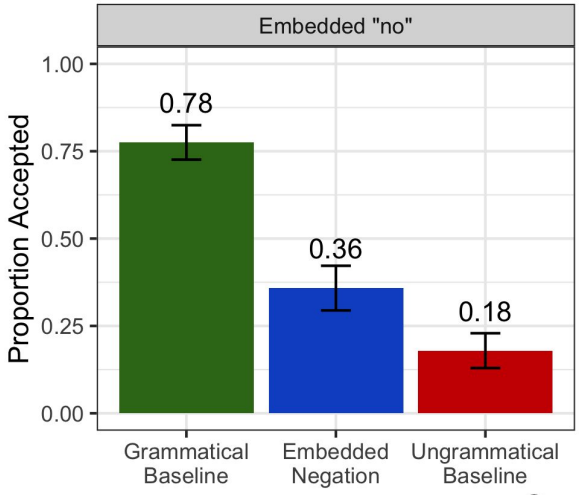

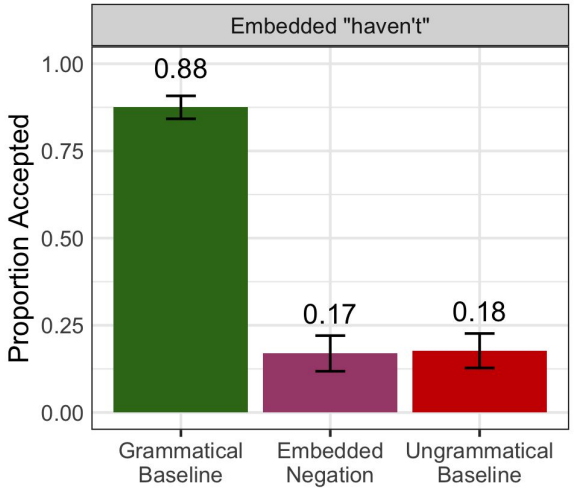

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Under a licensing-by-alternatives hypothesis:

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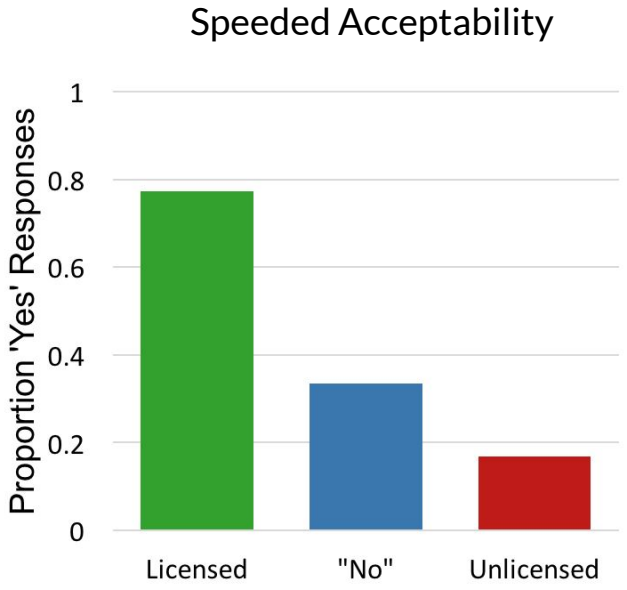

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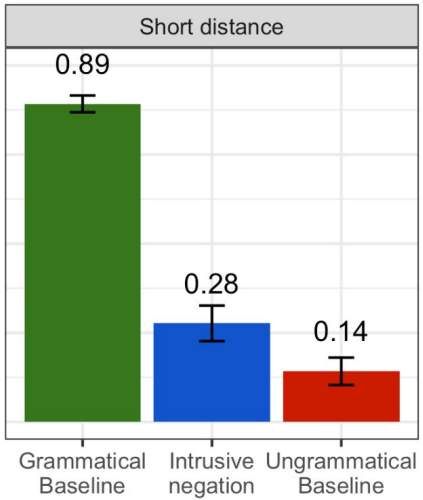

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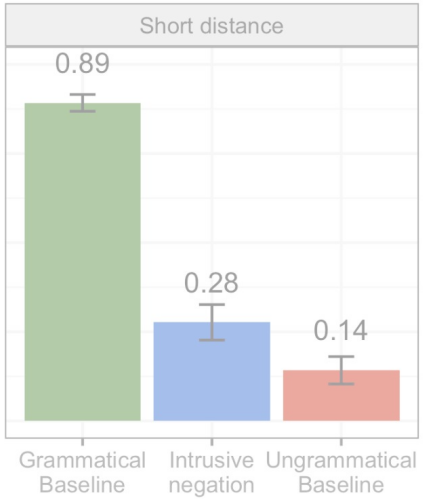

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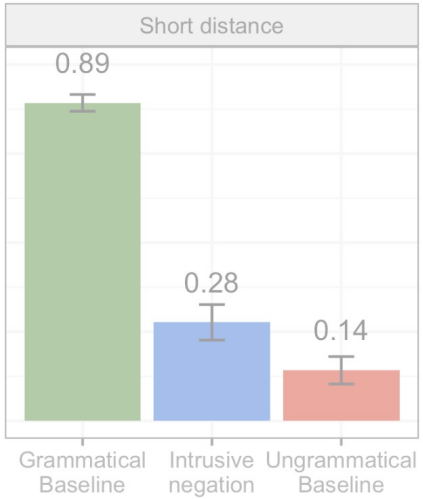

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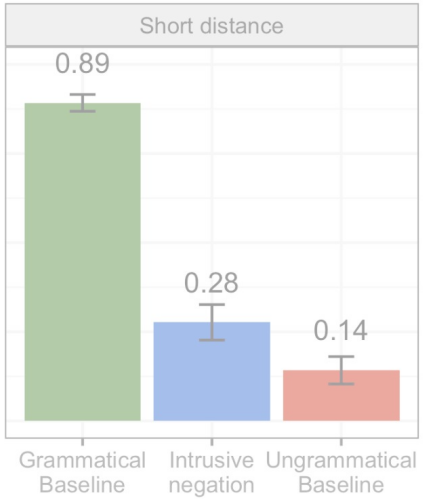

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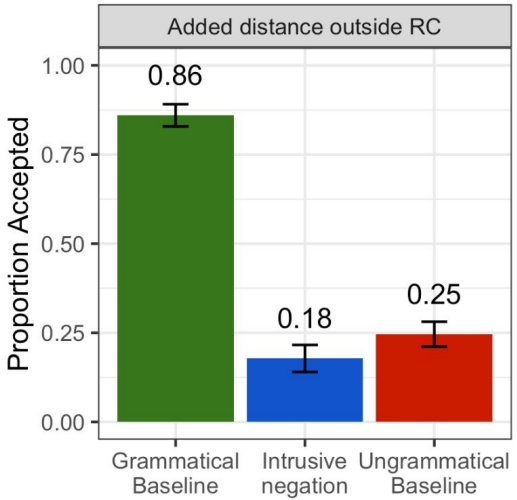

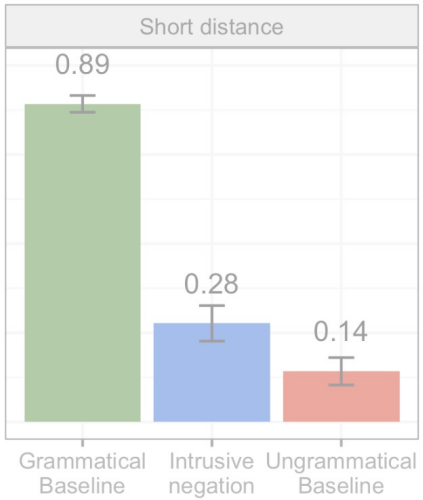

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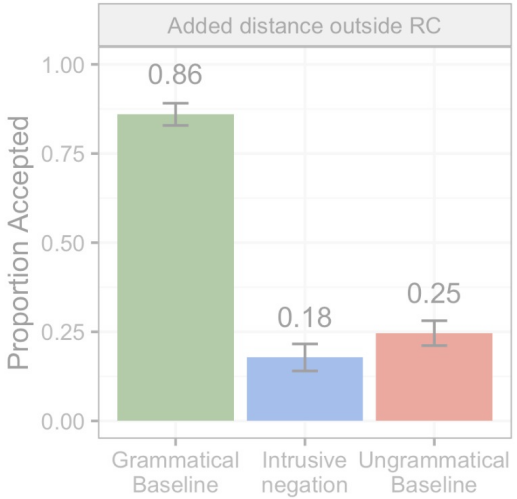

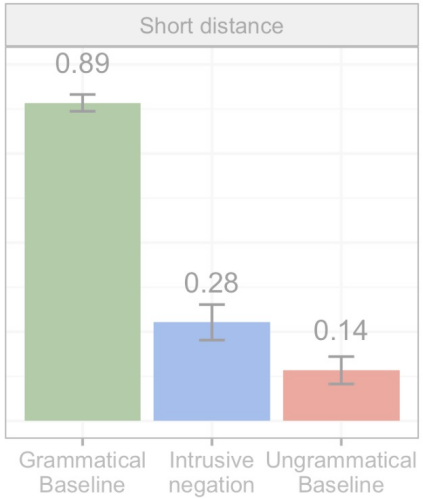

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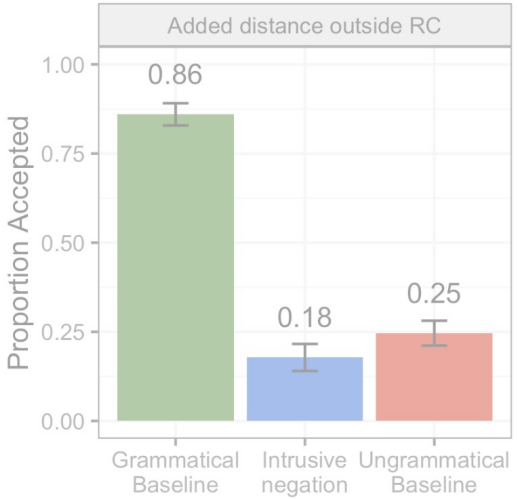

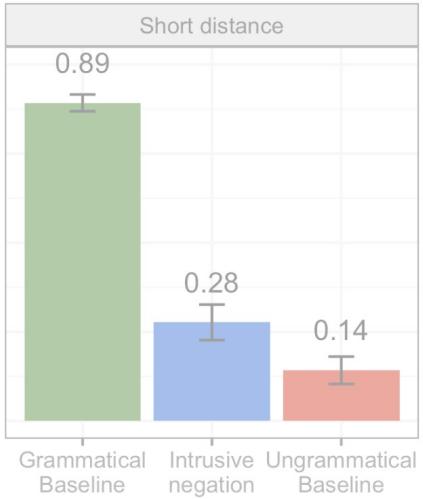

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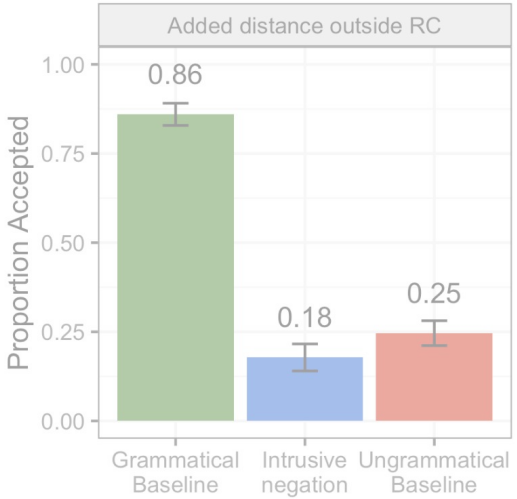

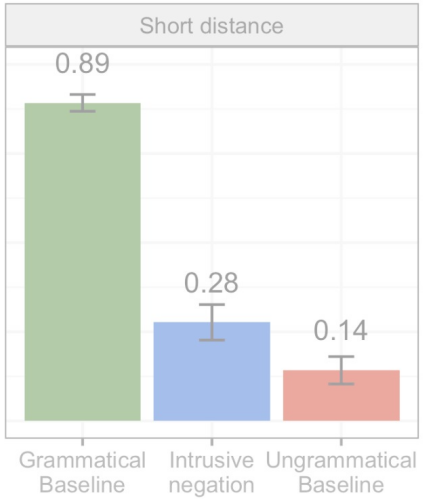

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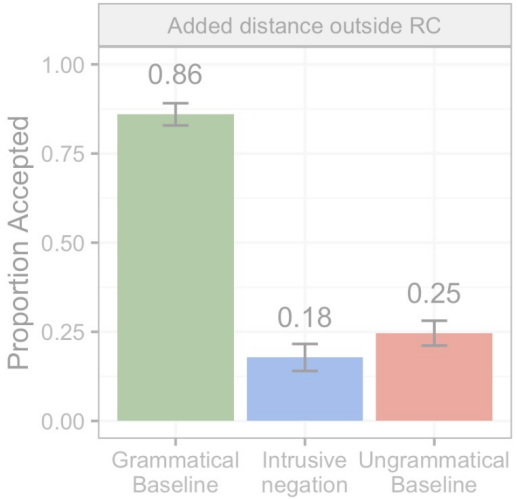

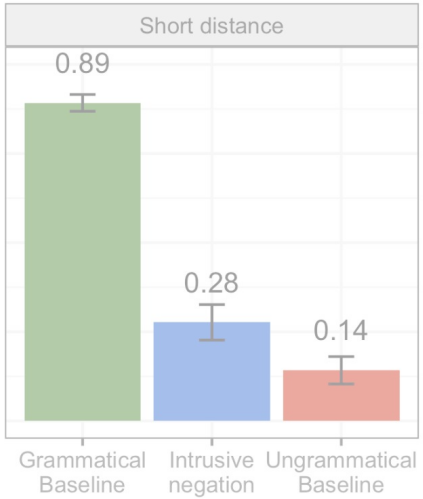

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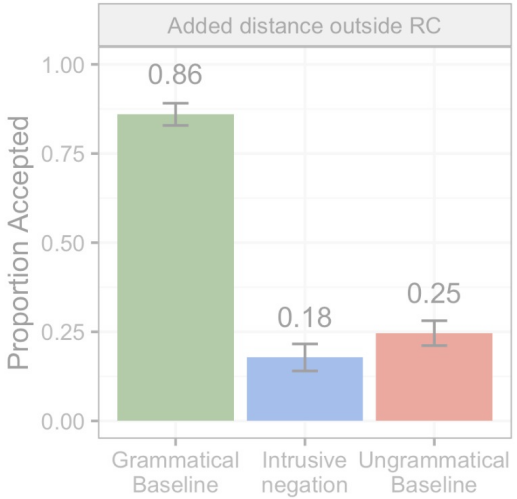

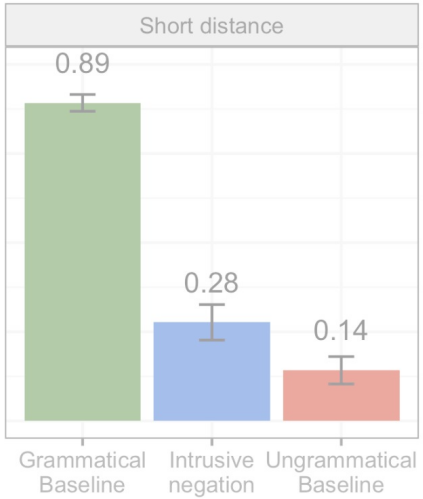

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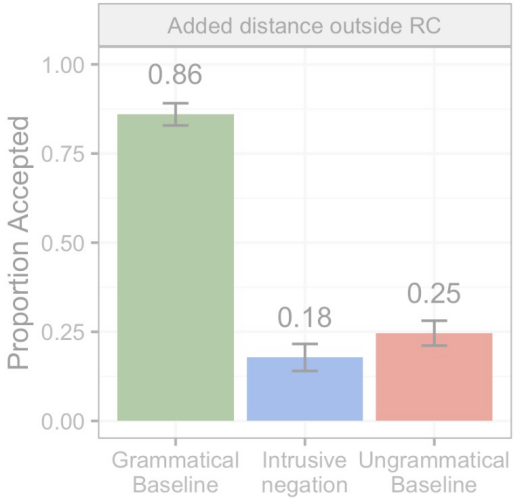

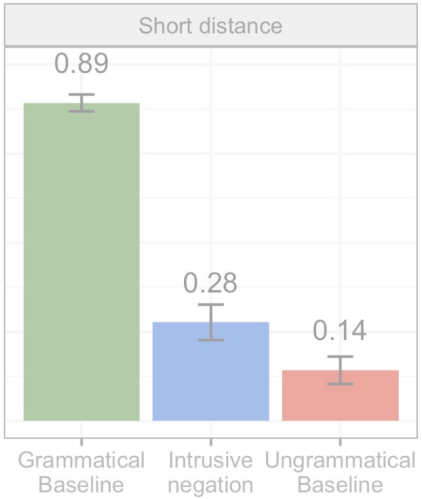

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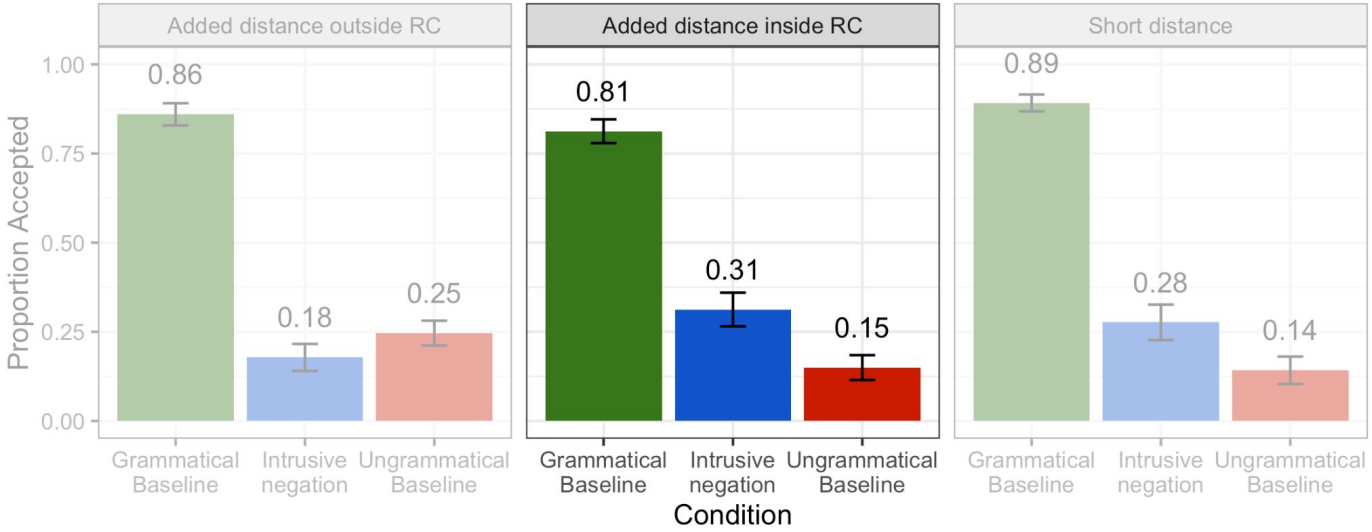

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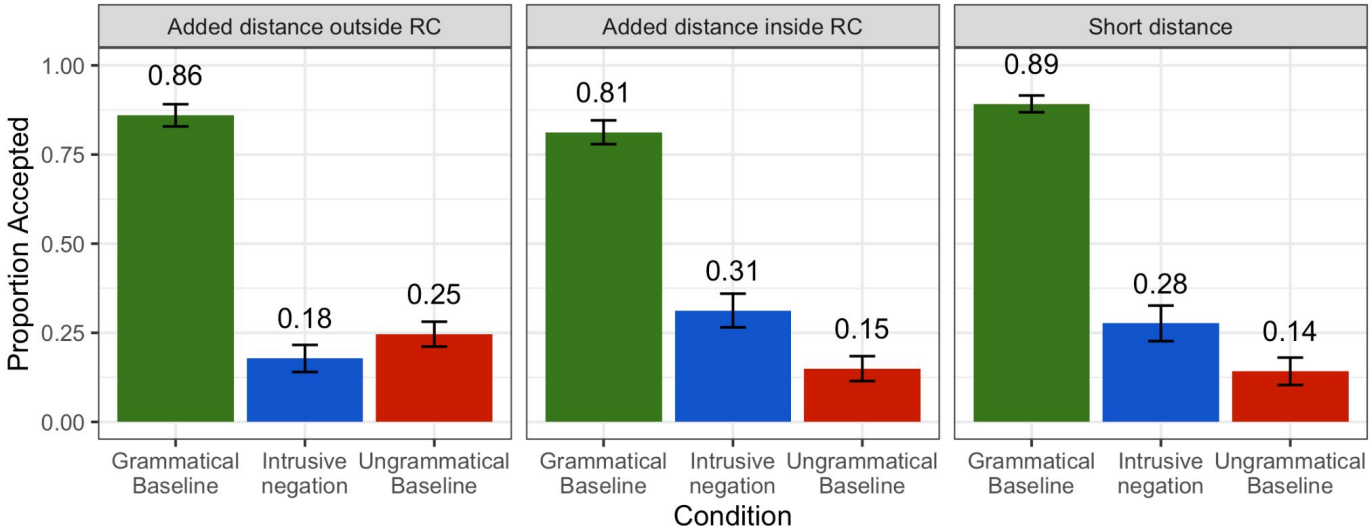

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Clause boundaries create windows of vulnerability in which active alternatives don’t seem to keep pace with parsing

The plan for today

1. Intro to linguistic illusions
2. Selective failures: the view from NPI illusions
    a. NPI illusion basics
    b. The licensor effect
    c. The distance effect
3. How can we “turn off” the Moses illusion?
    a. Item-wise variability
    b. Correlates of vulnerability
    c. Next steps

Moses illusions

What is the name of the holiday during which children dress up and walk from door to door to **give** candy?

What kind of fruit is said to have fallen out of a tree, leading Newton to discover the laws of gravity?

How many animals of each kind did **Moses** bring on the ark?

What is the name of the raised bumps on paper which enable **deaf** people to read?

Variability in the illusion

50 stimuli drawn from prior literature

- What is the name of the holiday during which children dress up and walk from door to door to **give** candy?
- What is the name of the holiday during which children dress up and walk from door to door to **collect** candy?

Variability in the illusion

50 stimuli drawn from prior literature

- What is the name of the holiday during which children dress up and walk from door to door to **give** candy?
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100 Mechanical Turk workers

Variability in the illusion

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- What is the name of the holiday during which children dress up and walk from door to door to **give** candy?
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100 Mechanical Turk workers

2 part task:

Variability in the illusion

50 stimuli drawn from prior literature

- What is the name of the holiday during which children dress up and walk from door to door to **give** candy?
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100 Mechanical Turk workers

2 part task: answer questions

Variability in the illusion

50 stimuli drawn from prior literature

- What is the name of the holiday during which children dress up and walk from door to door to **give** candy?
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100 Mechanical Turk workers

2 part task: answer questions, then knowledge check

Part One

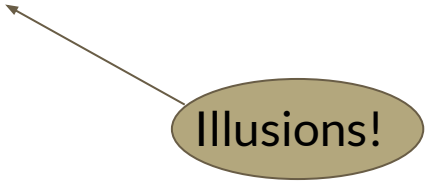
What is the name of the holiday during which children dress up and walk from door to door to give candy?

- ❏ [ ]
- ❏ I cannot answer
- ❏ I don’t know

Part One

What is the name of the holiday during which children dress up and walk from door to door to give candy?

- ❑ `Halloween`
- ❑ I cannot answer
- ❑ I don't know



Part Two

The name of the holiday during which children dress up and walk from door to door to XXX candy is Halloween.

- ❏ steal
- ❏ offer
- ❏ collect
- ❏ give
- ❏ none of these
- ❏ I don’t know

Moses illusions

What is the name of the raised bumps on paper which enable deaf people to read?

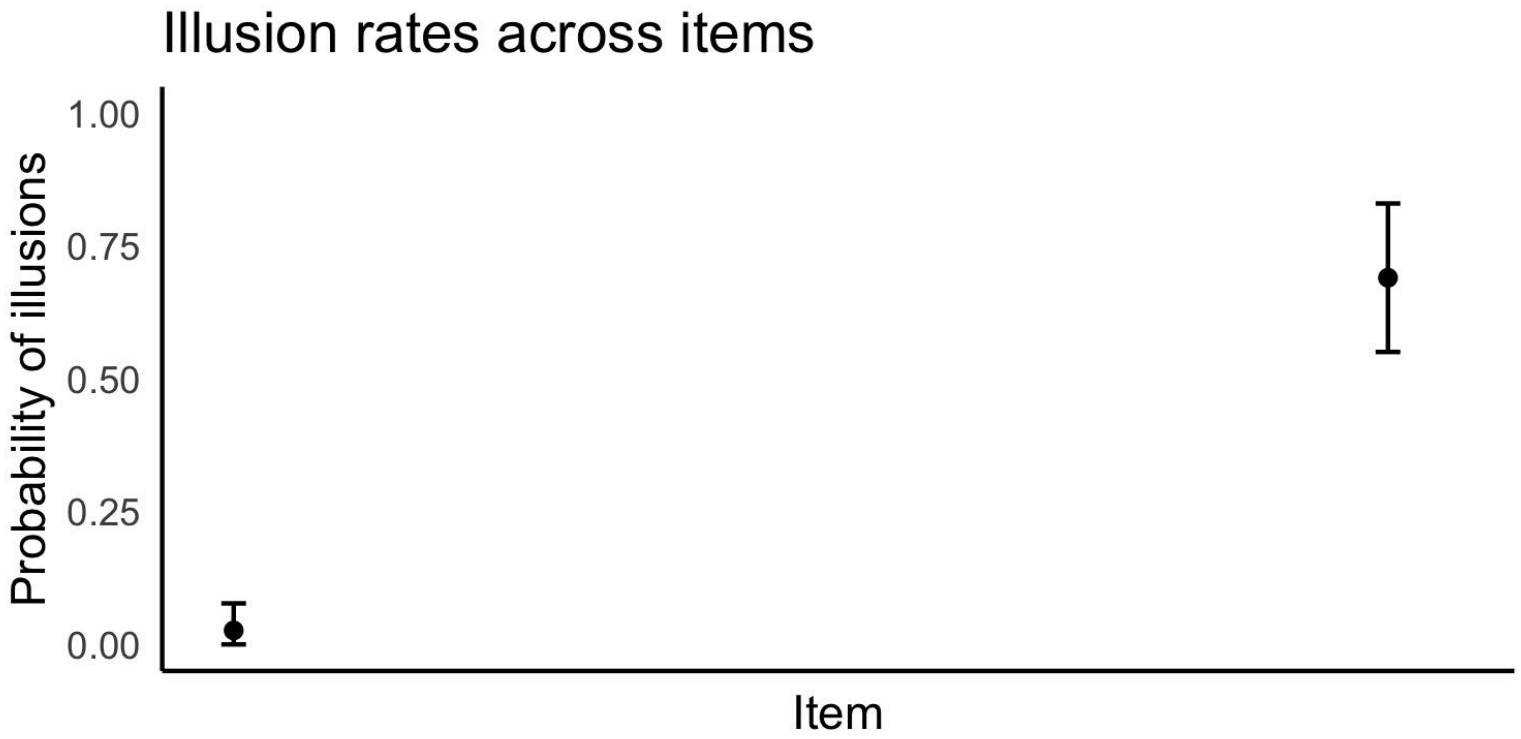
How did painter Vincent van Gogh lose his eye during his life?

Moses illusions

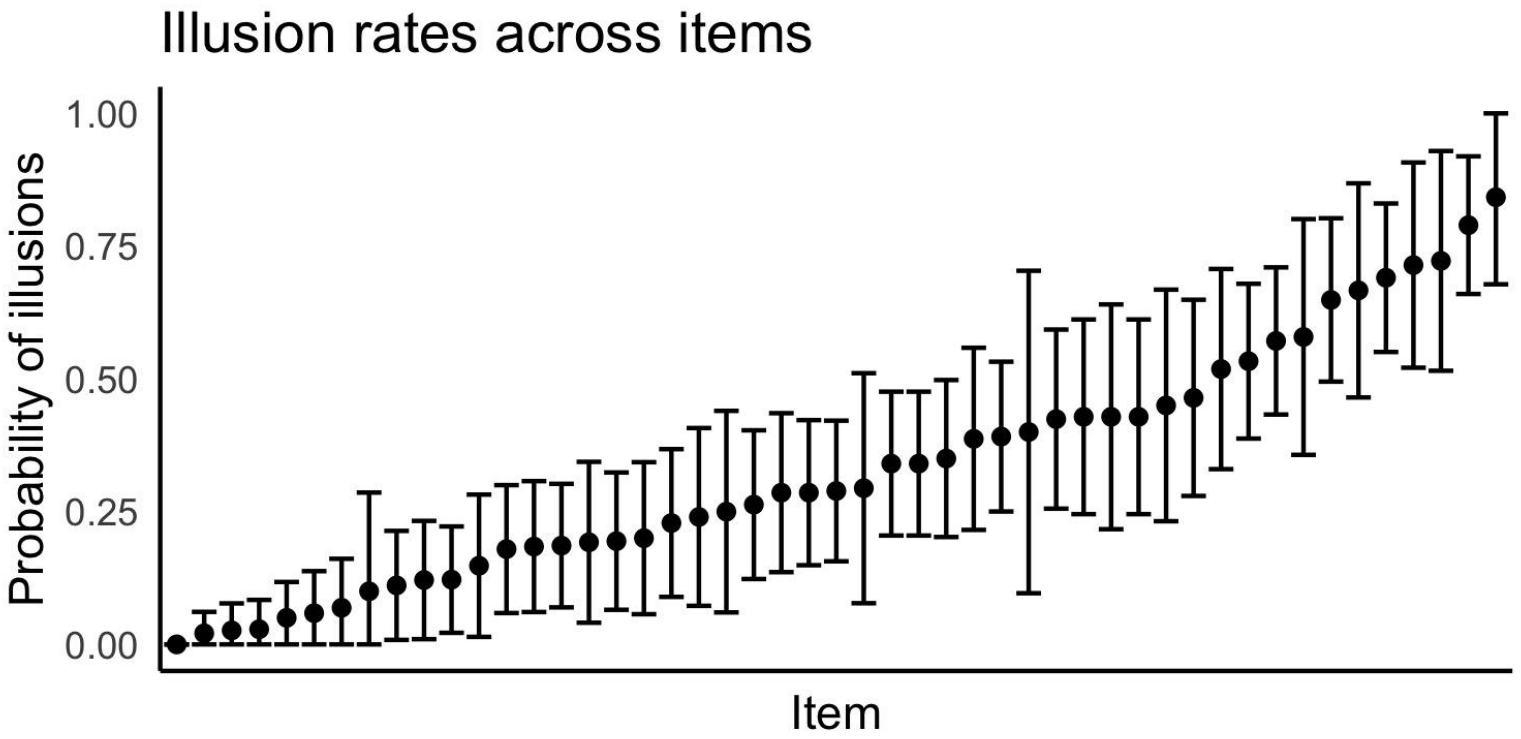
What is the name of the raised bumps on paper which enable **deaf** people to read?

How did painter Vincent van Gogh lose his **eye** during his life?

Results


Illusion rates across items
Probability of illusions
1.00
0.75
0.50
0.25
0.00
Item

Results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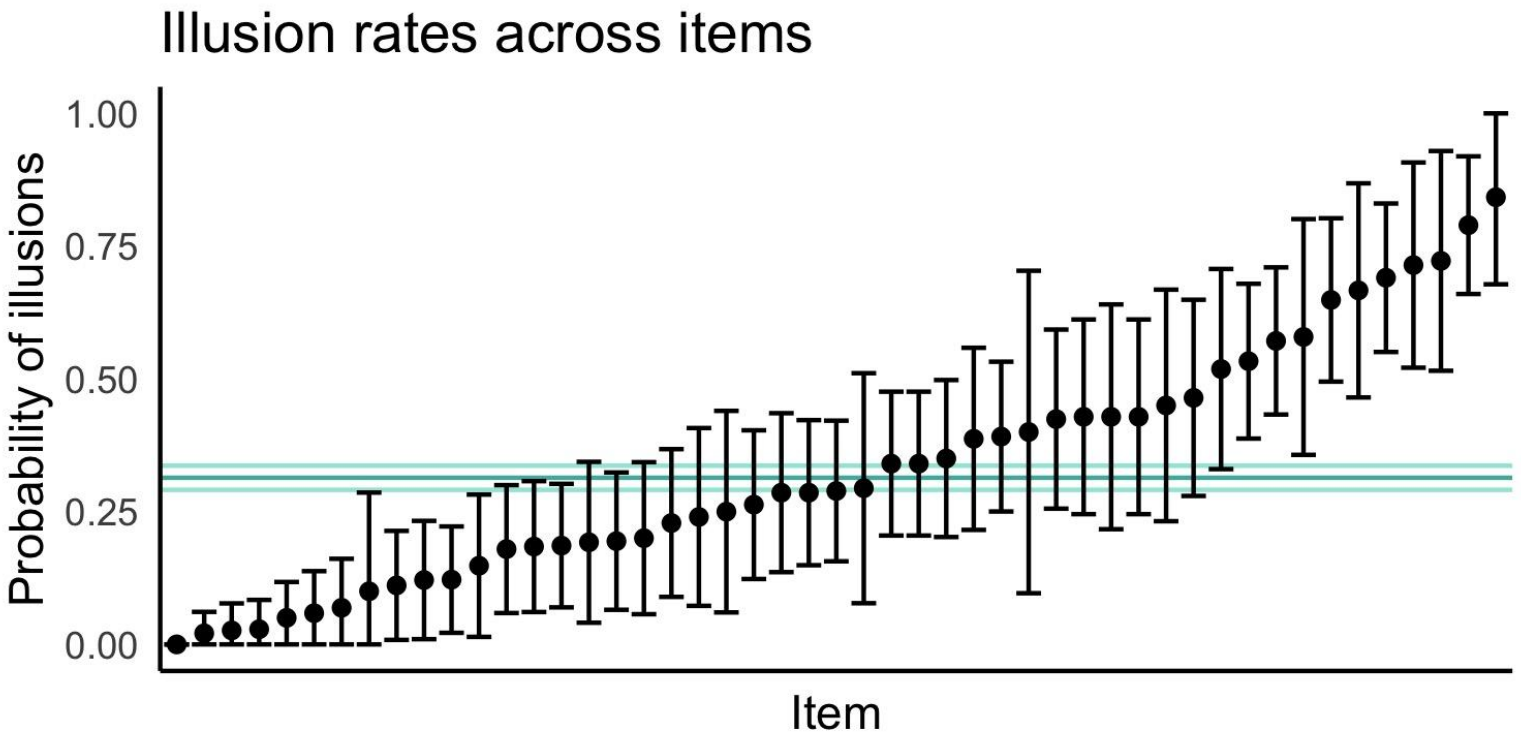
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1.00
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0.25
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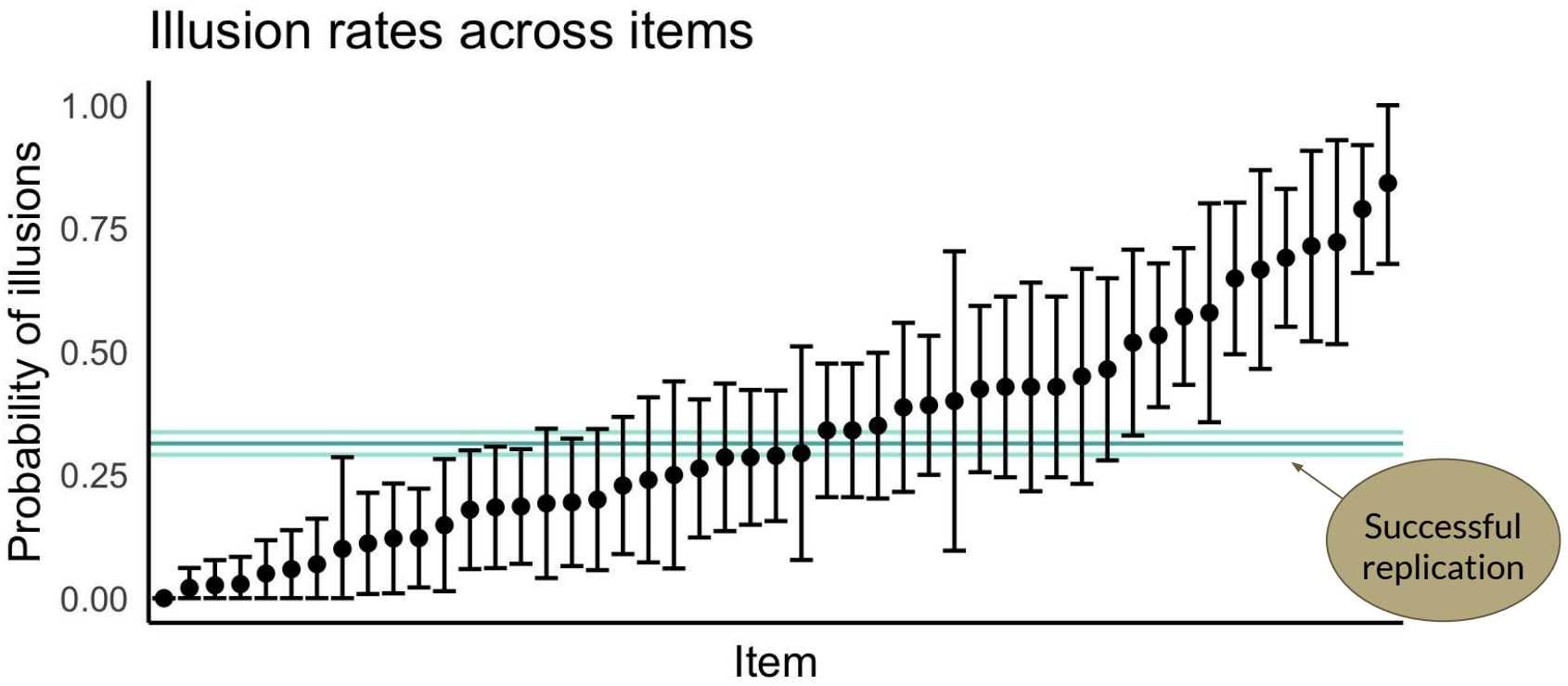
Item

Results


Illusion rates across items
Probability of illusions
1.00
0.75
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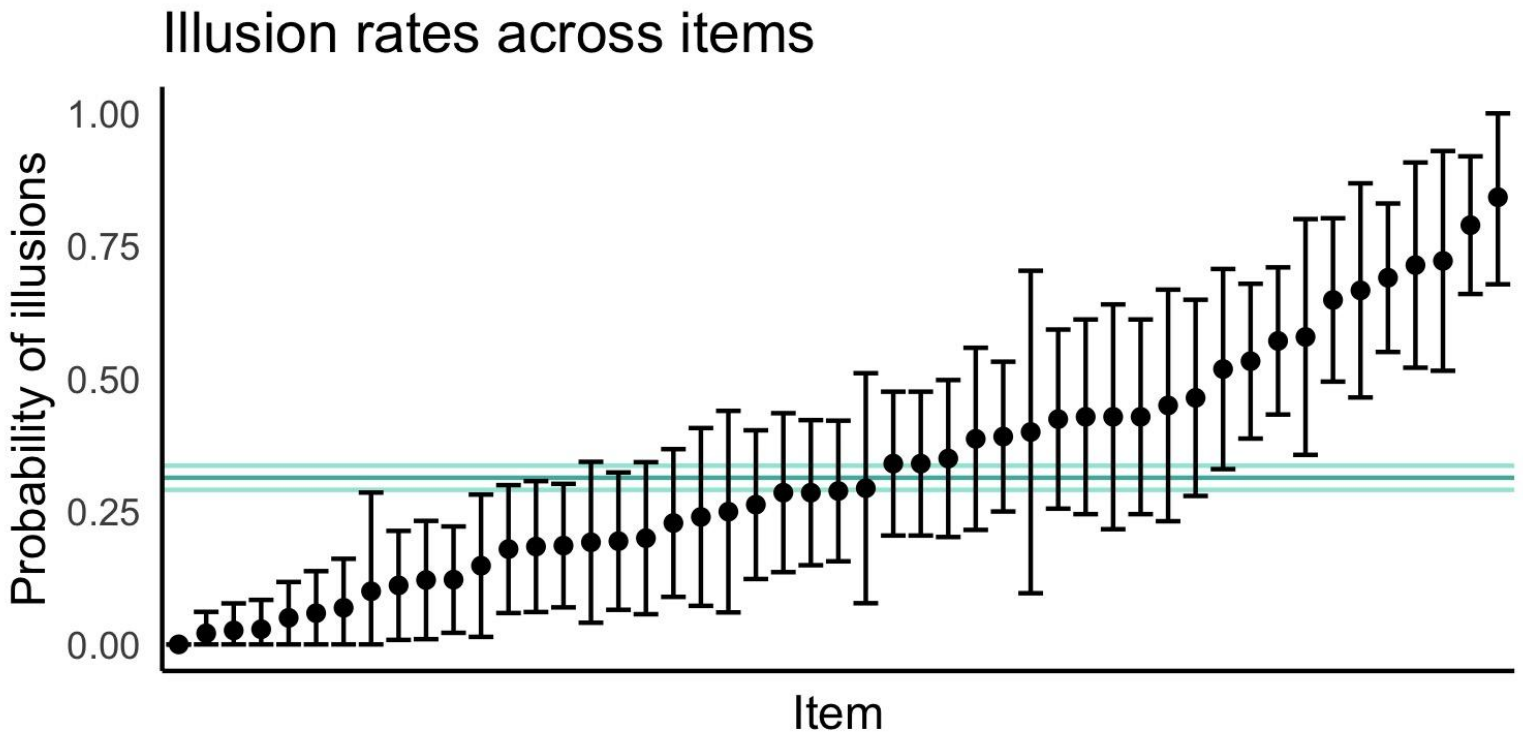
Item
Successful replication

Results


Illusion rates across items
Probability of illusions
1.00
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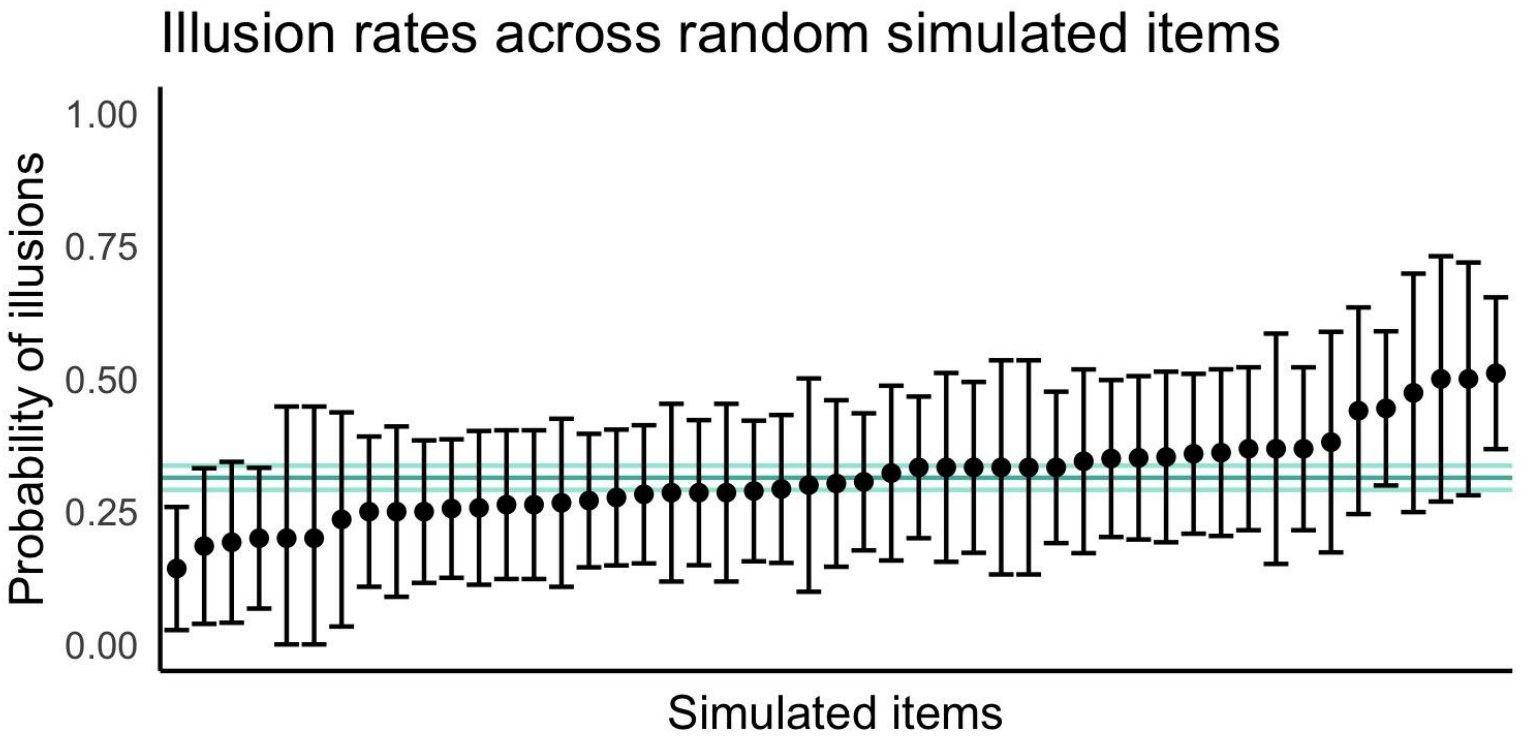
Item

Results


Illusion rates across random simulated items
Probability of illusions
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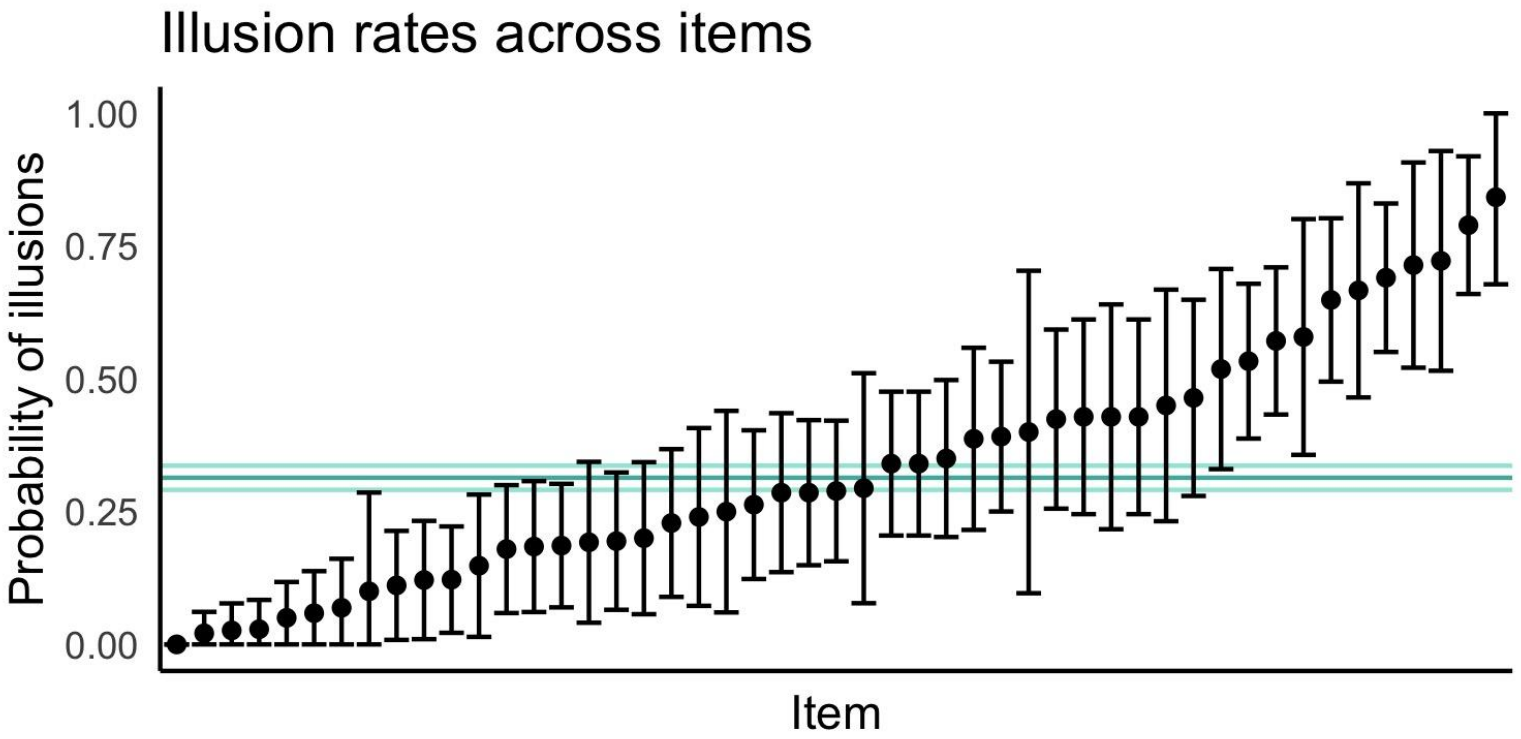
Simulated items

Results


Illusion rates across items
Probability of illusions
1.00
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0.50
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Item

Explaining the variability

- How many animals of each kind did **Moses** take on the ark?
- How many animals of each kind did **Nixon** take on the ark?

Explaining the variability

Words that are highly dissimilar to the word they're swapped in for are much less likely to yield illusions

- How many animals of each kind did **Moses** take on the ark?
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Erickson & Mattson (1981), Van Oostendorp & De Mul (1990), Van Jaarsveld, Dijkstra, & Hermans (1997), Cook, Walsh, Bills, Kircher, & OBrien (2016)

Explaining the variability

Words that are highly dissimilar to the word they're swapped in for are much less likely to yield illusions

- How many animals of each kind did **Moses** take on the ark?
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Does variability in word similarity accross our items explain the differing illusion rates?

Erickson & Mattson (1981), Van Oostendorp & De Mul (1990), Van Jaarsveld, Dijkstra, & Hermans (1997), Cook, Walsh, Bills, Kircher, & OBrien (2016)

Measuring semantic similarity

Word2vec

- Assign a vector to each word based on the distribution of contexts in which that word appears
- Words that appear in similar contexts are likely to be semantically similar

Measuring semantic similarity

Cook, Walsh, Bills, Kircher, & OBrien (2016)

- Halloween is the holiday when children go door to door **giving out** candy and treats.
- Halloween is the holiday when children go door to door **stealing** candy and treats.

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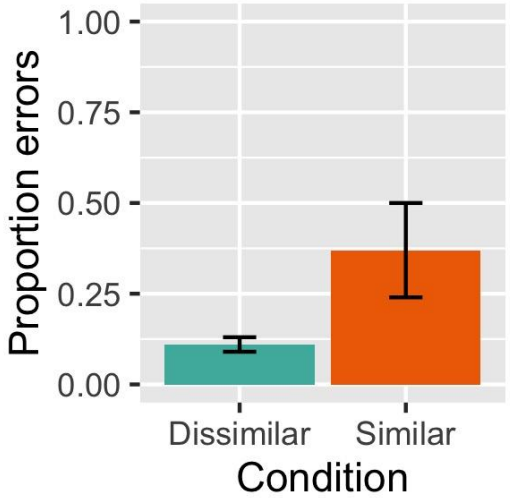

Measuring semantic similarity

Cook, Walsh, Bills, Kircher, & OBrien (2016)

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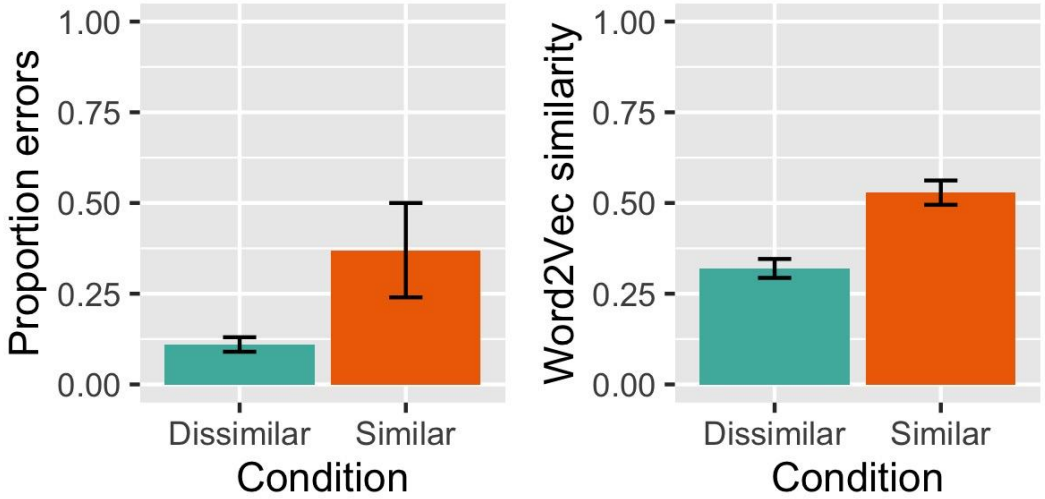
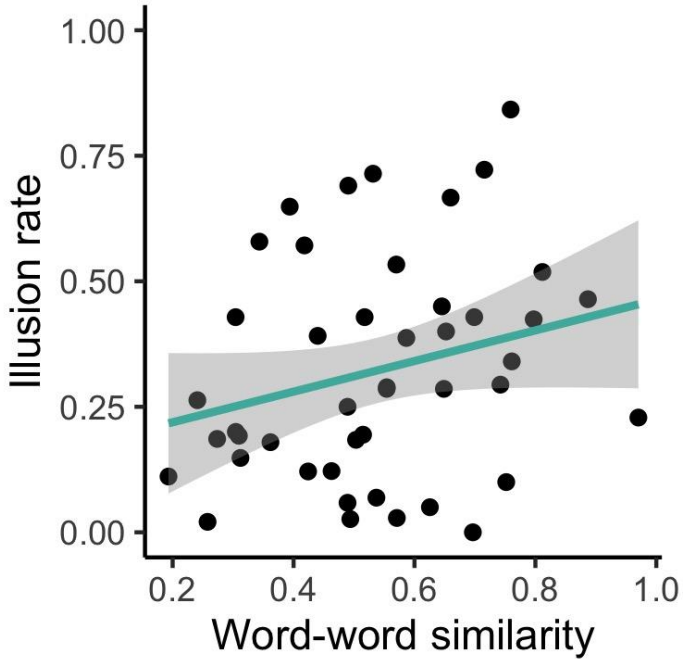


Semantic similarity (word2vec)



How much do you know before the anomaly?

For some items, you have a good idea about what the question is asking:

How much do you know before the anomaly?

For some items, you have a good idea about what the question is asking:

What is the name of the holiday during which children dress up and walk from door to door to…

How much do you know before the anomaly?

For some items, you have a good idea about what the question is asking:

What is the name of the holiday during which children dress up and walk from door to door to…

For others, it’s less clear:

How much do you know before the anomaly?

For some items, you have a good idea about what the question is asking:

What is the name of the holiday during which children dress up and walk from door to door to…

For others, it's less clear:

What is the second largest …

How much do you know before the anomaly?

For some items, you have a good idea about what the question is asking:

What is the name of the holiday during which children dress up and walk from door to door to…

For others, it's less clear:

What is the second largest …

Items that allow the comprehender to infer the question before the anomaly may create vulnerability because you don't have to pay attention to the rest of the words in order to answer the question

Approximating the information state

Contemporary language models can generate believable sentences (using a lead-in sentence fragment)

Unclear whether the mechanisms they use are a reasonable approximation of human mechanisms, but their performance is a reasonable approximation of human-generated corpora

Language models have the key advantage that they don't just give you one predicted next word, they assign a probability to every word in the lexicon

Language models

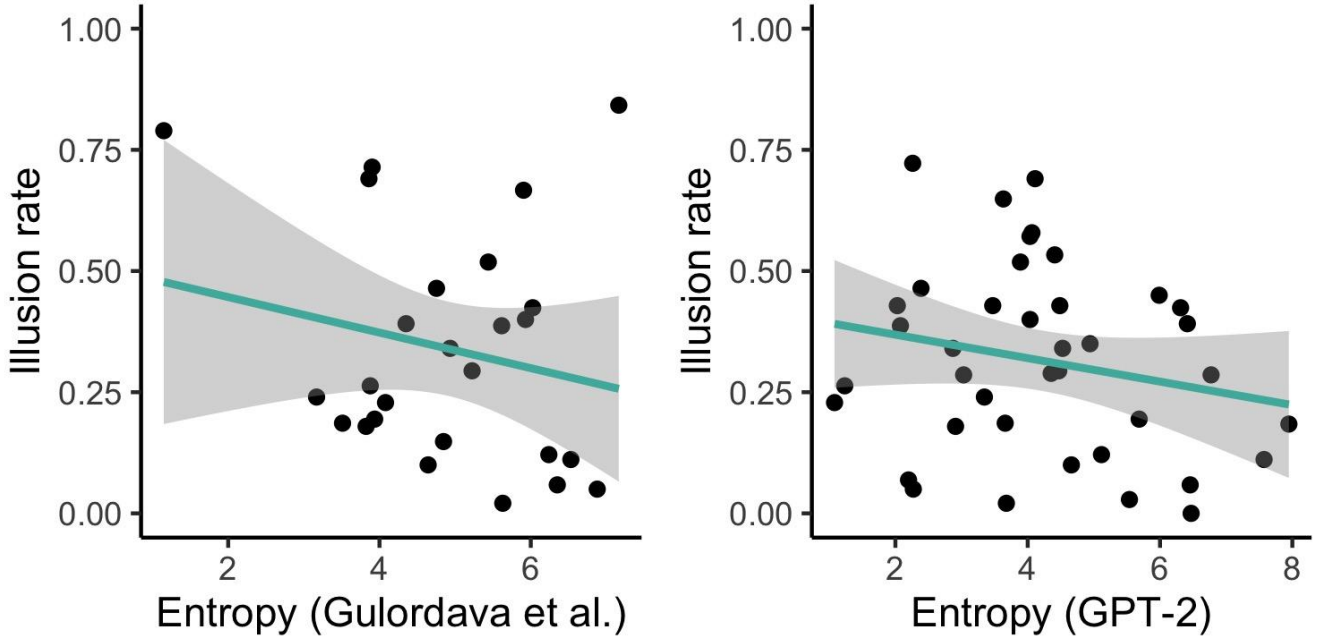
Entropy: higher means less certainty about what's coming next

So we expect that the stimuli with lower entropy (you have a good idea about what's coming next) will have higher illusion rates (because you know what's coming, you don't have to attend to it as much)

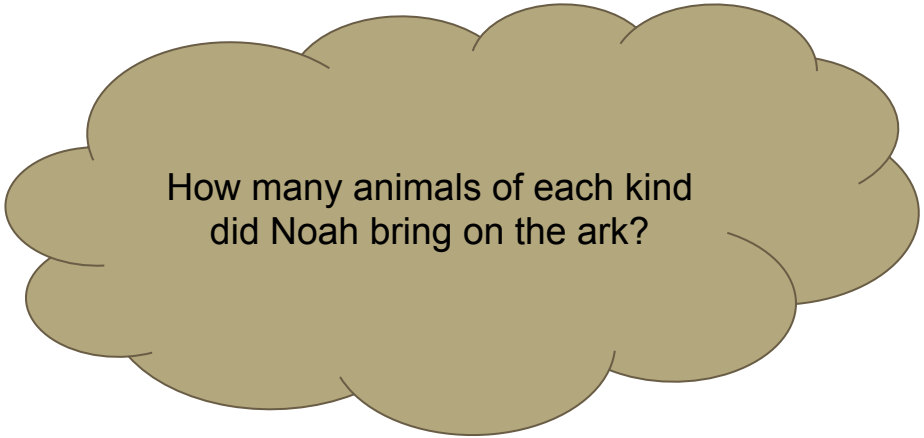
Two models: LSTM that has been used to approximate human language behavior, and GPT-2

Gulordava et al, Van Schijndel & Linzen, GPT-2

Language model predictions



The basic phenomenon = The Moses Illusion

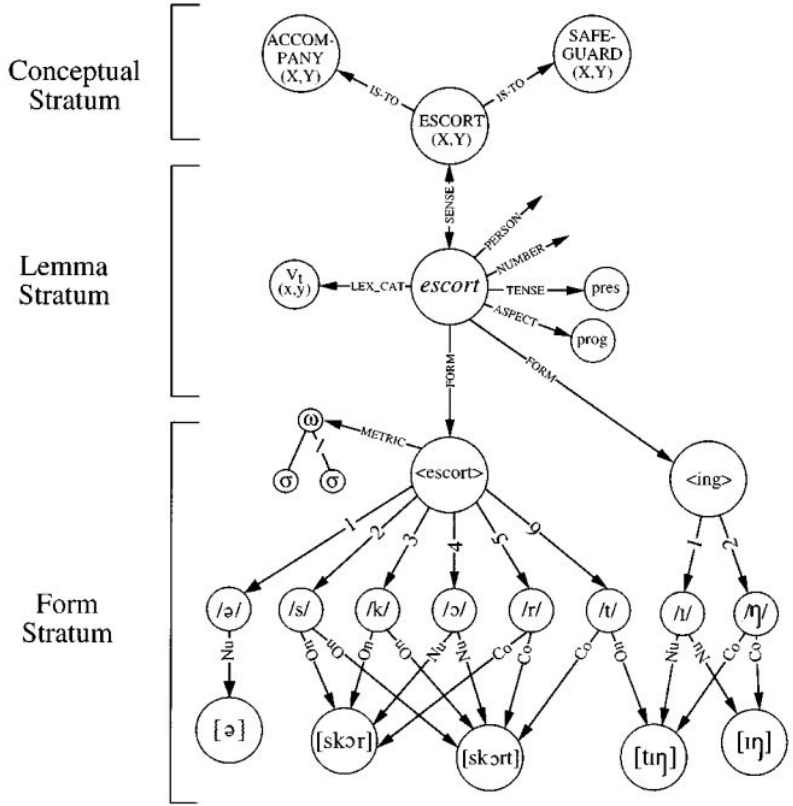


How many animals of each kind did Moses bring on the ark?

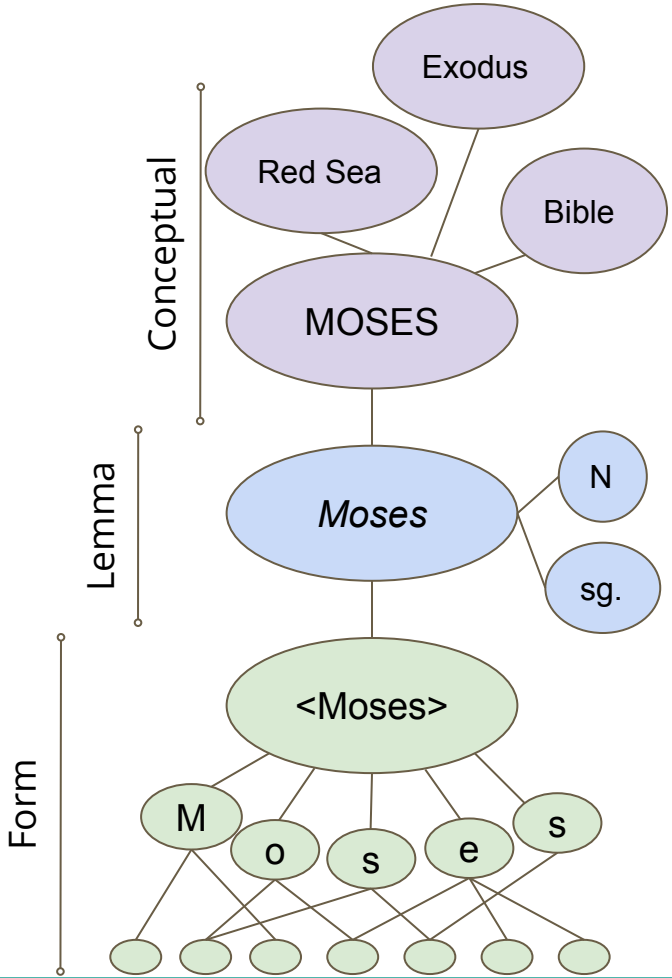
What causes the Moses illusion?

What is it about our *normal* sentence processing that leads us astray in precisely the contexts where we get illusions?

The lemma model



Levelt, Roelofs, & Meyer (1999)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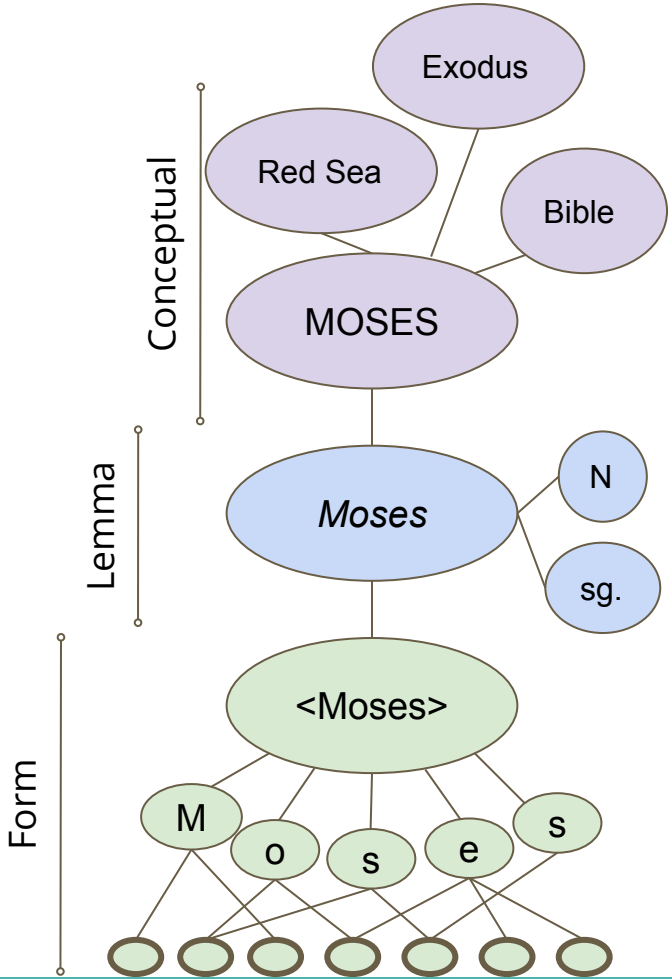
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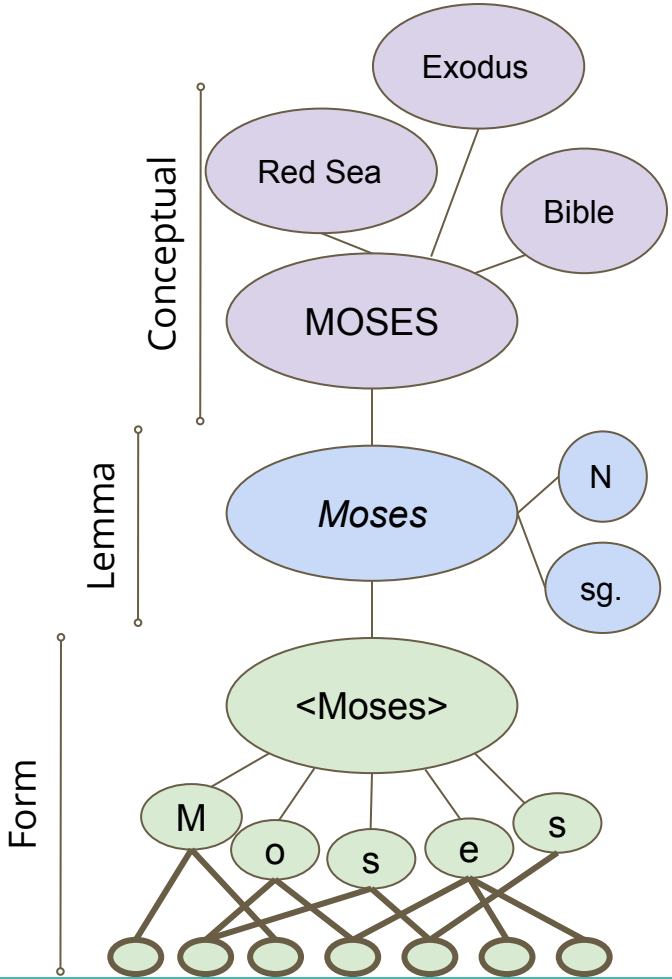
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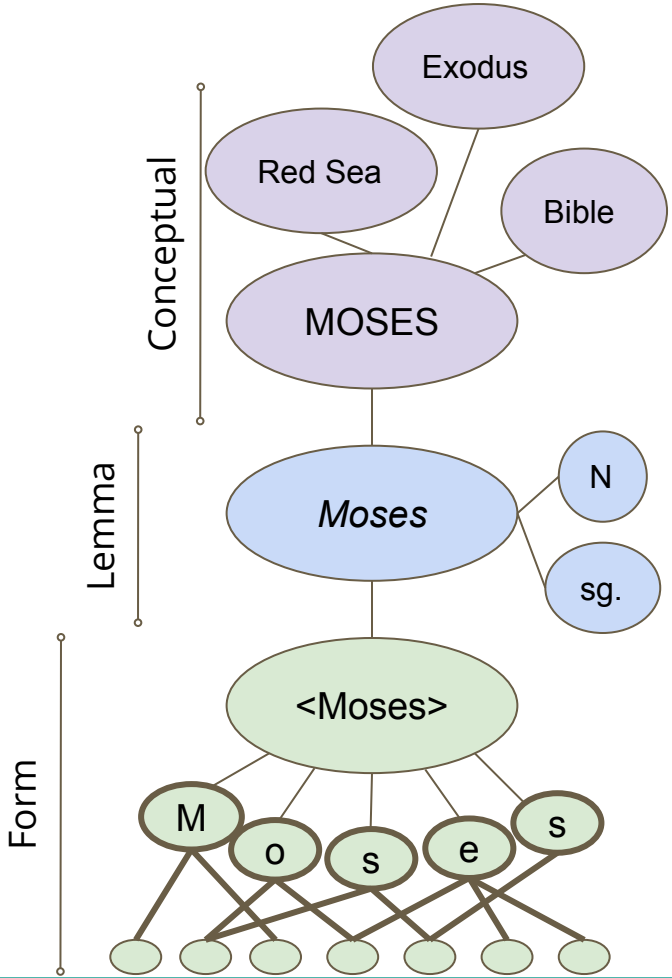
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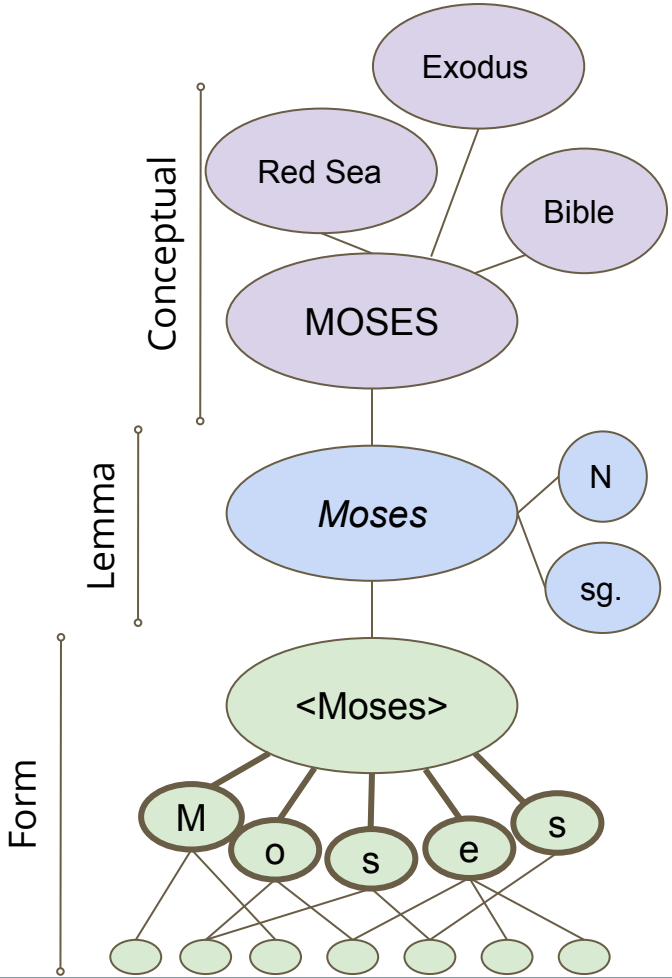
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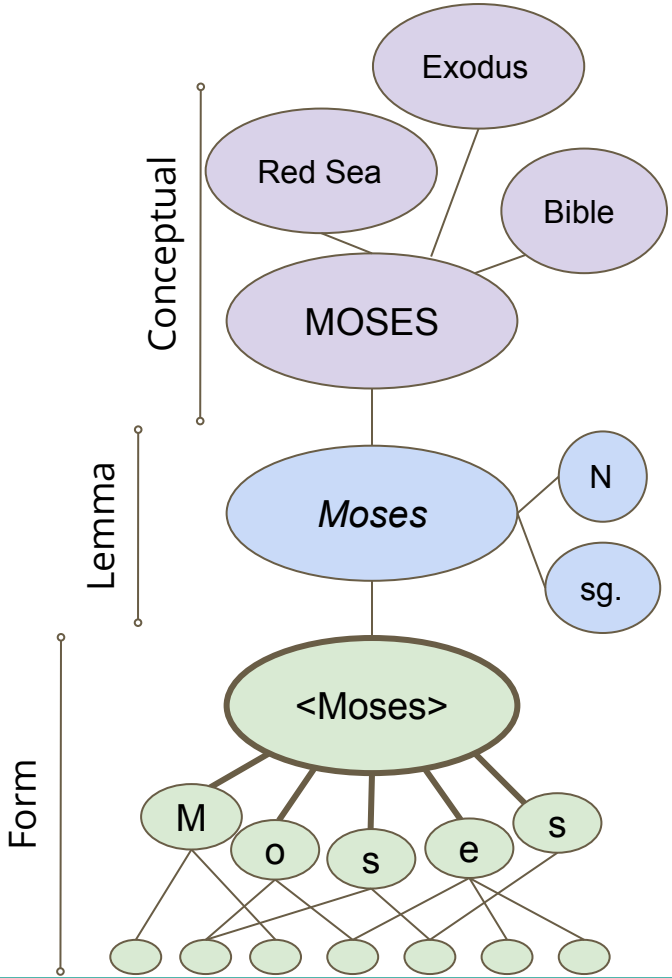
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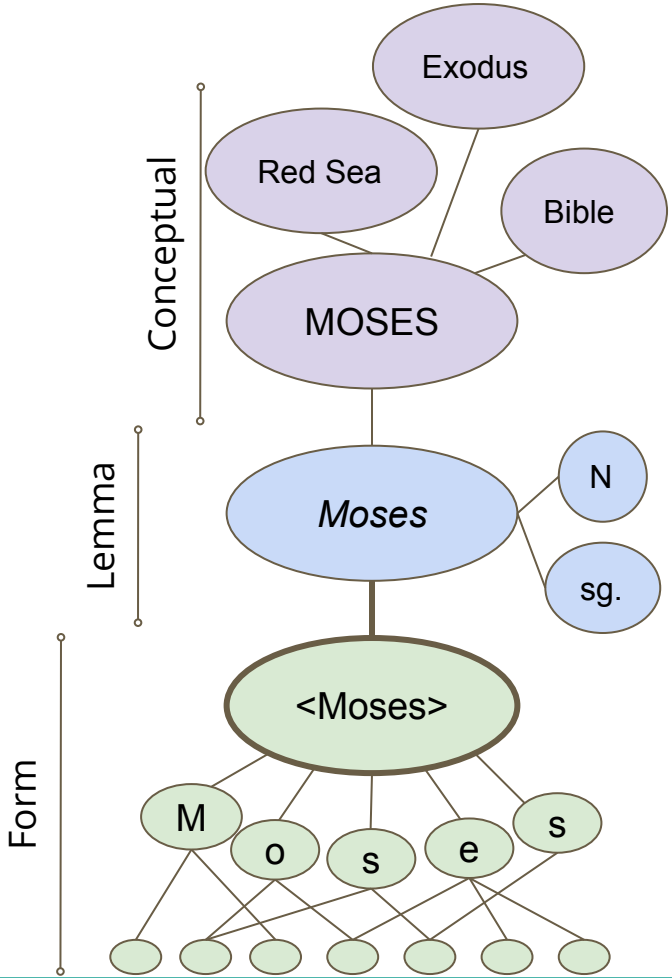
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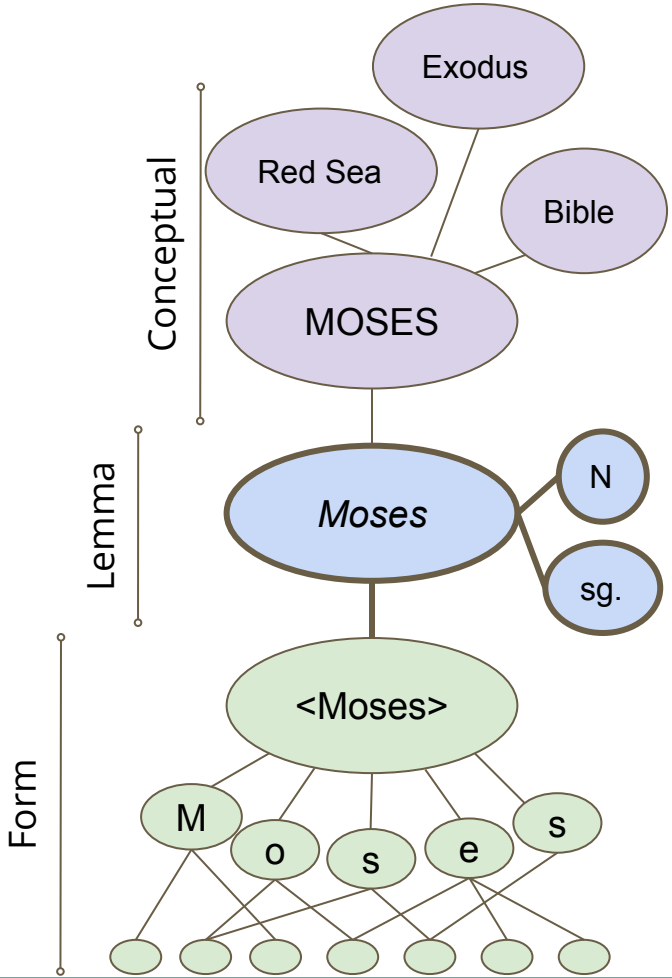
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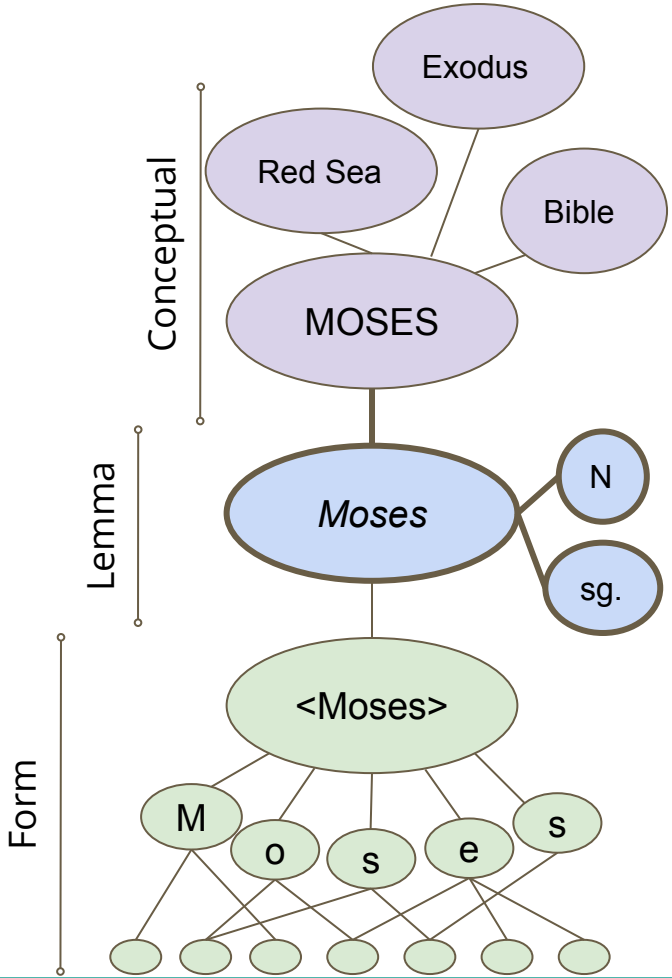
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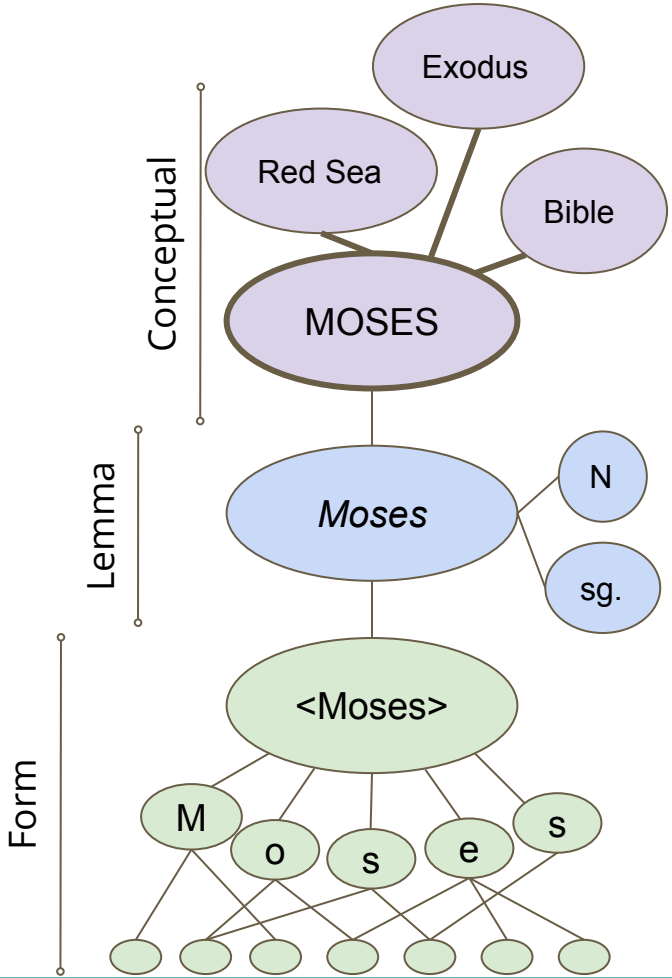
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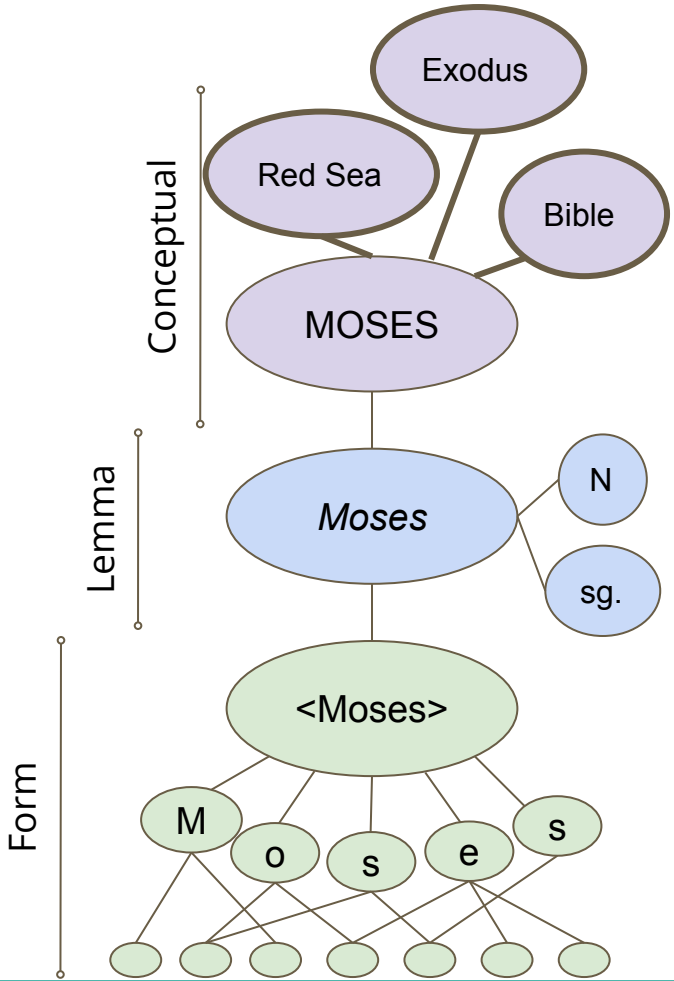
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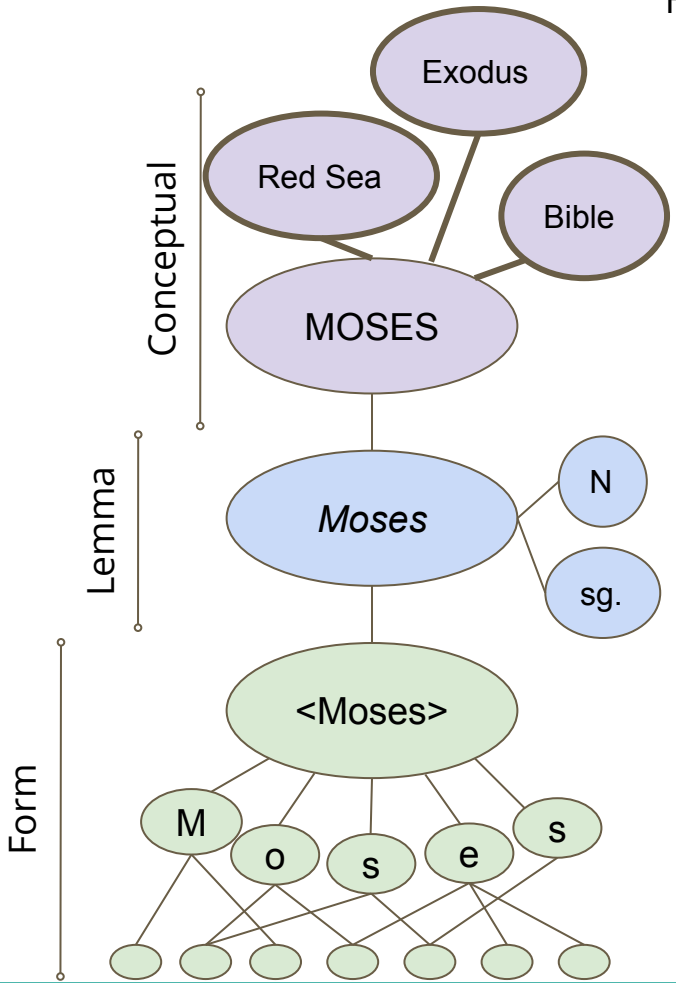
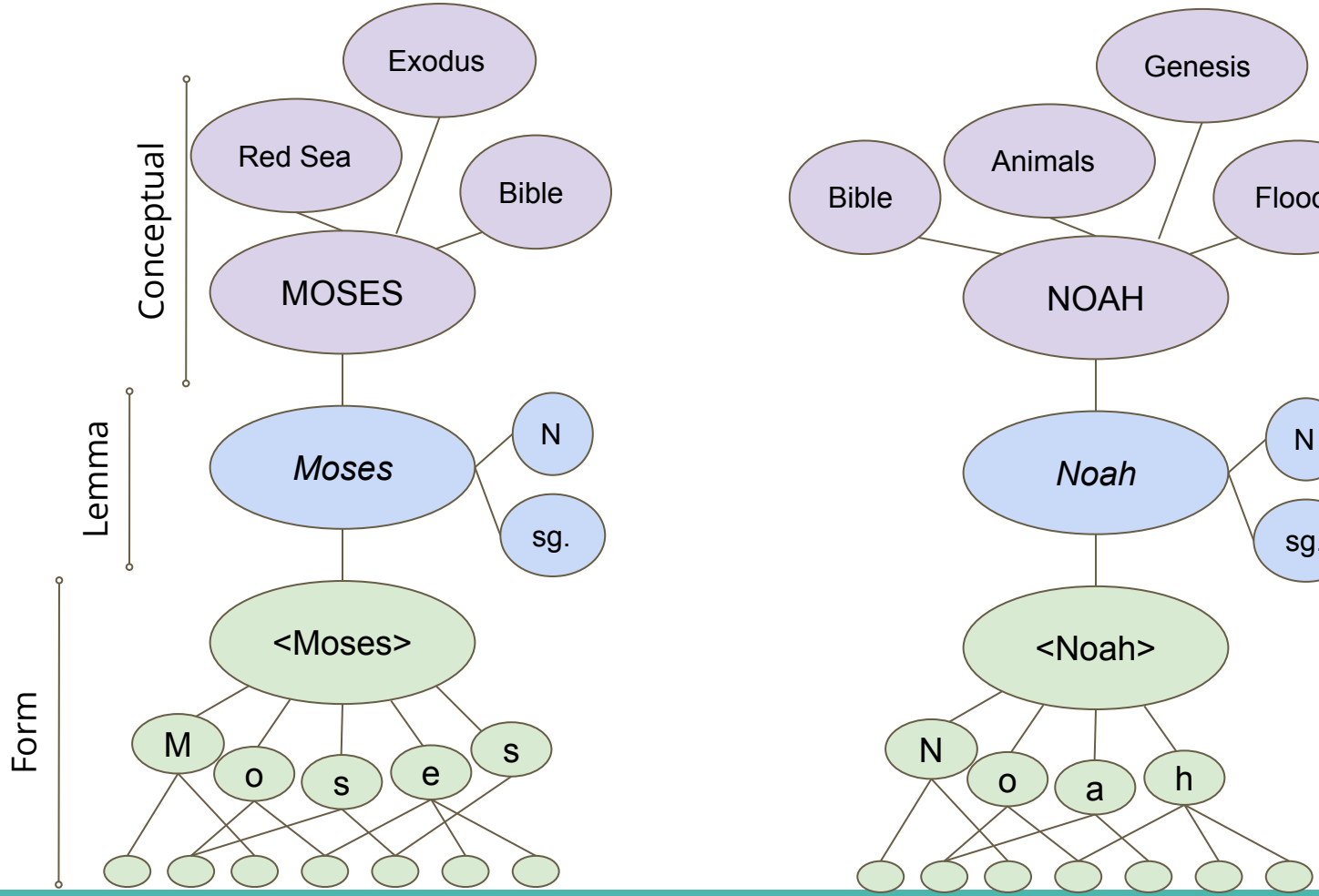
How many animals of each kind did Moses bring on the ark?

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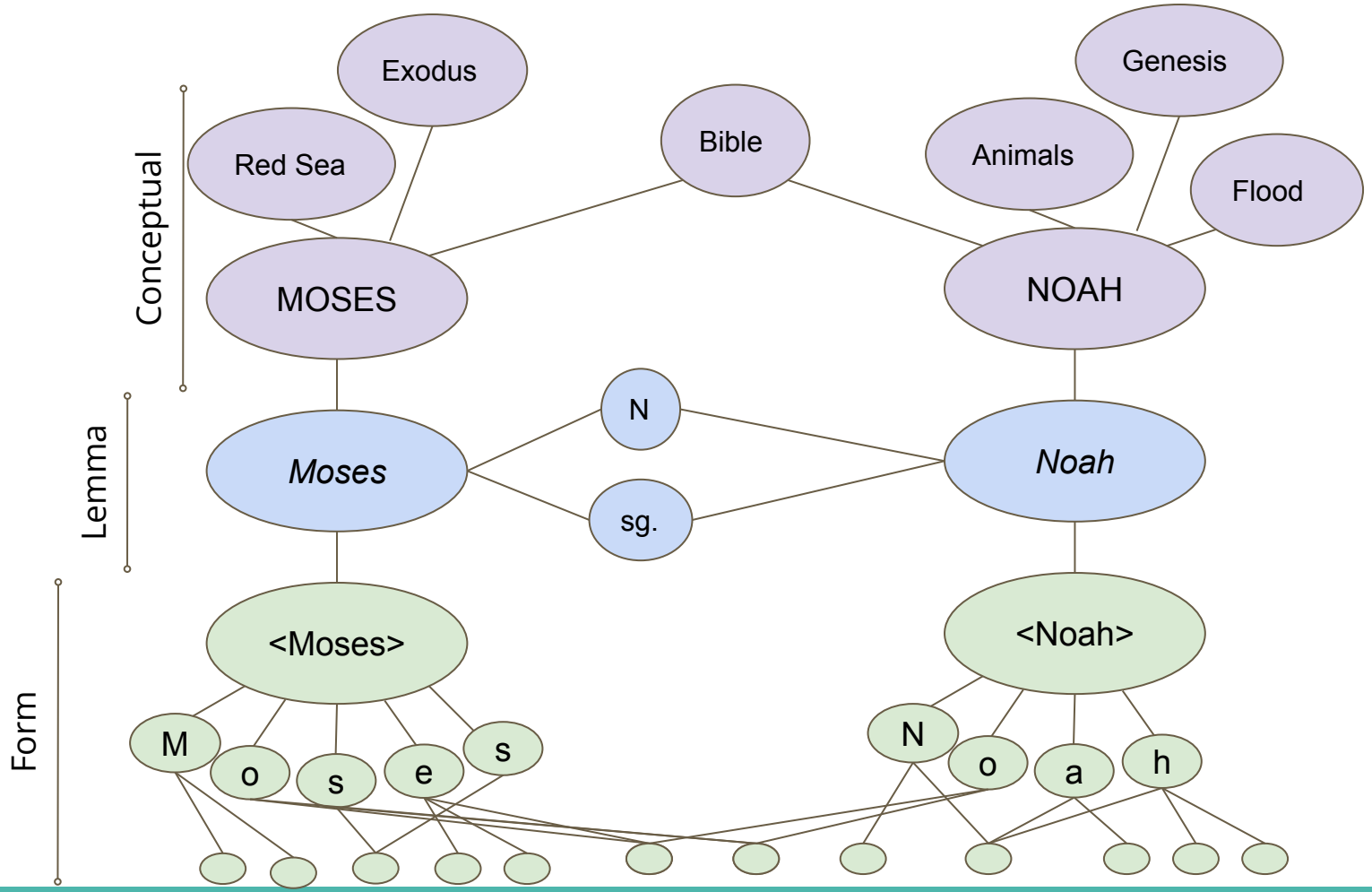
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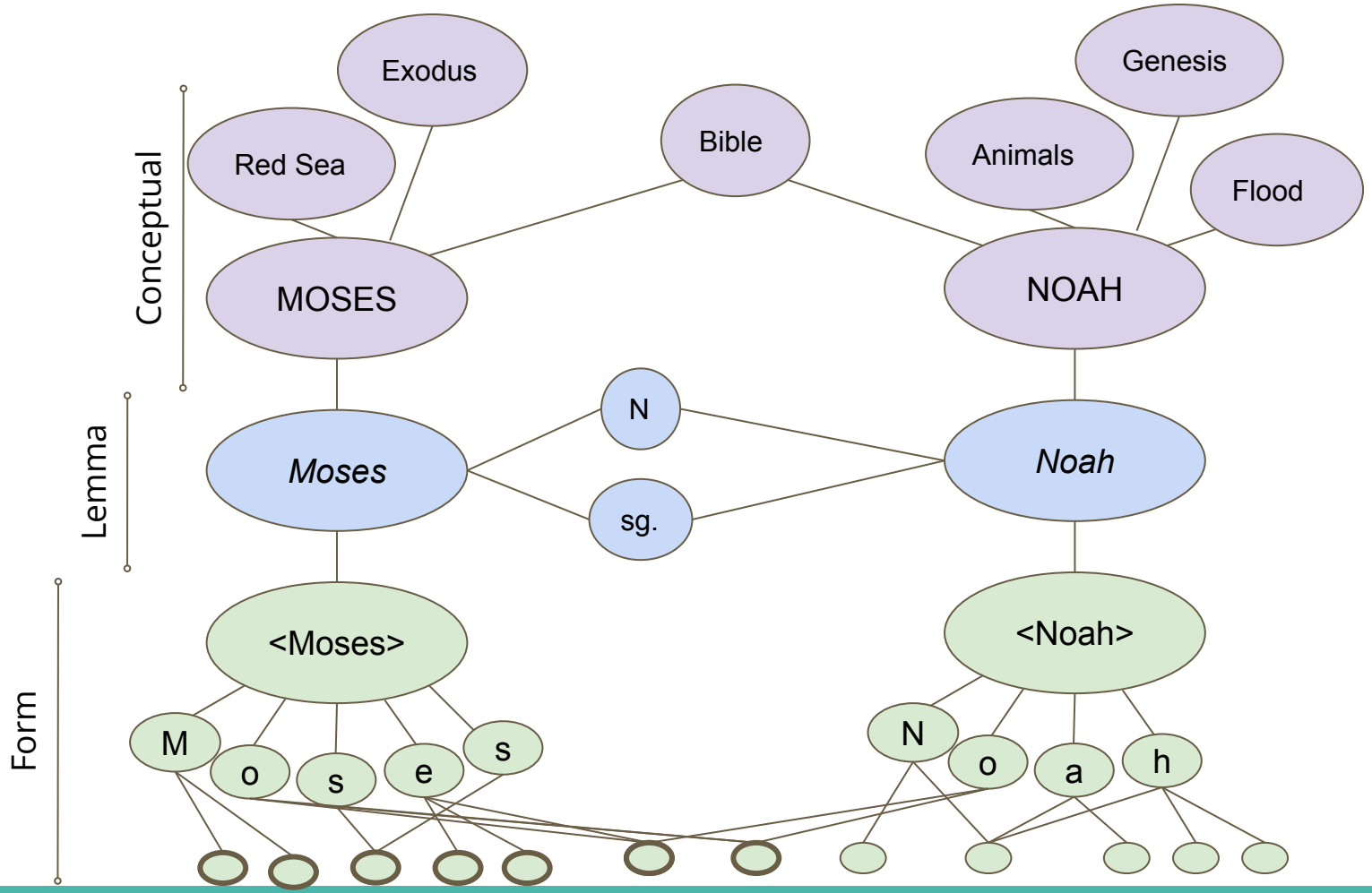
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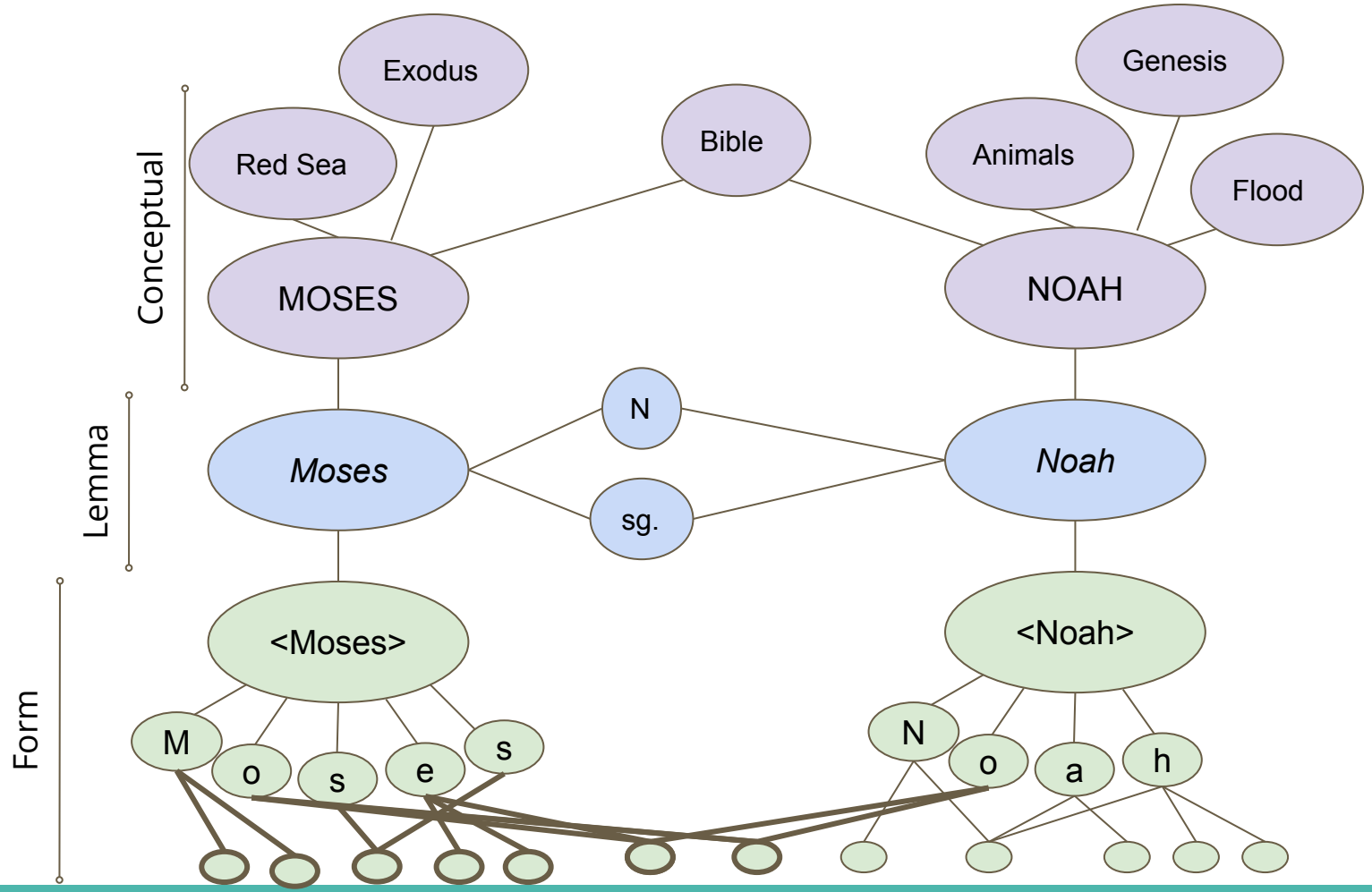
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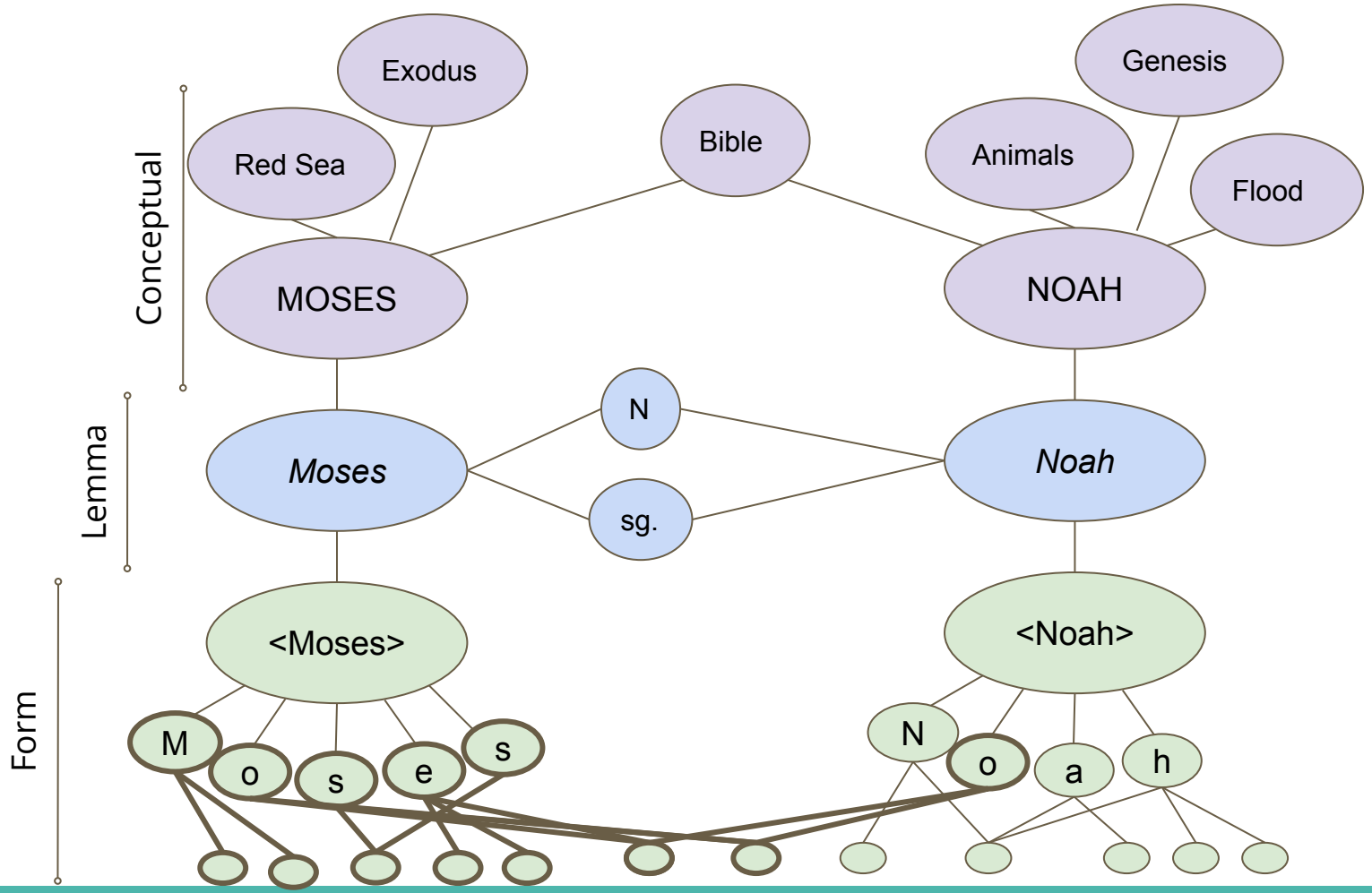
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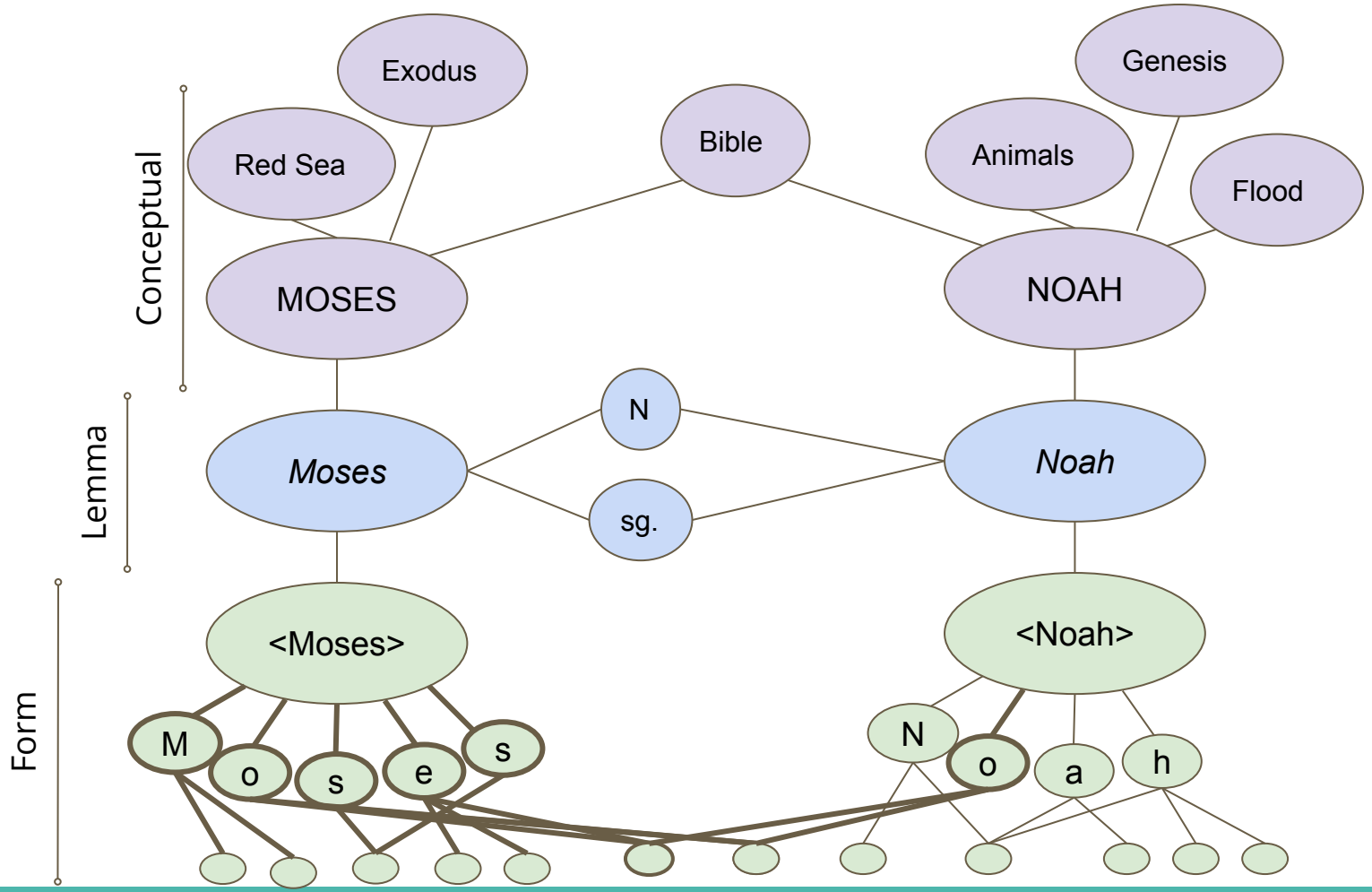
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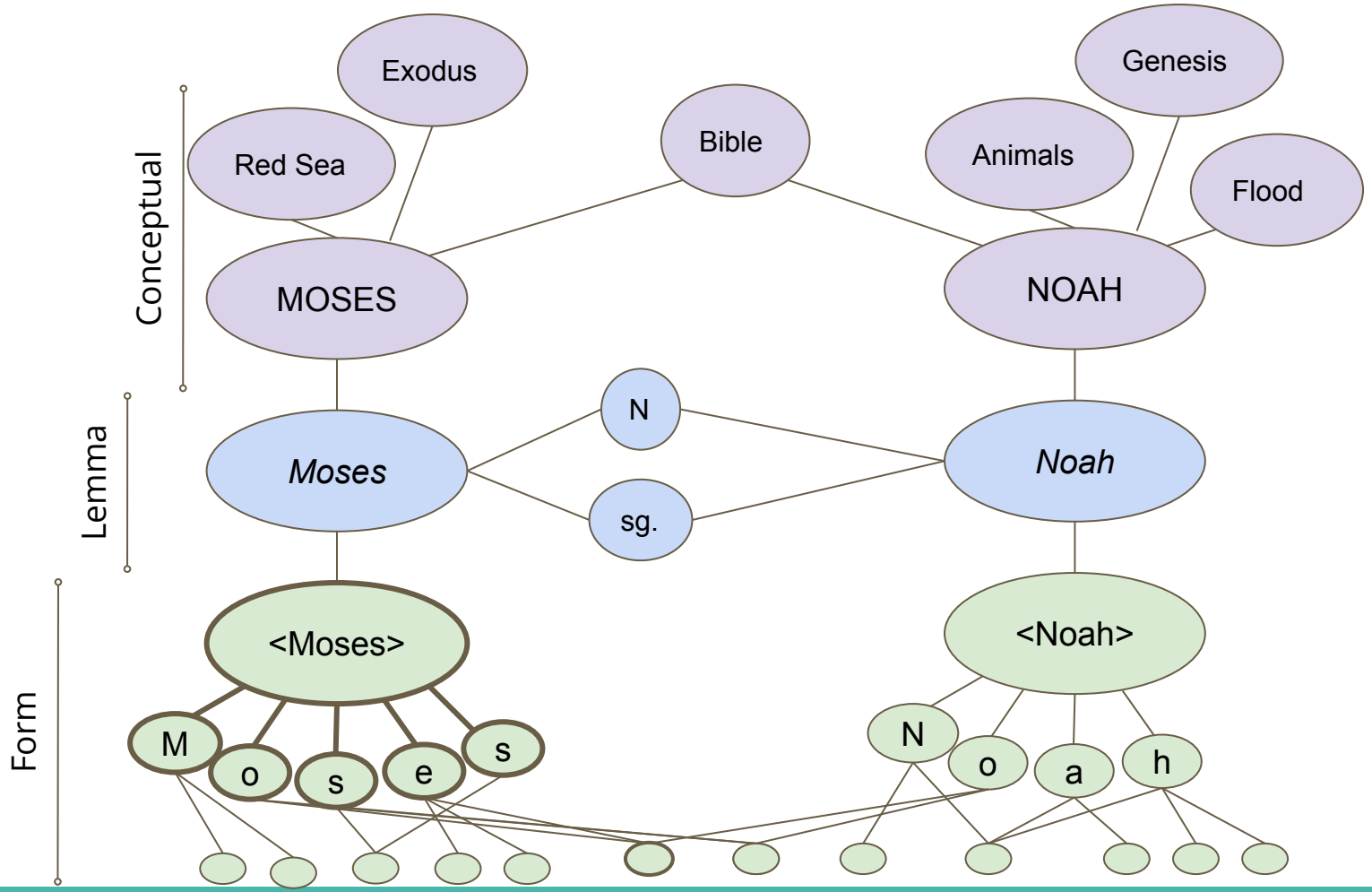
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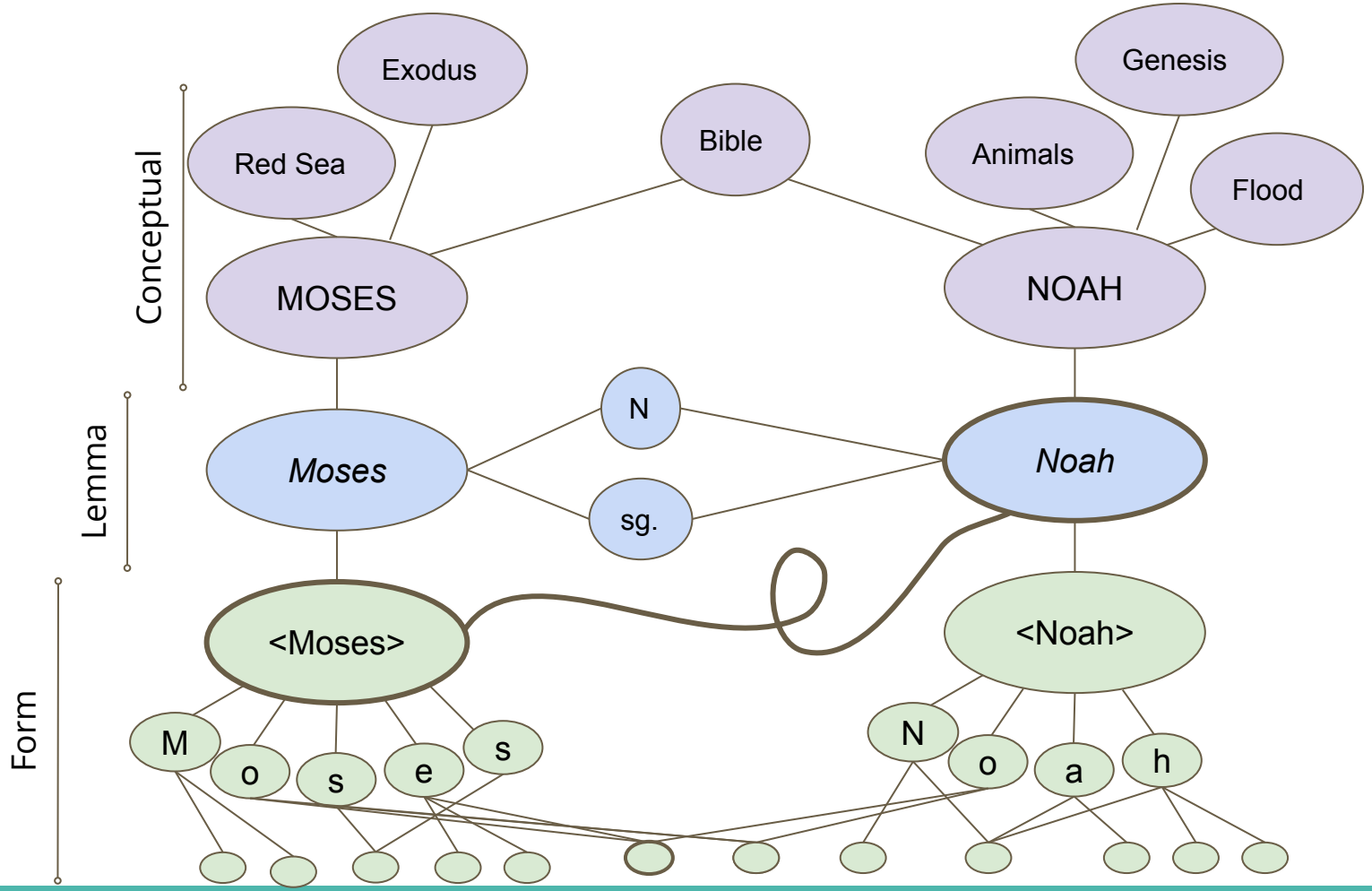
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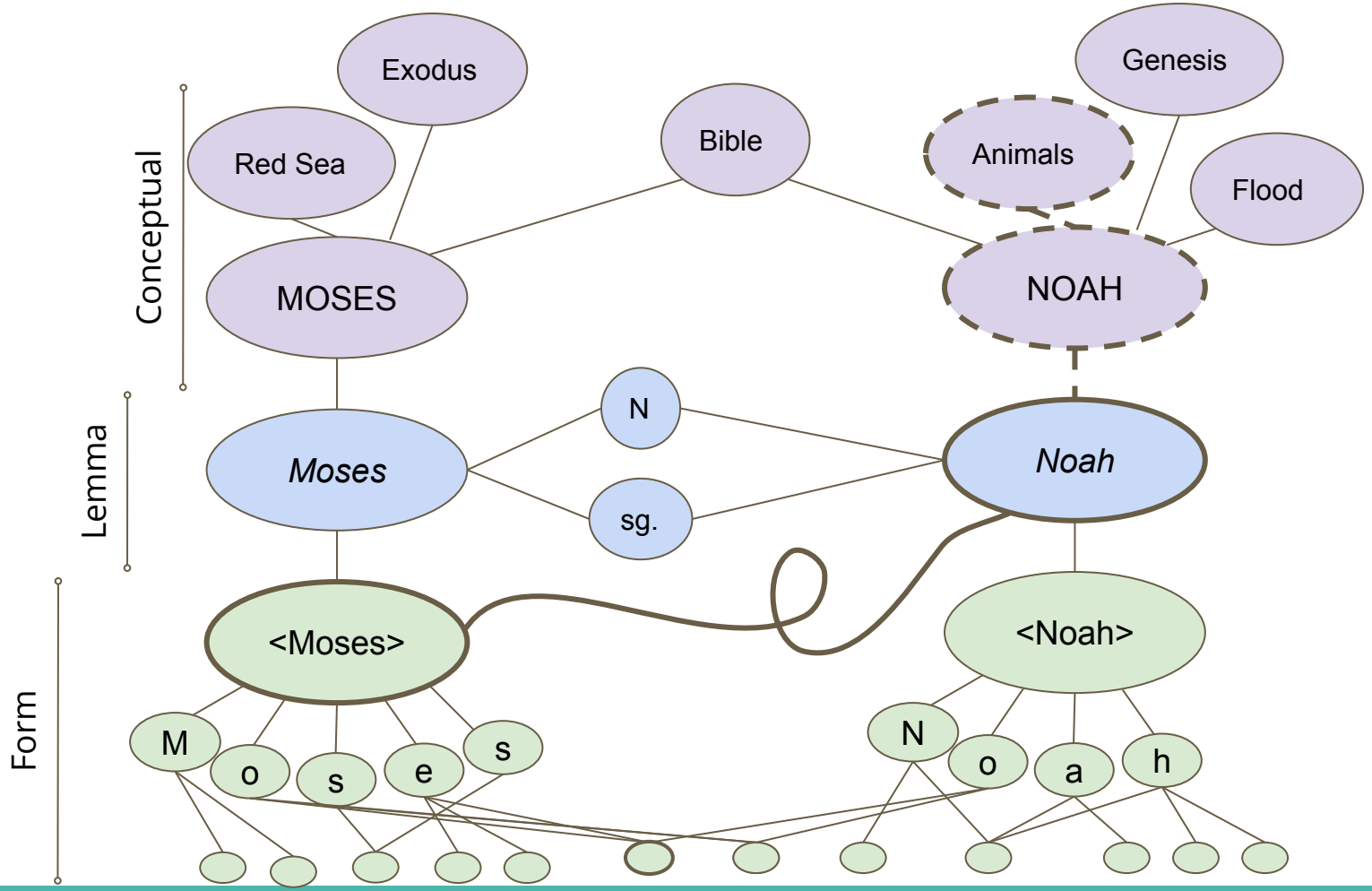
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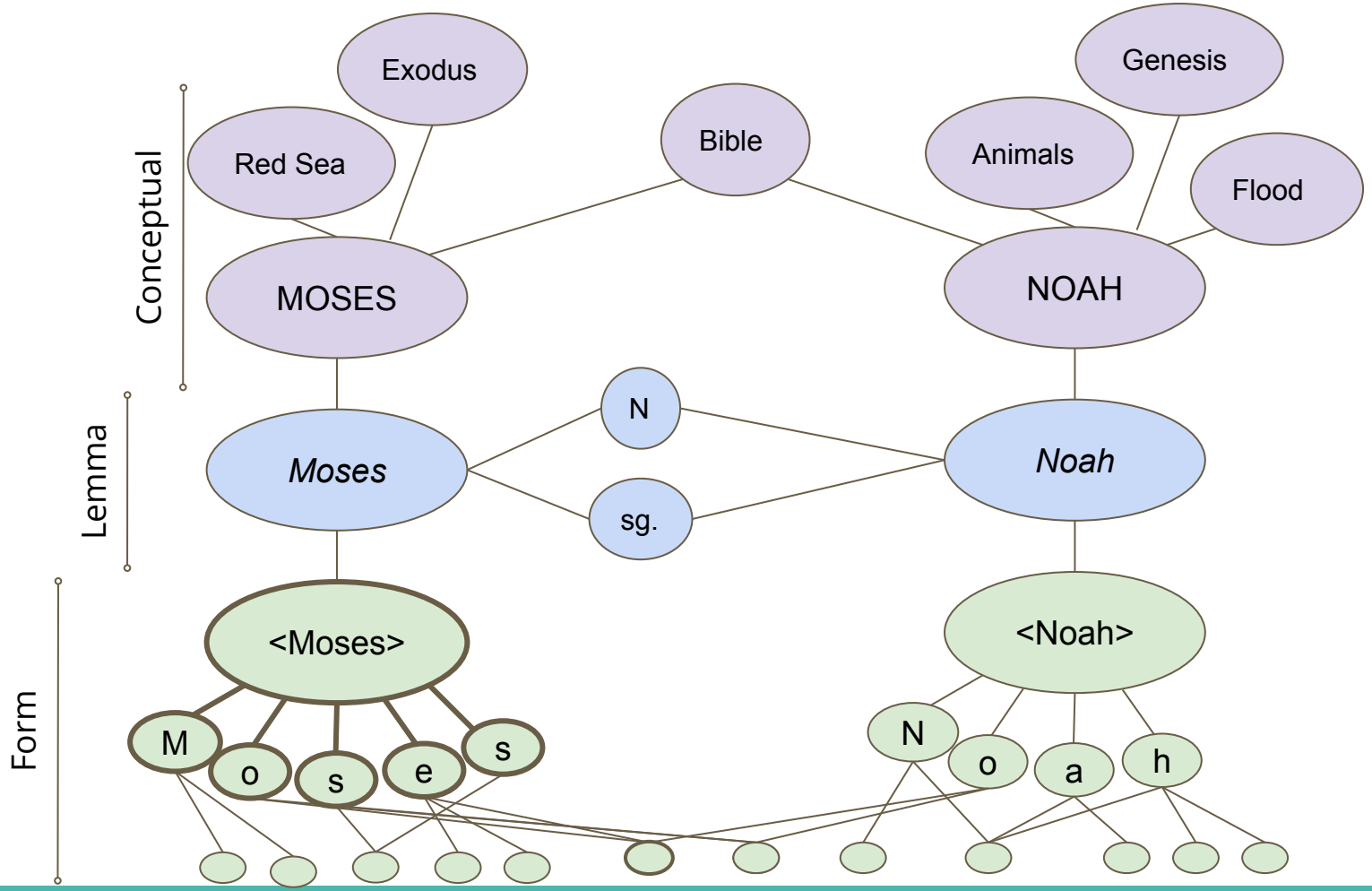
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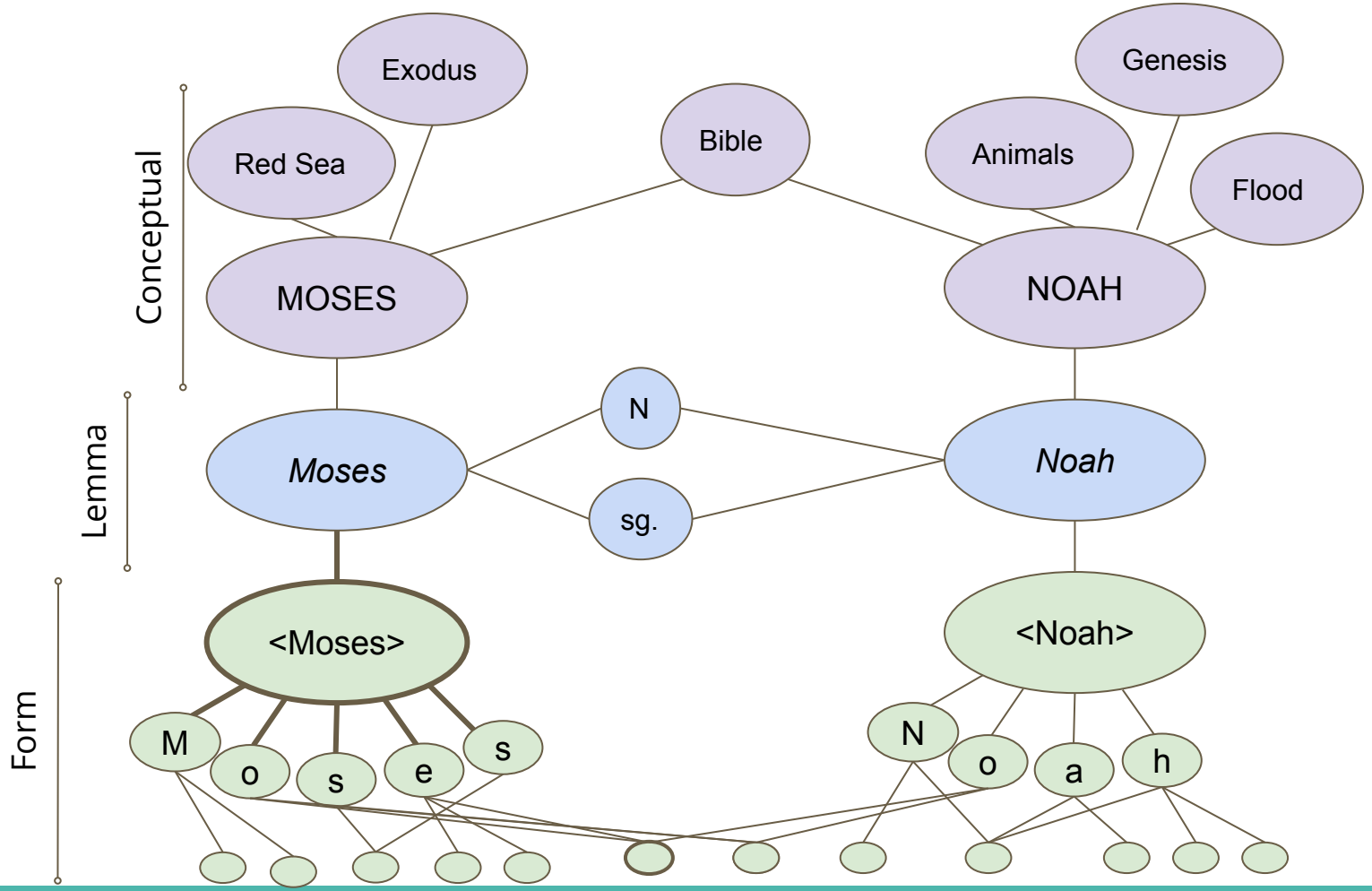
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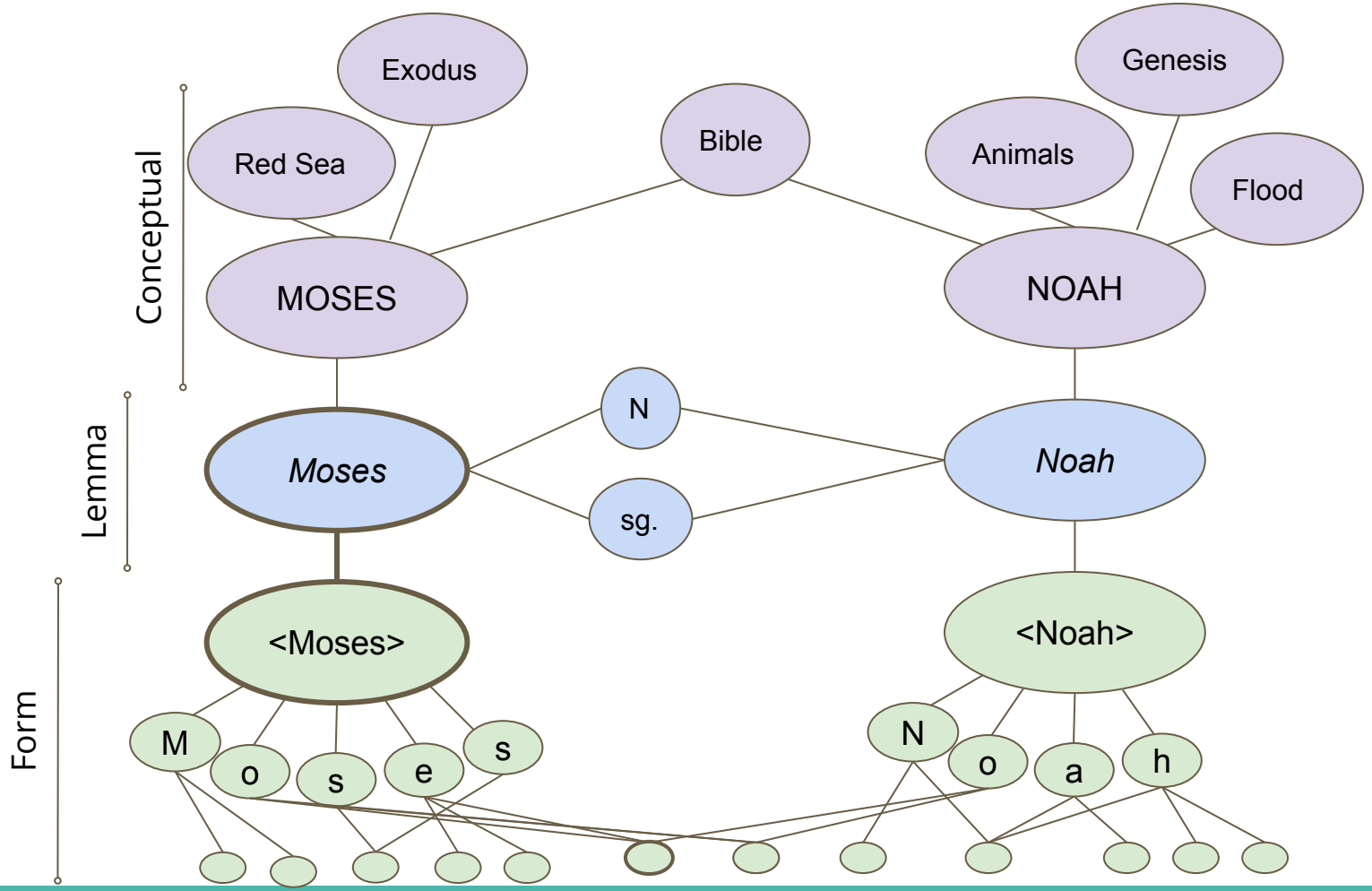
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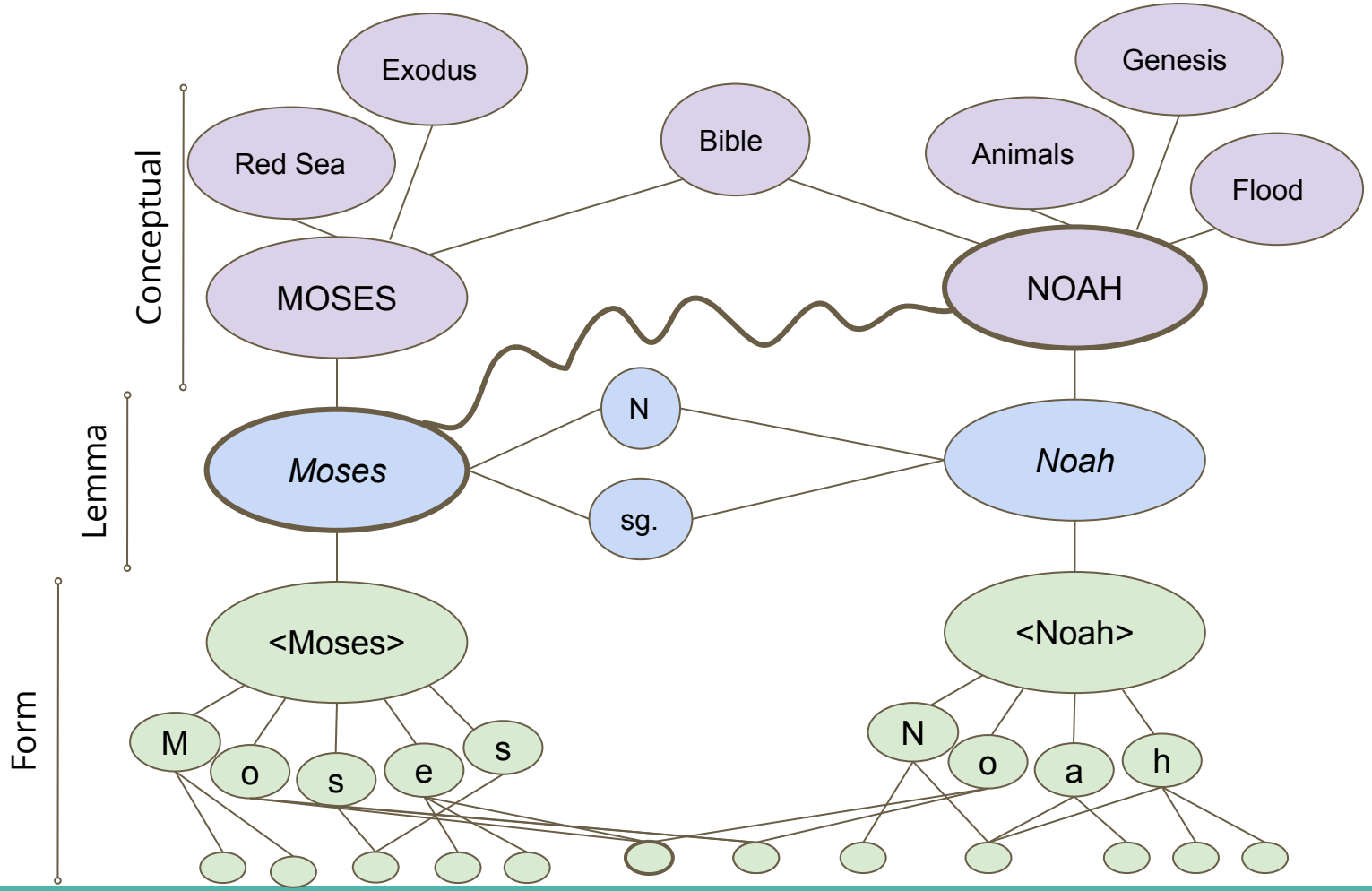
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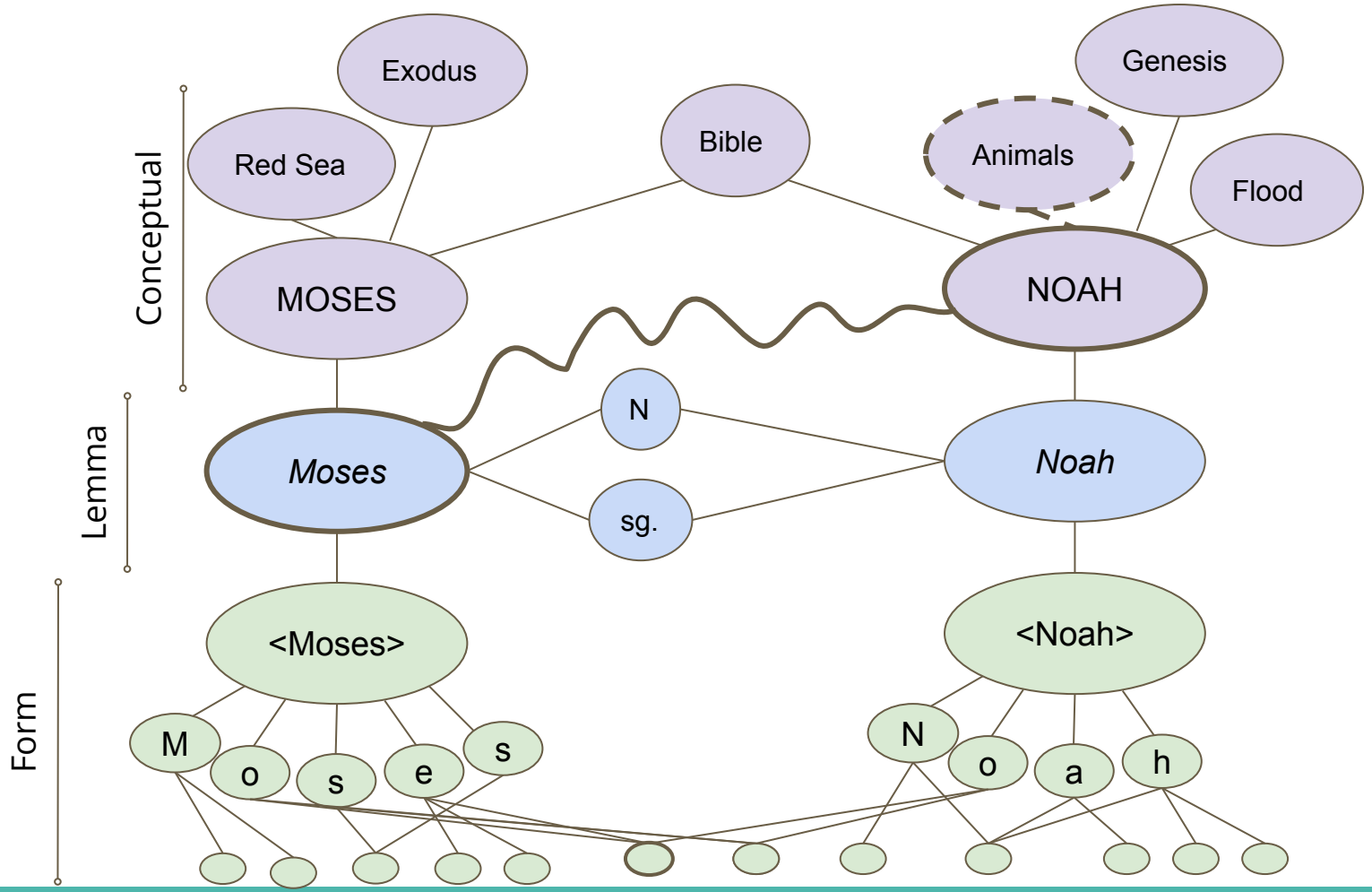
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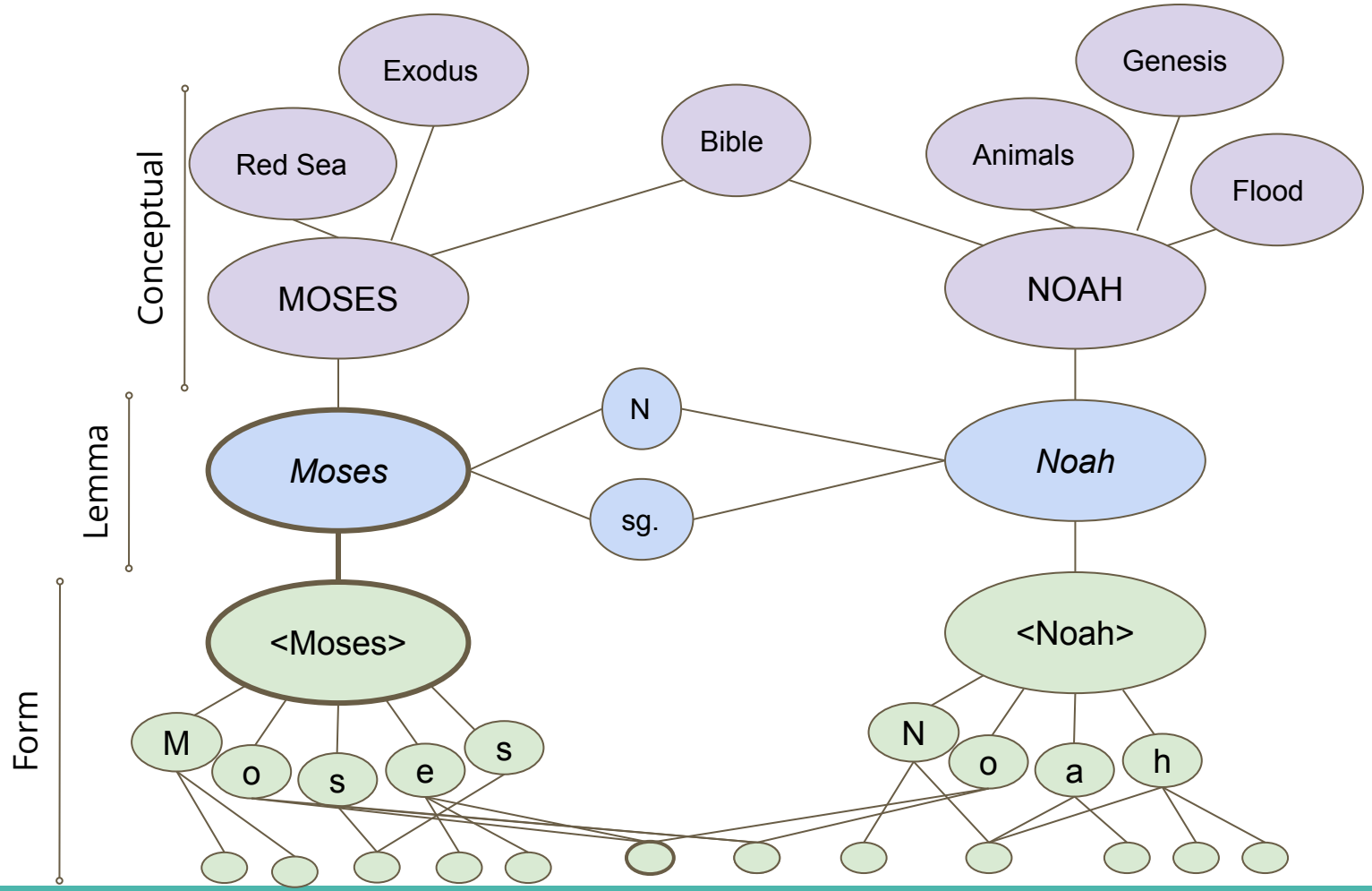
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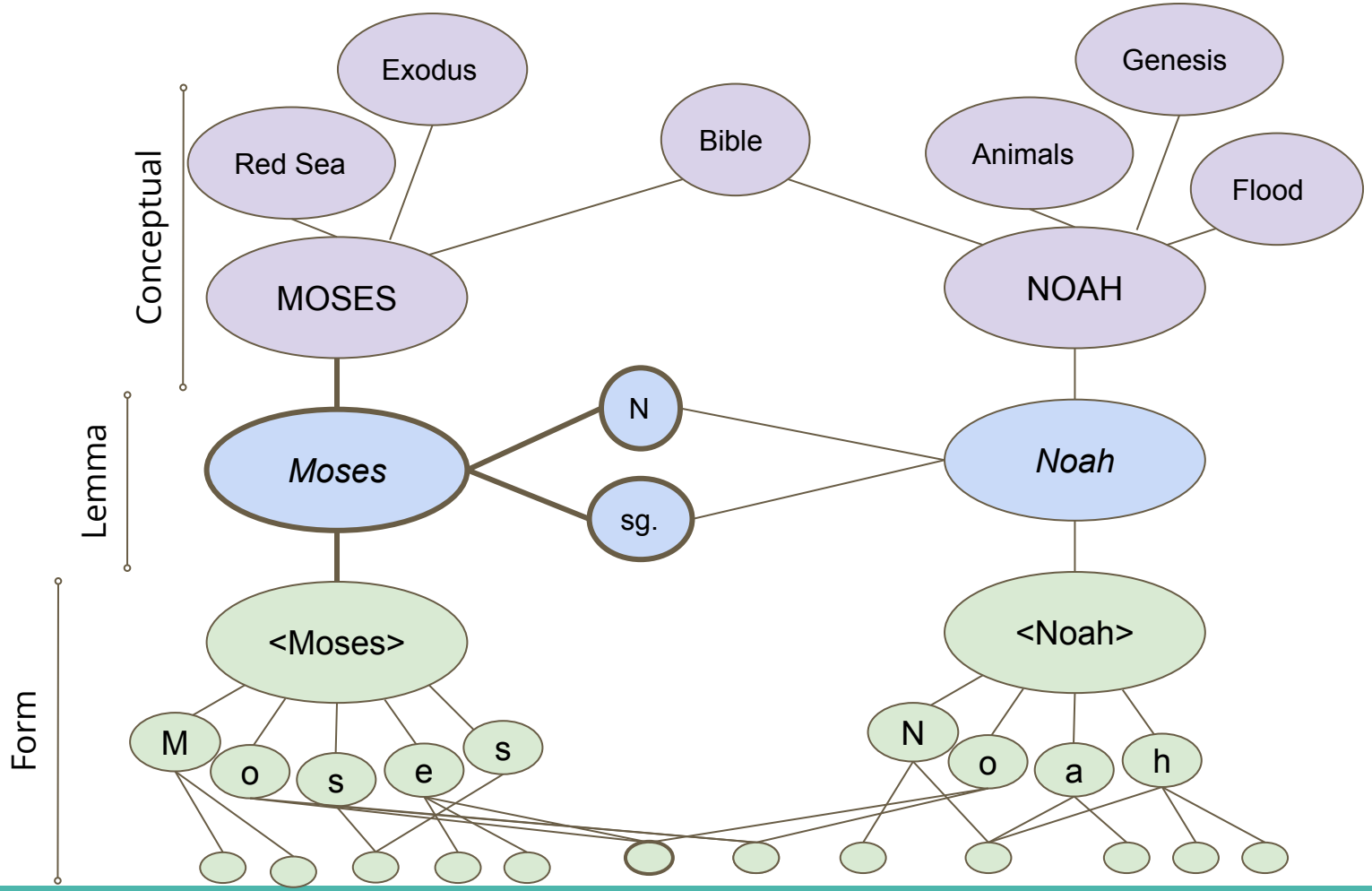
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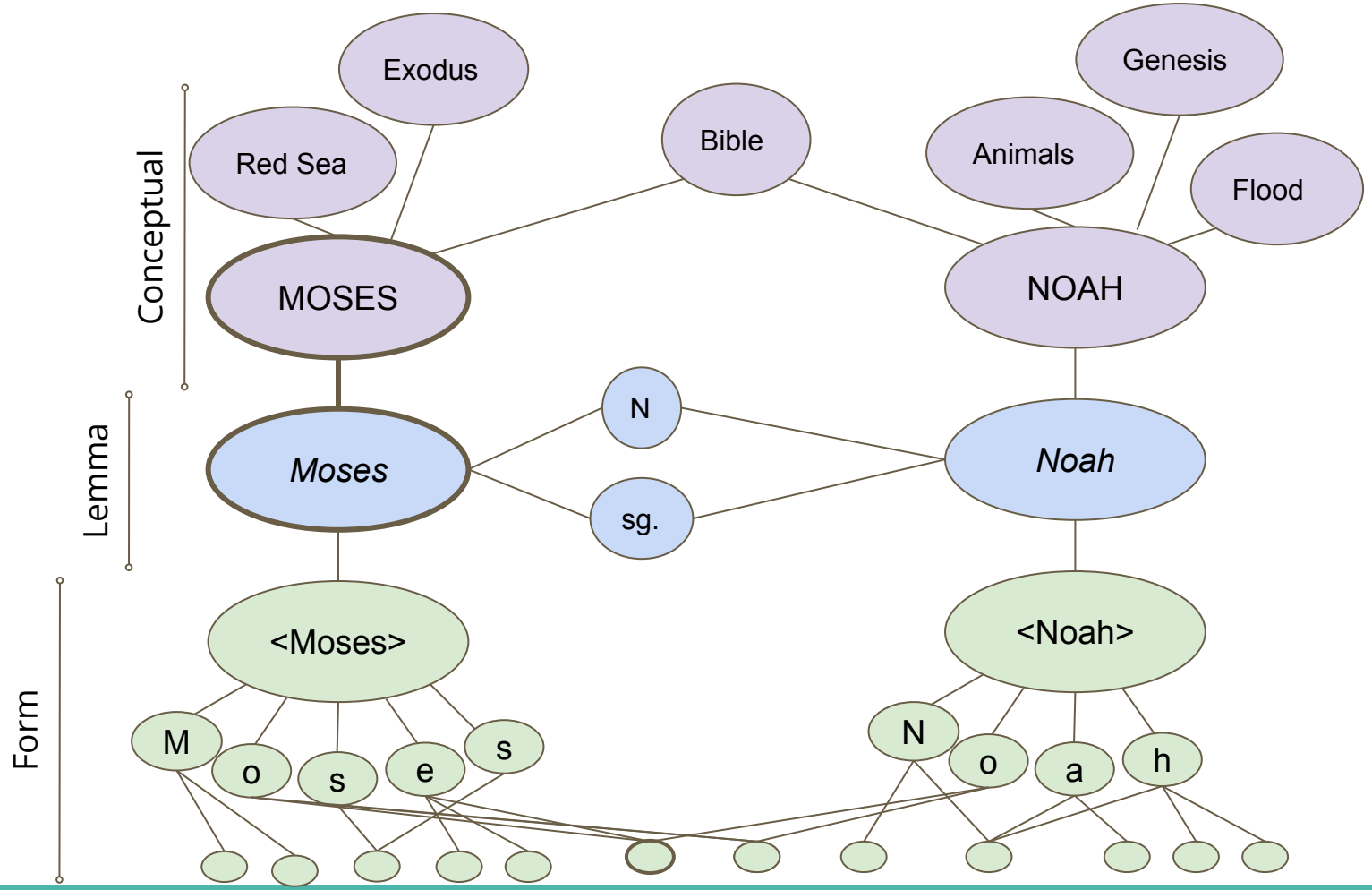
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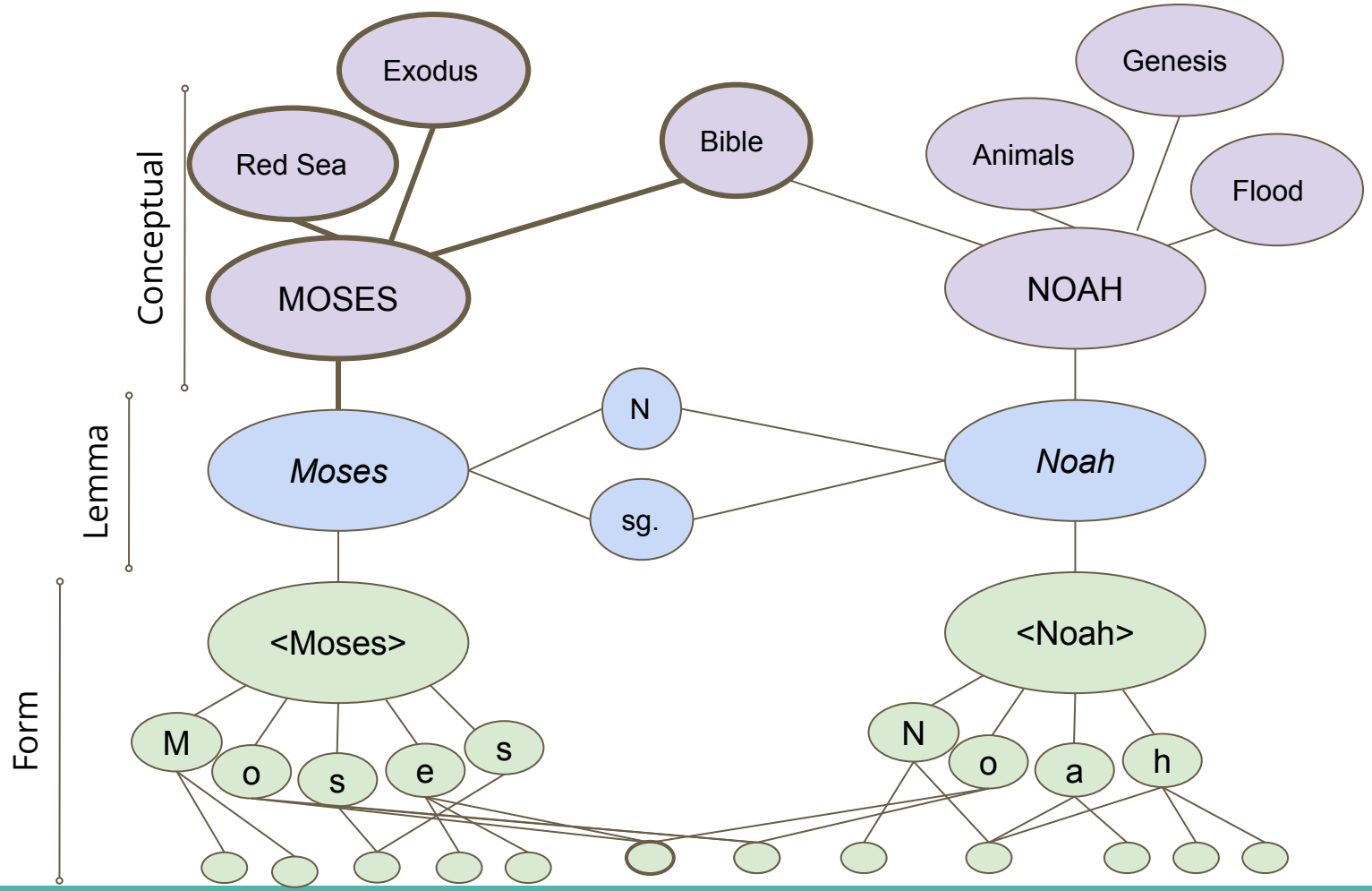
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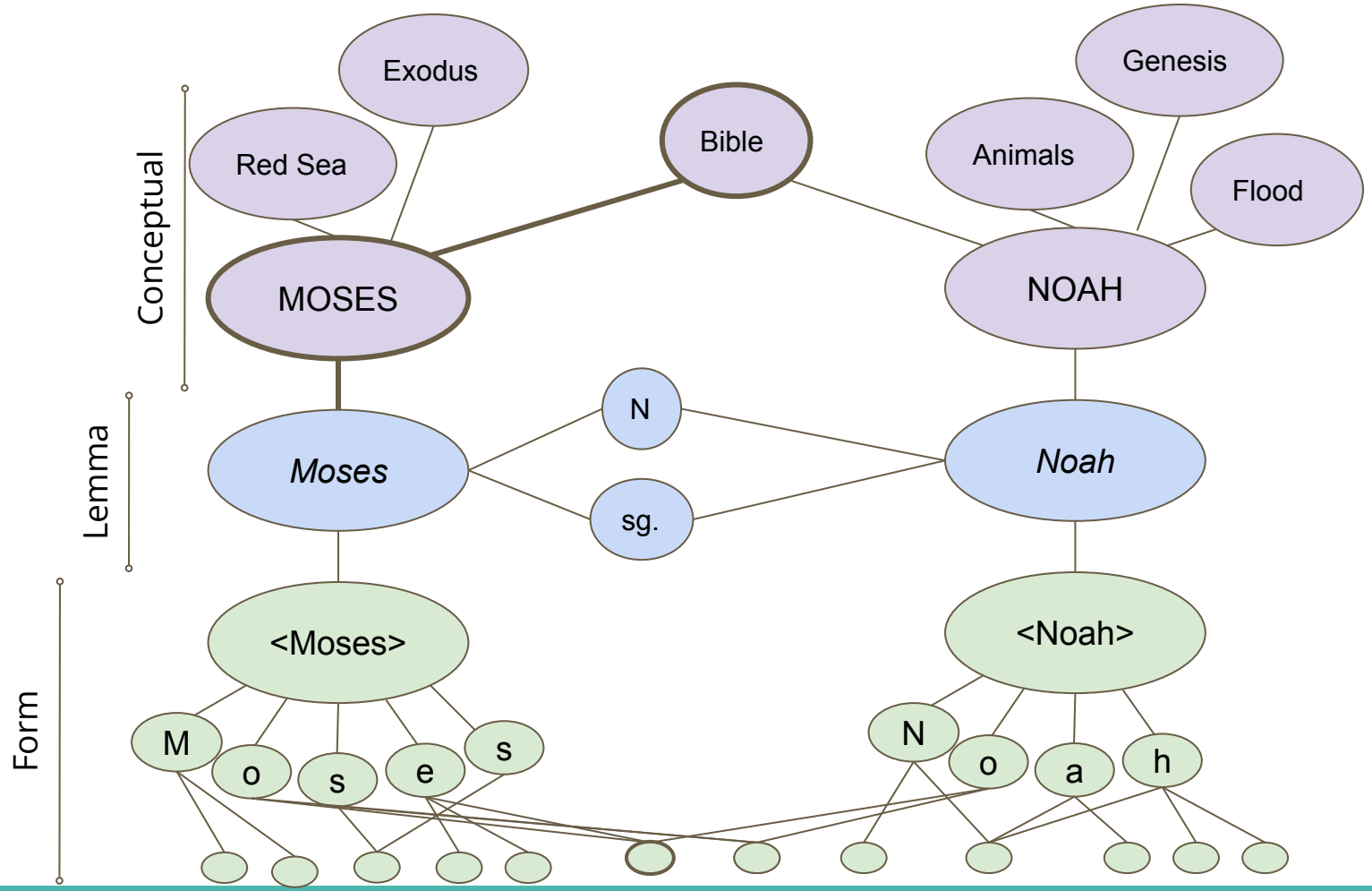
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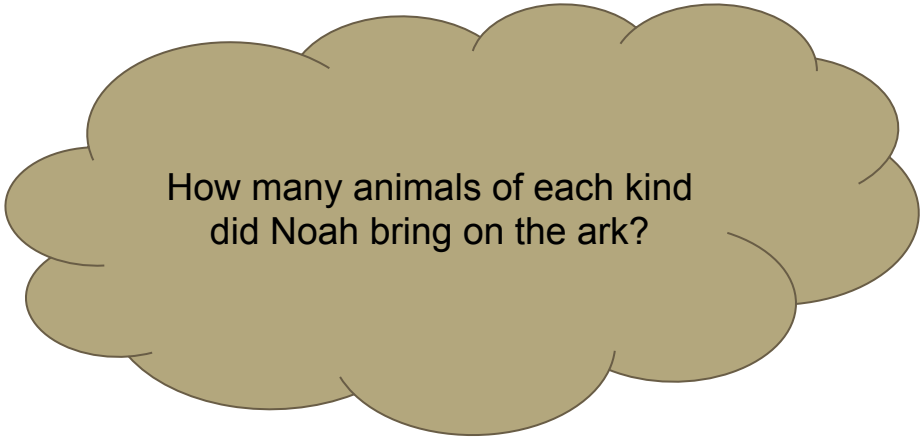
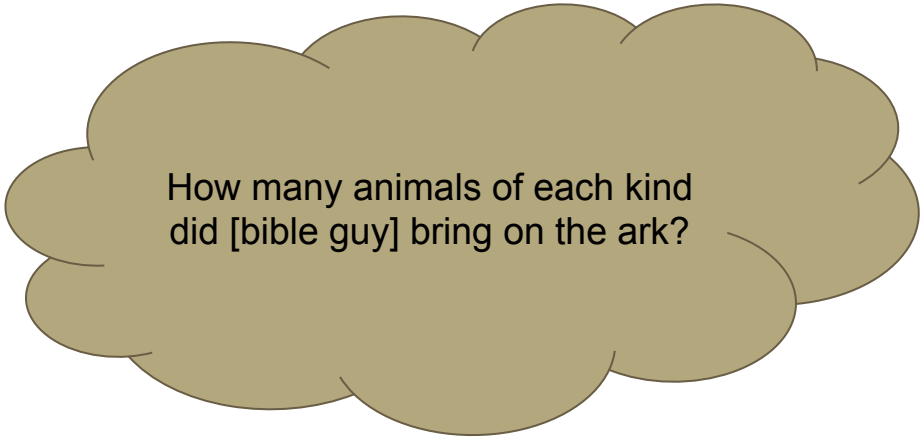
The basic phenomenon = The Moses Illusion



How many animals of each kind did Moses bring on the ark?

The basic phenomenon = The Moses Illusion



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Planned experiment: Moses illusions and priming

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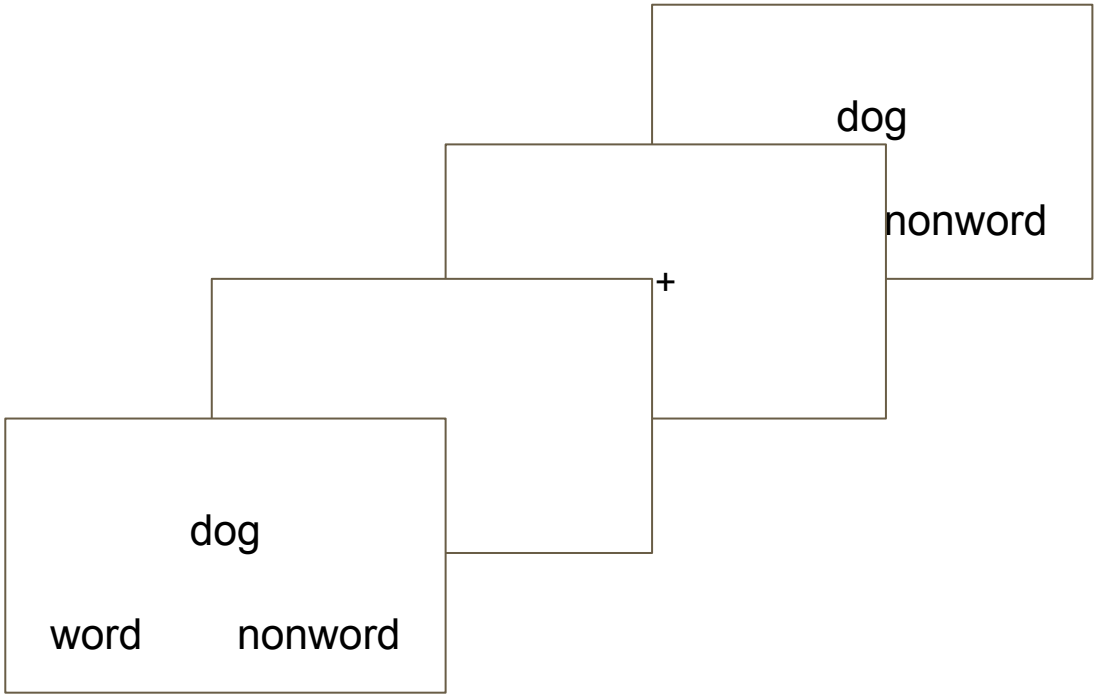

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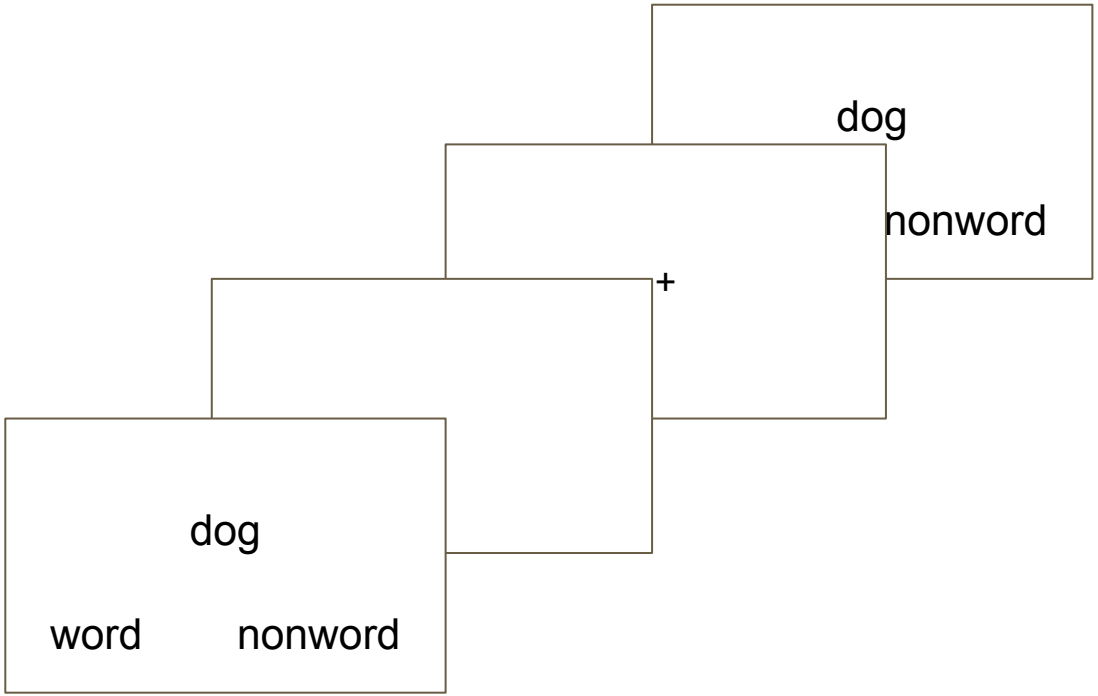

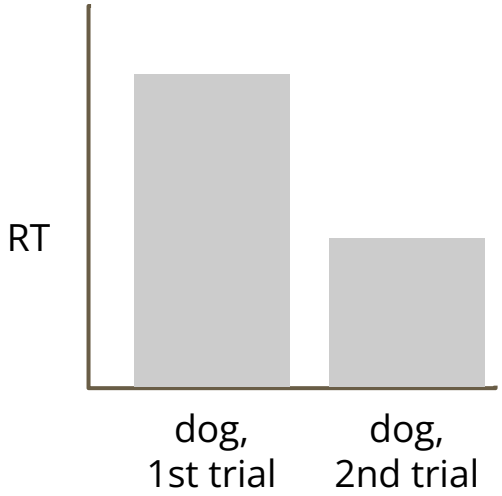

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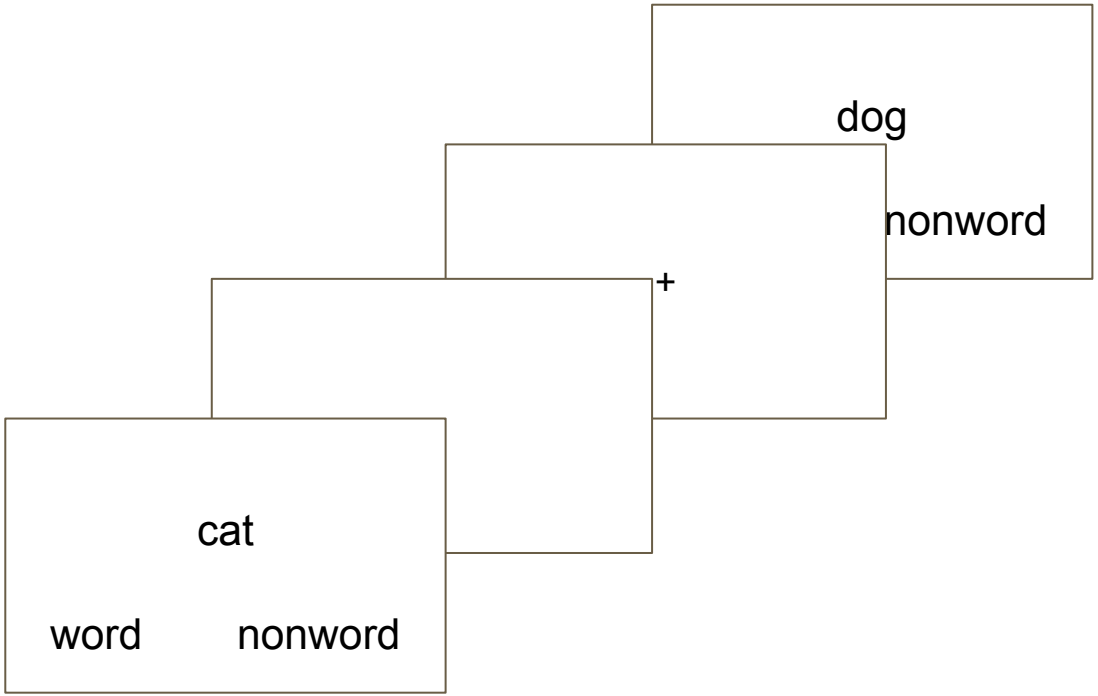

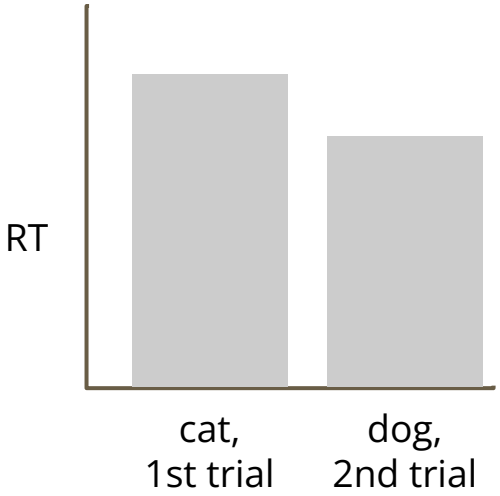

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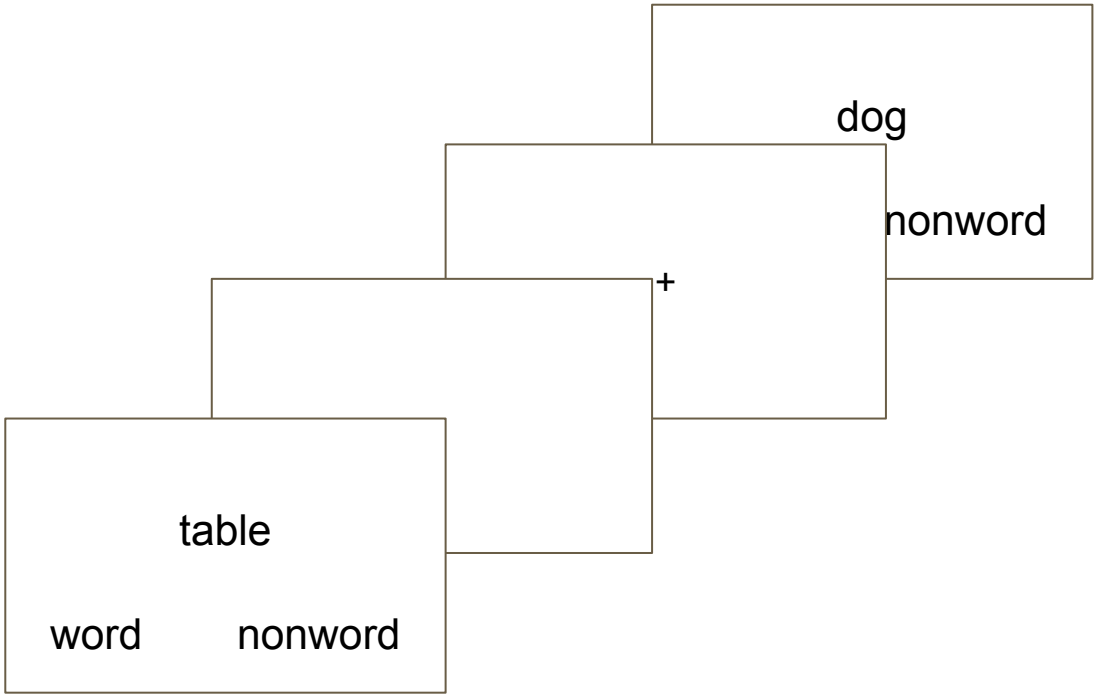

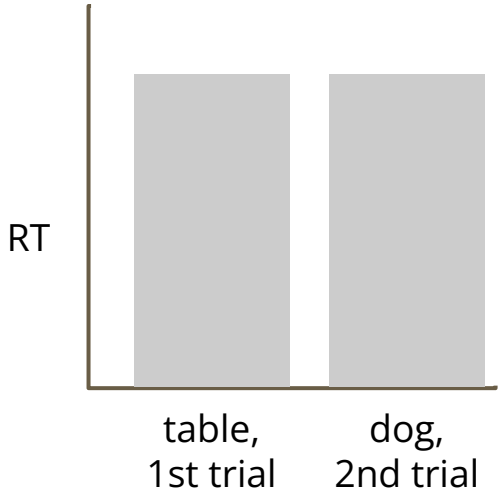

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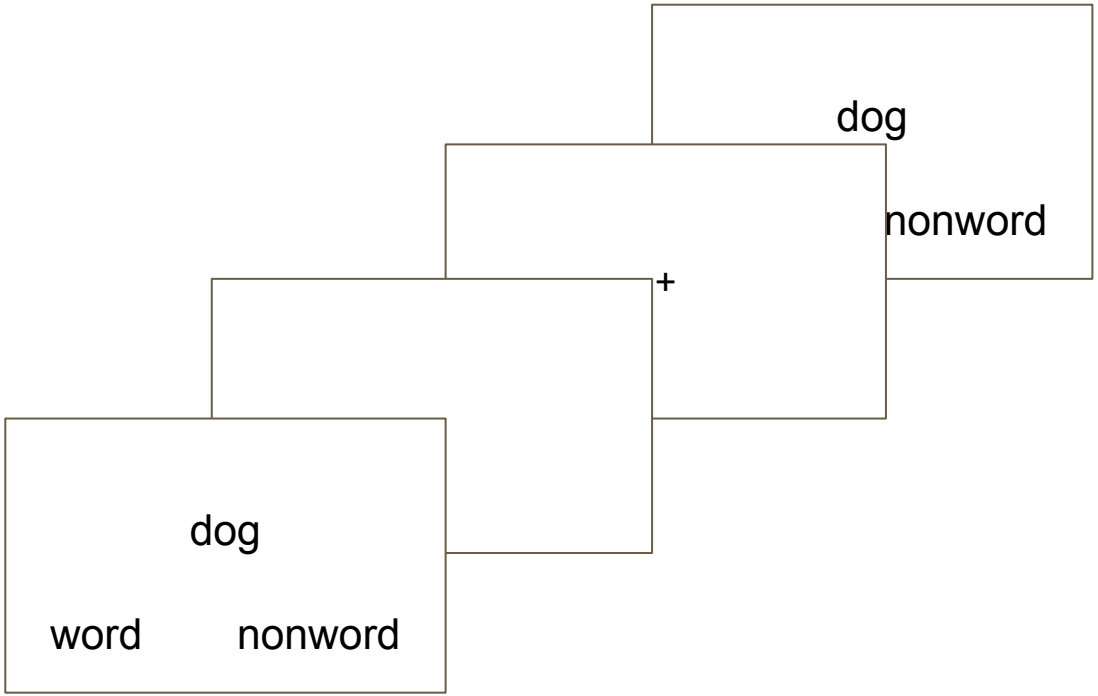

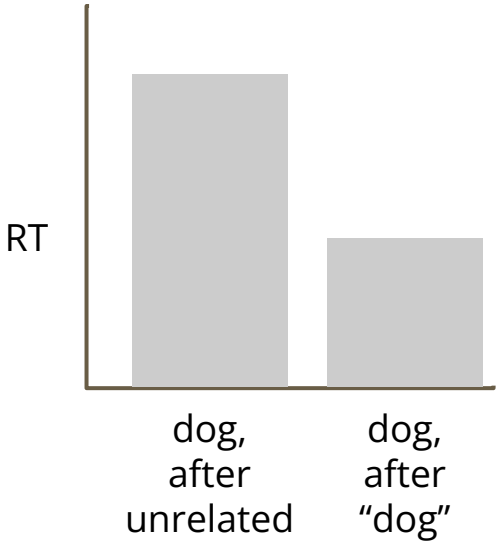

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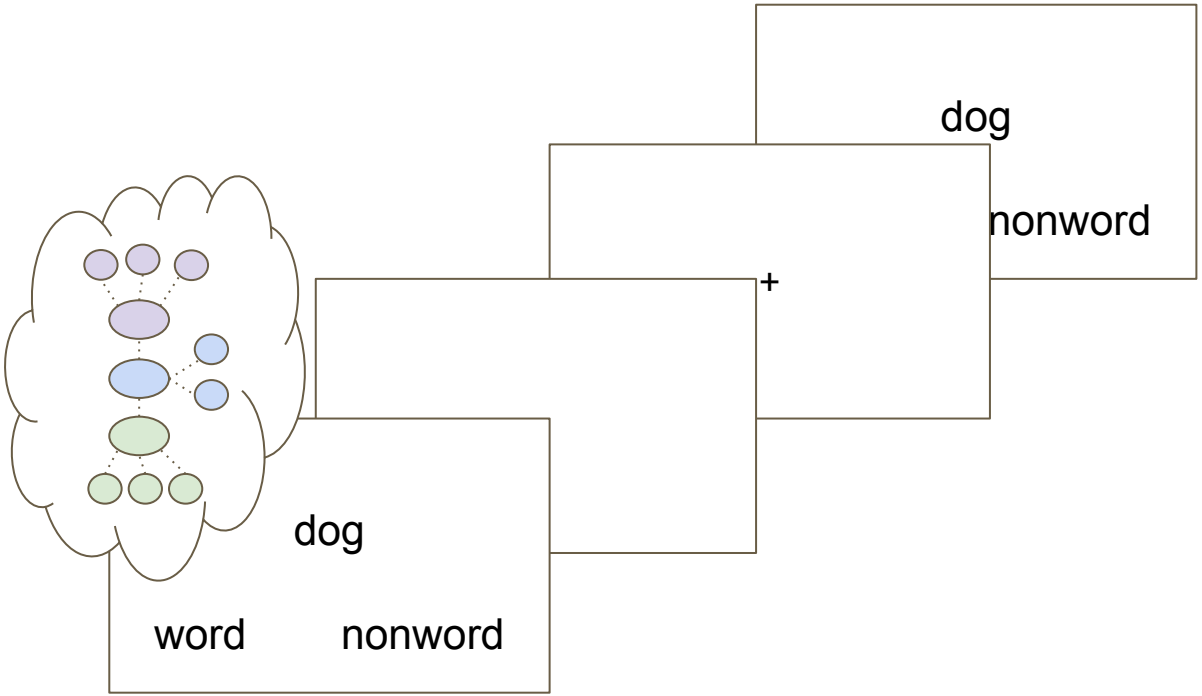

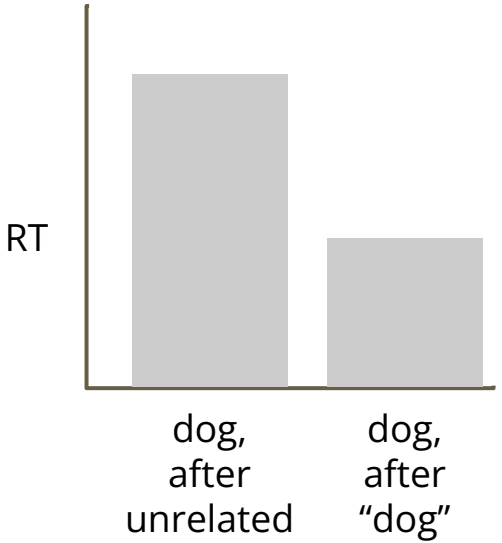

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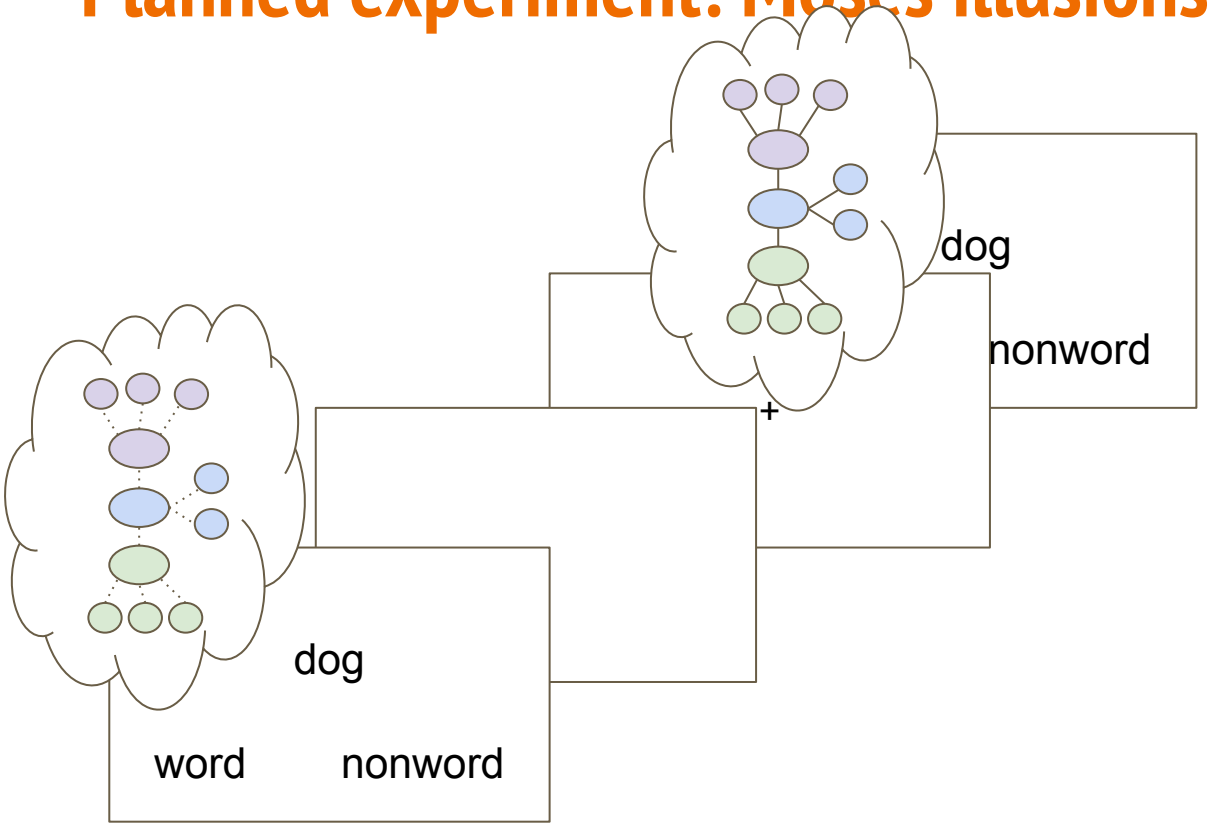

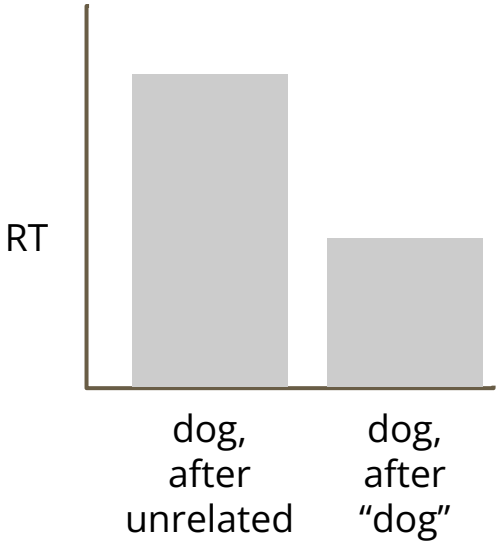

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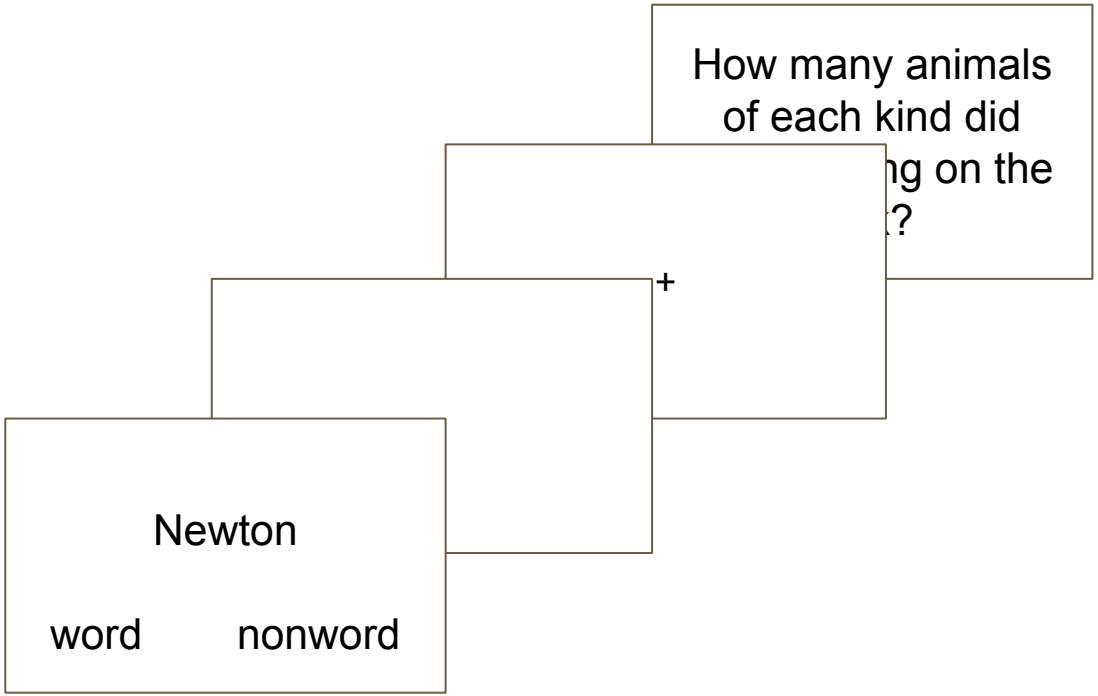

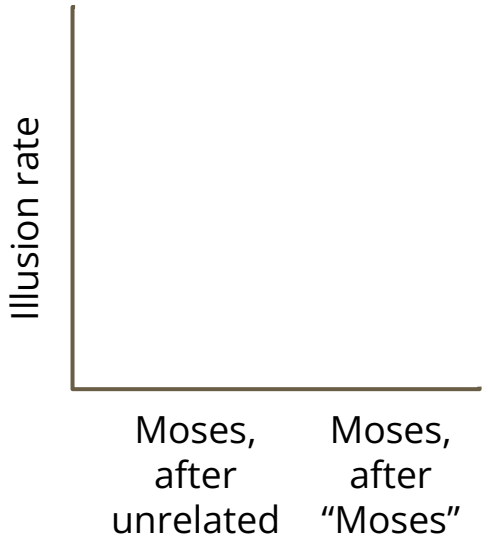

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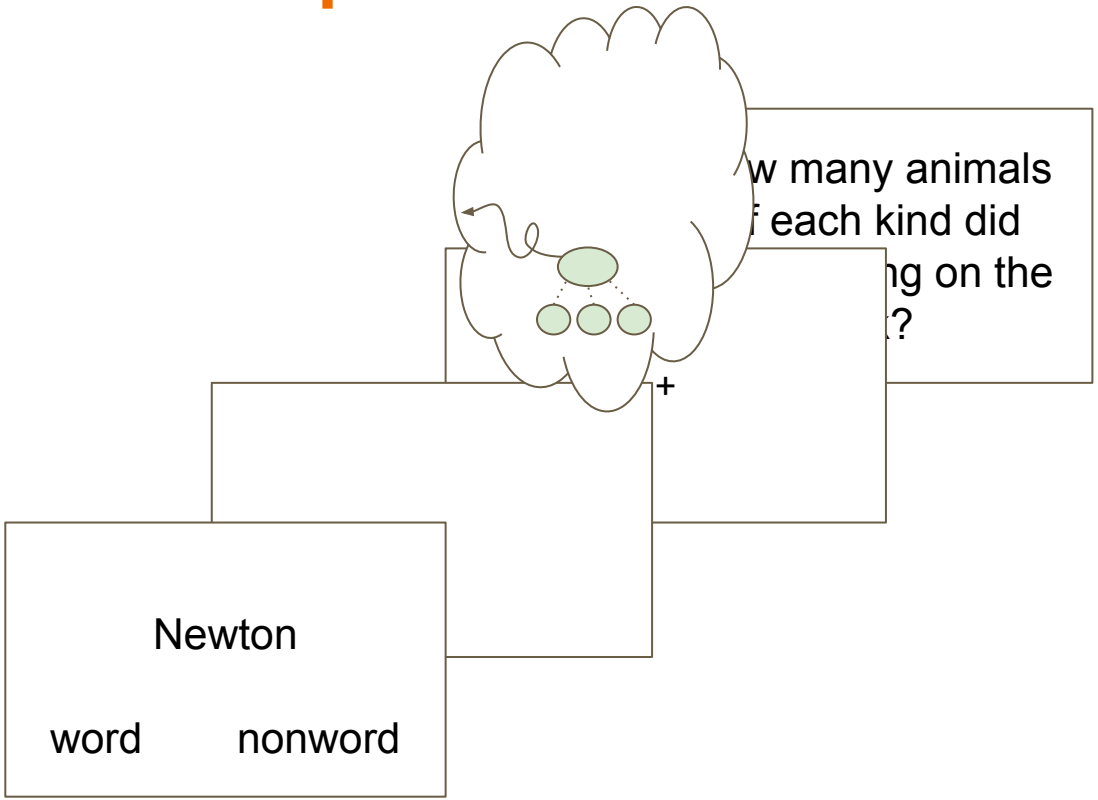

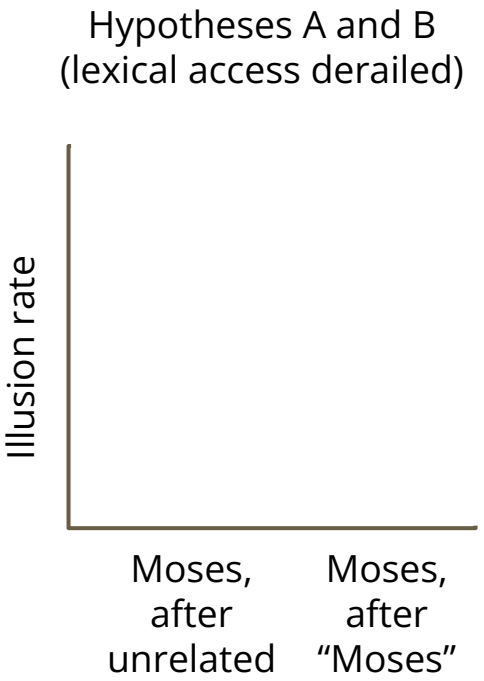

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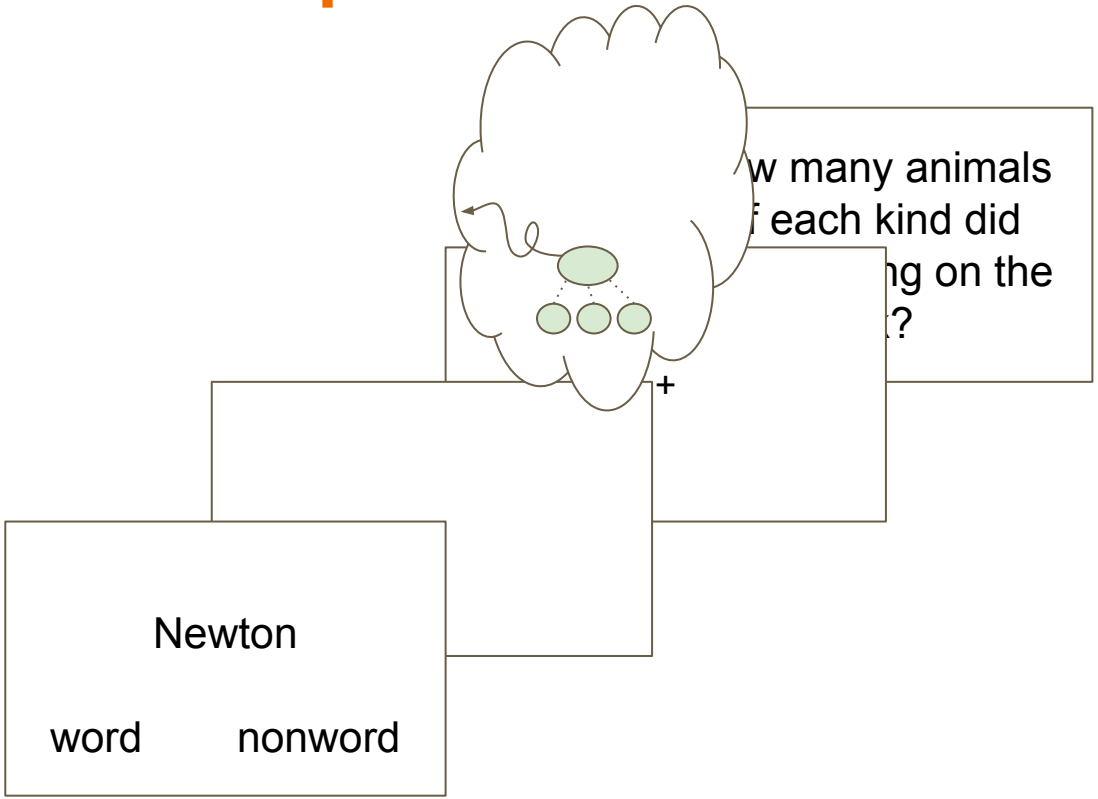

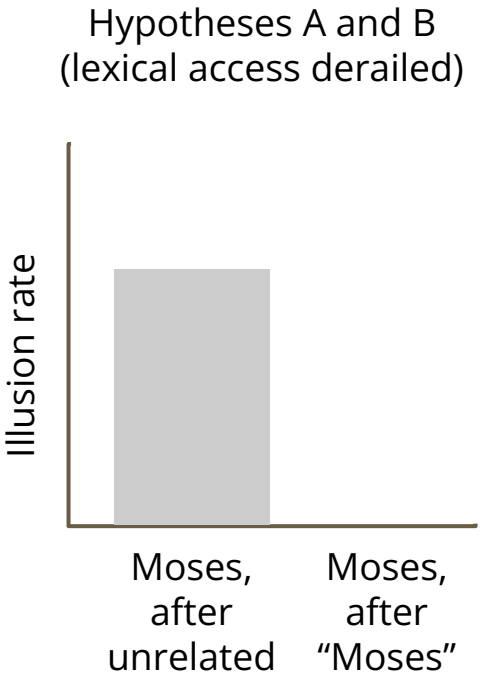

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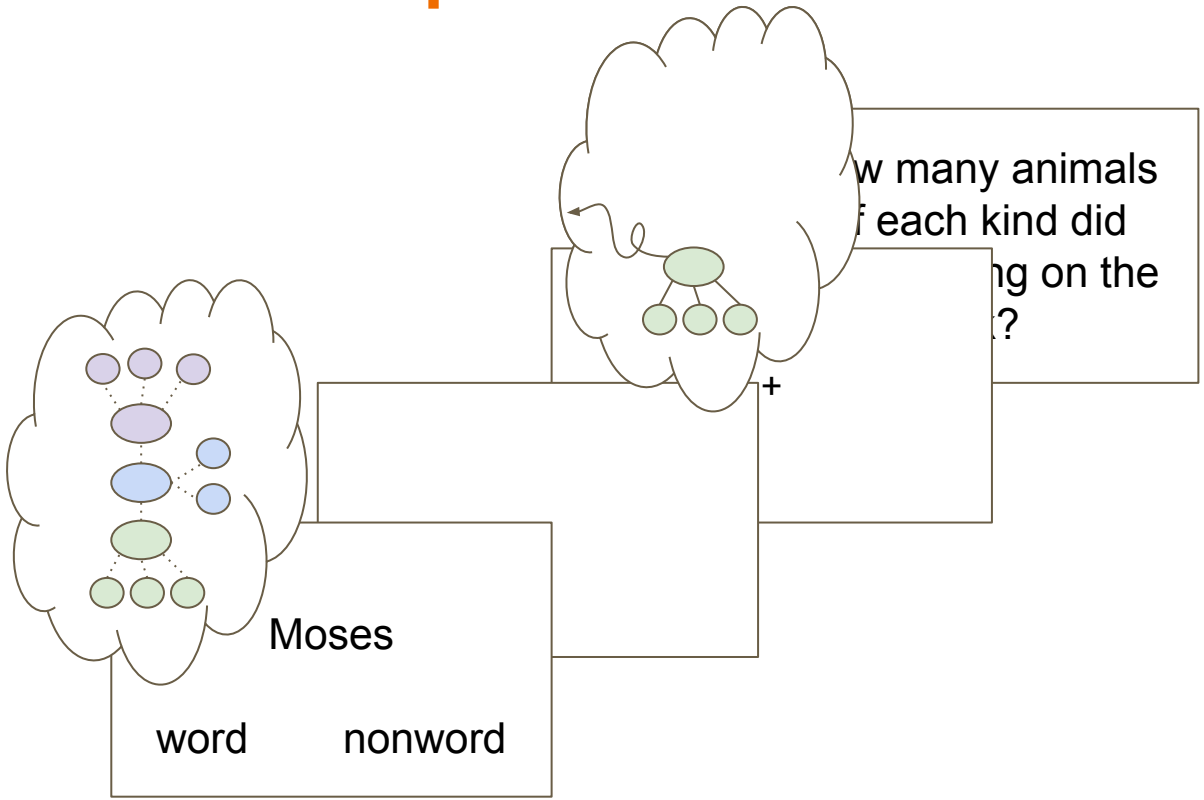

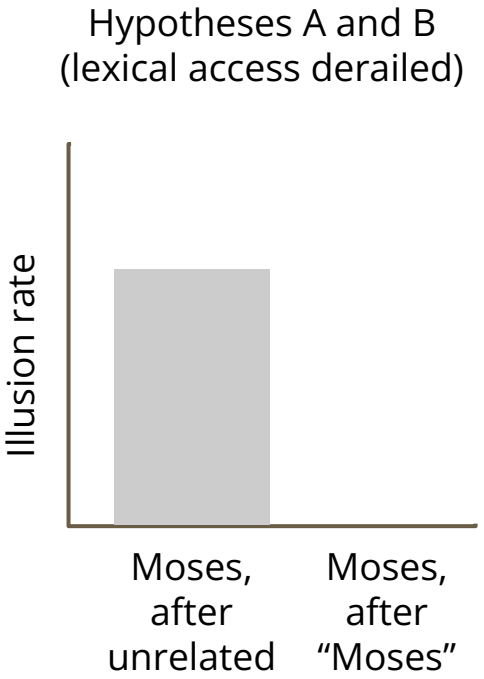

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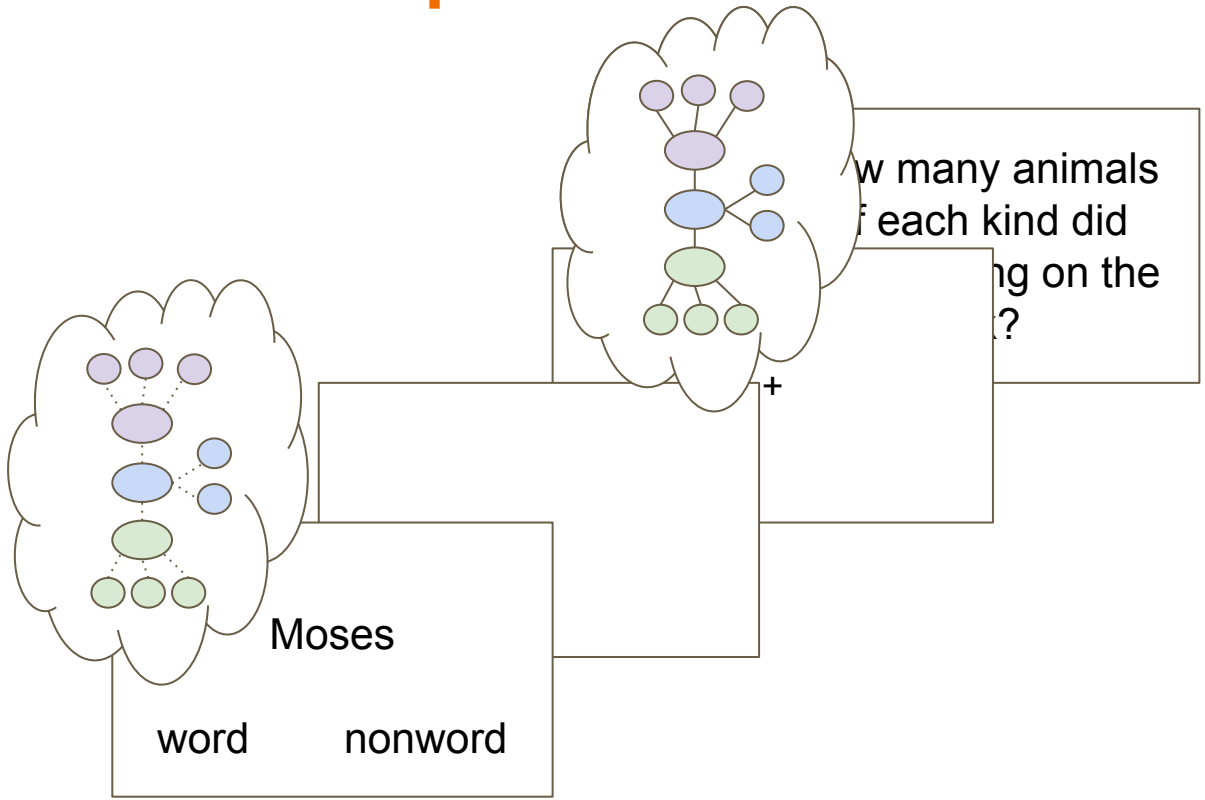

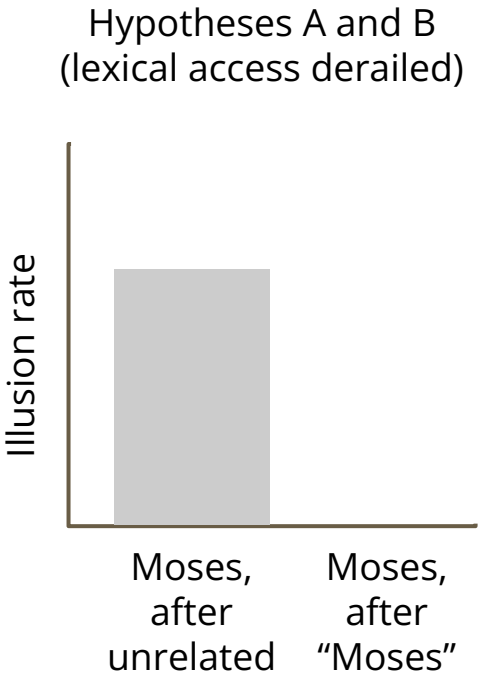

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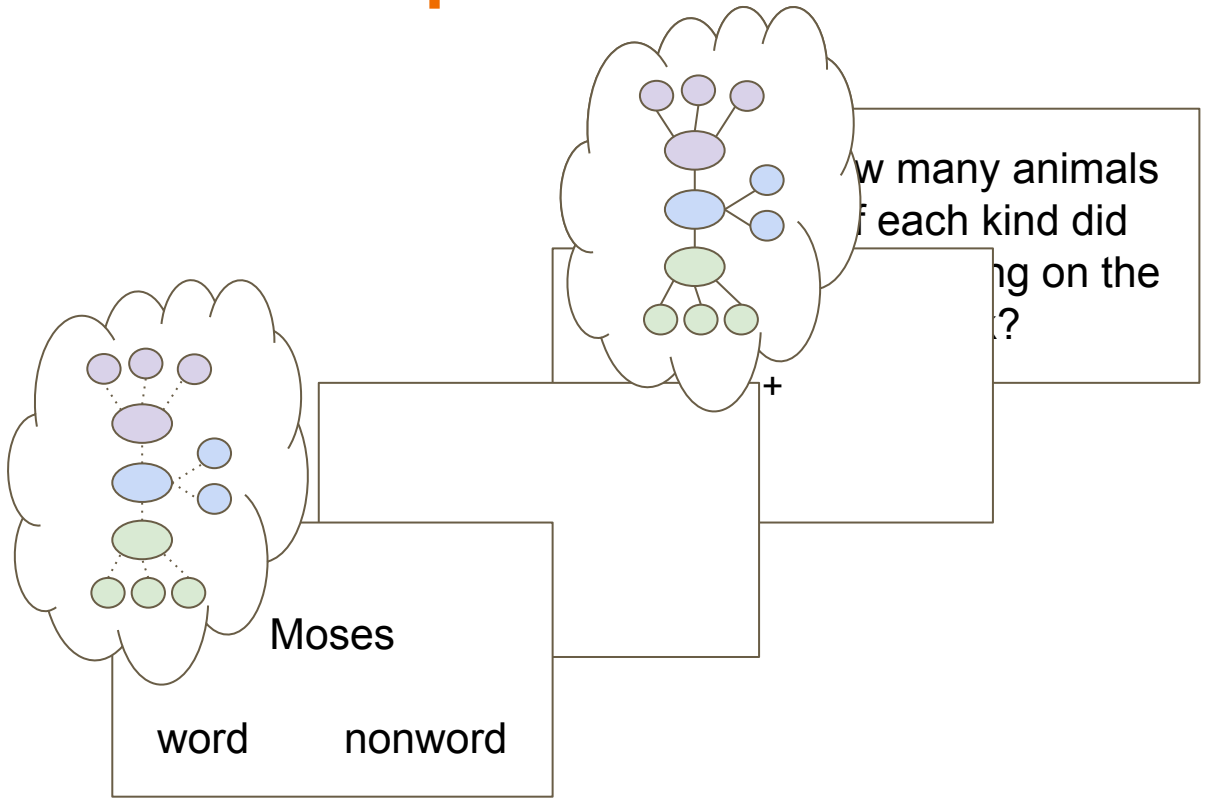
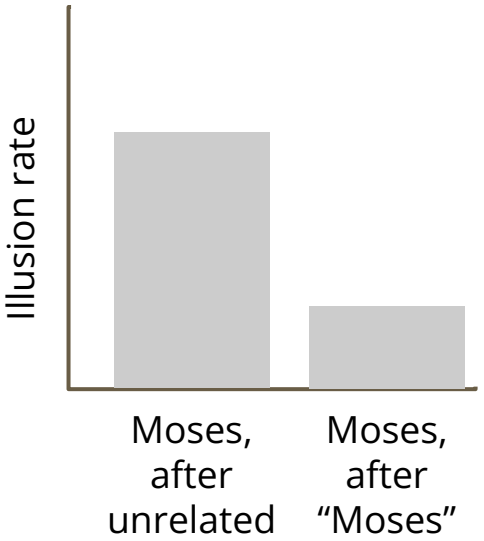


Hypotheses A and B
(lexical access derailed)



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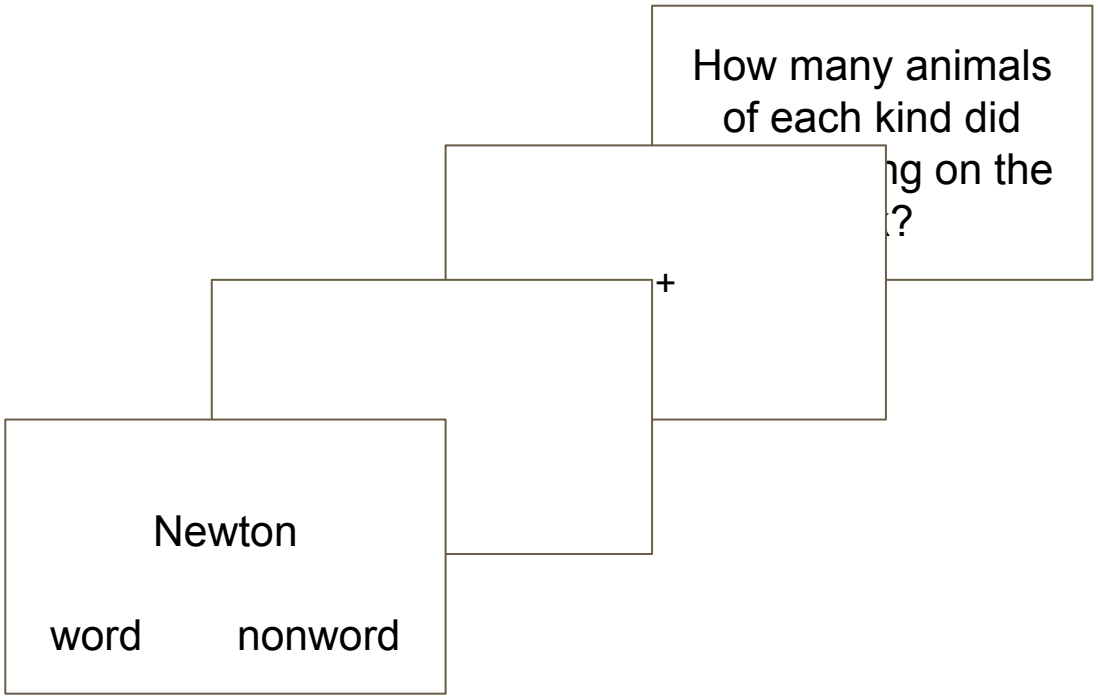

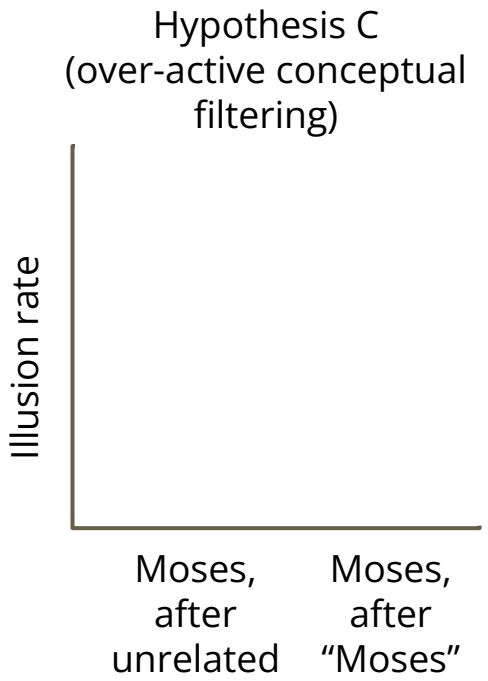

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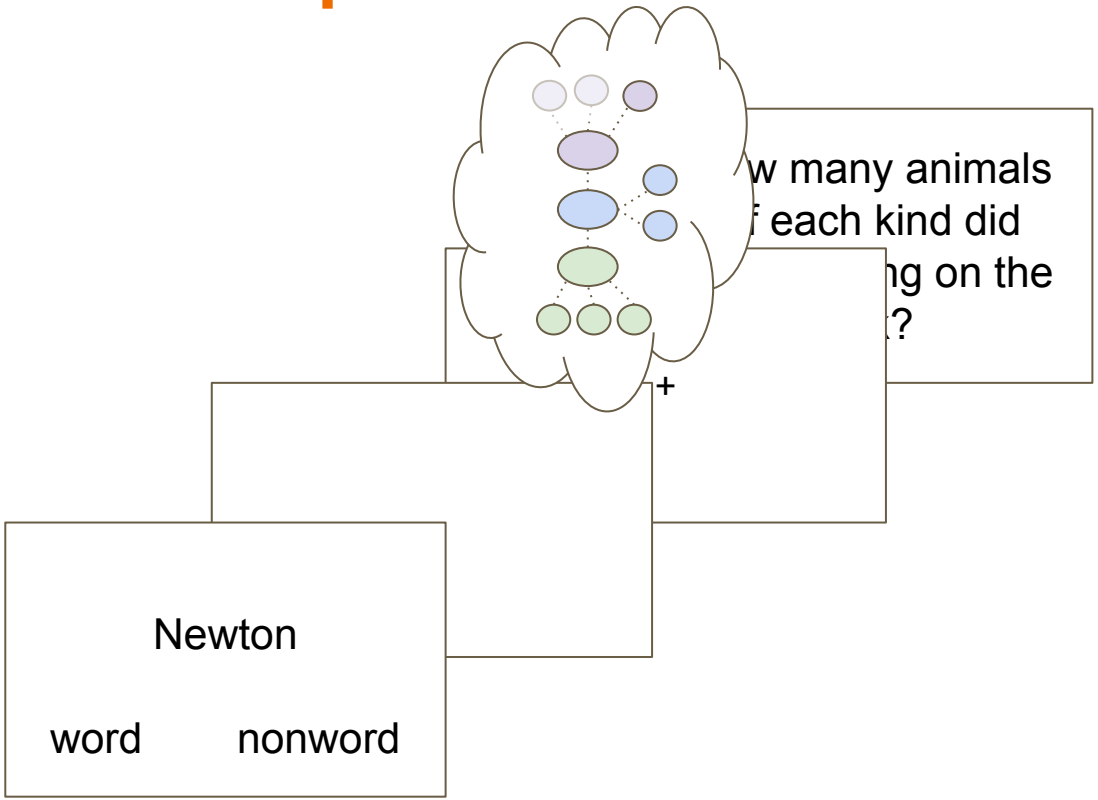

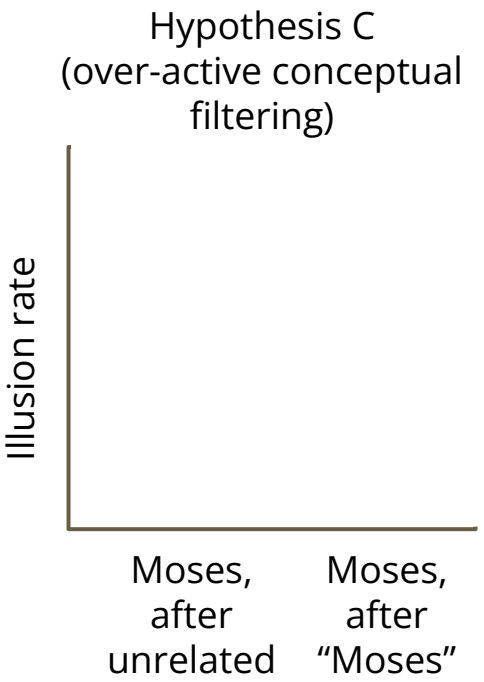

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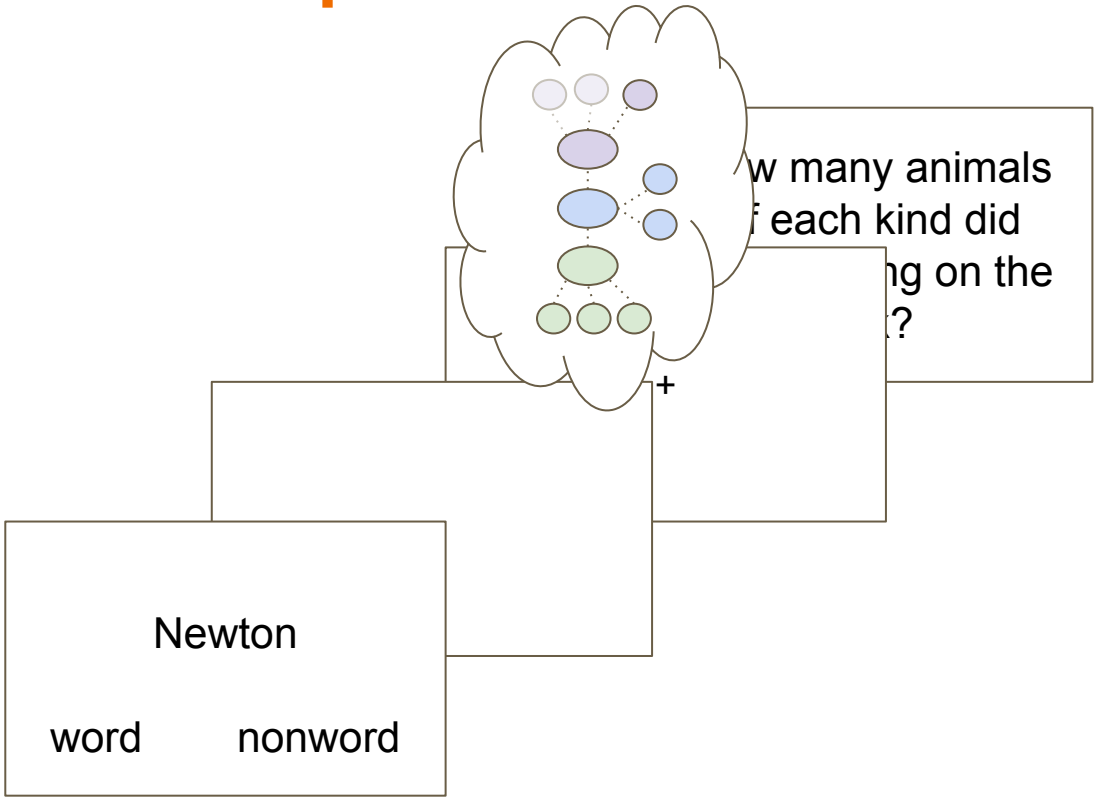
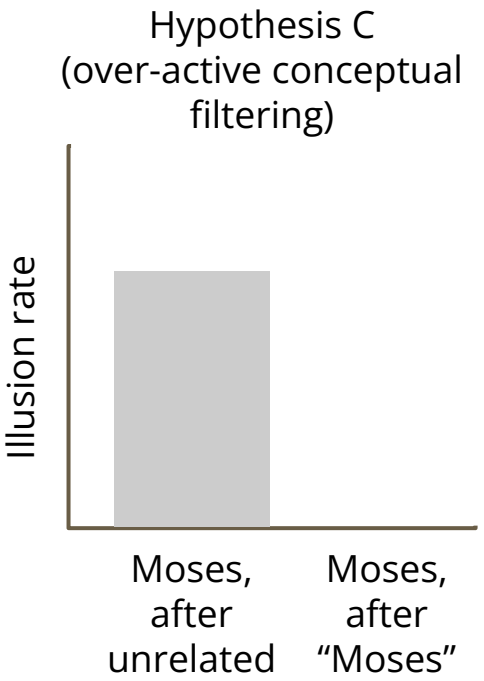
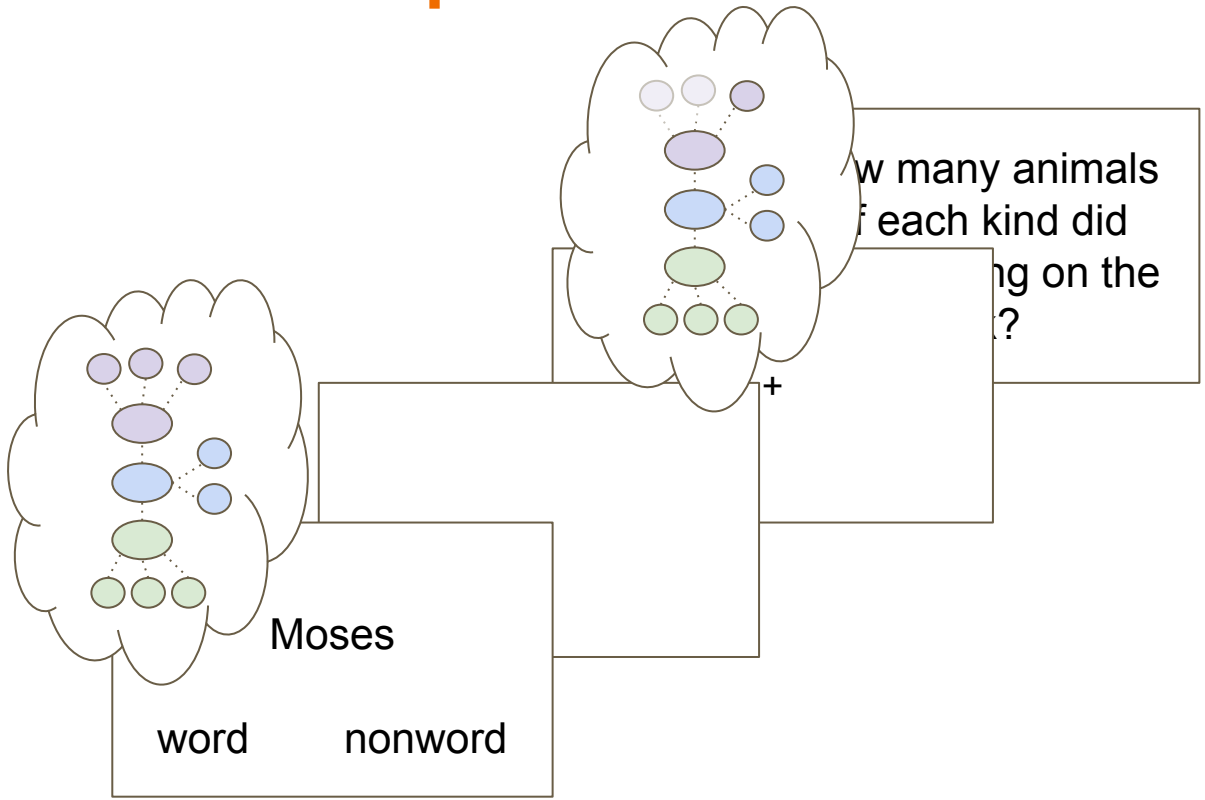
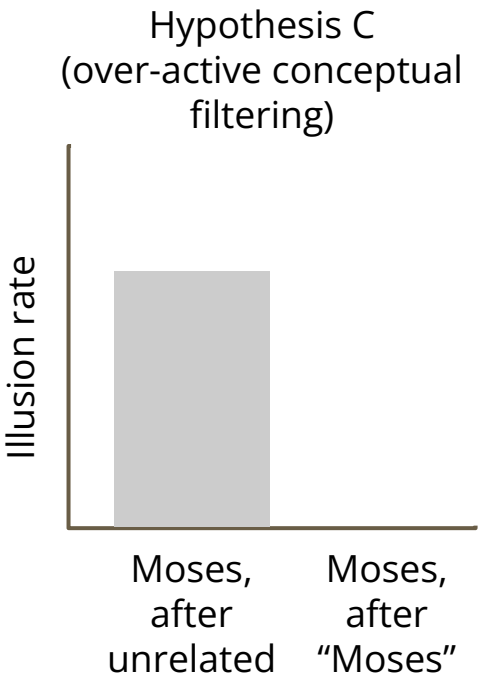


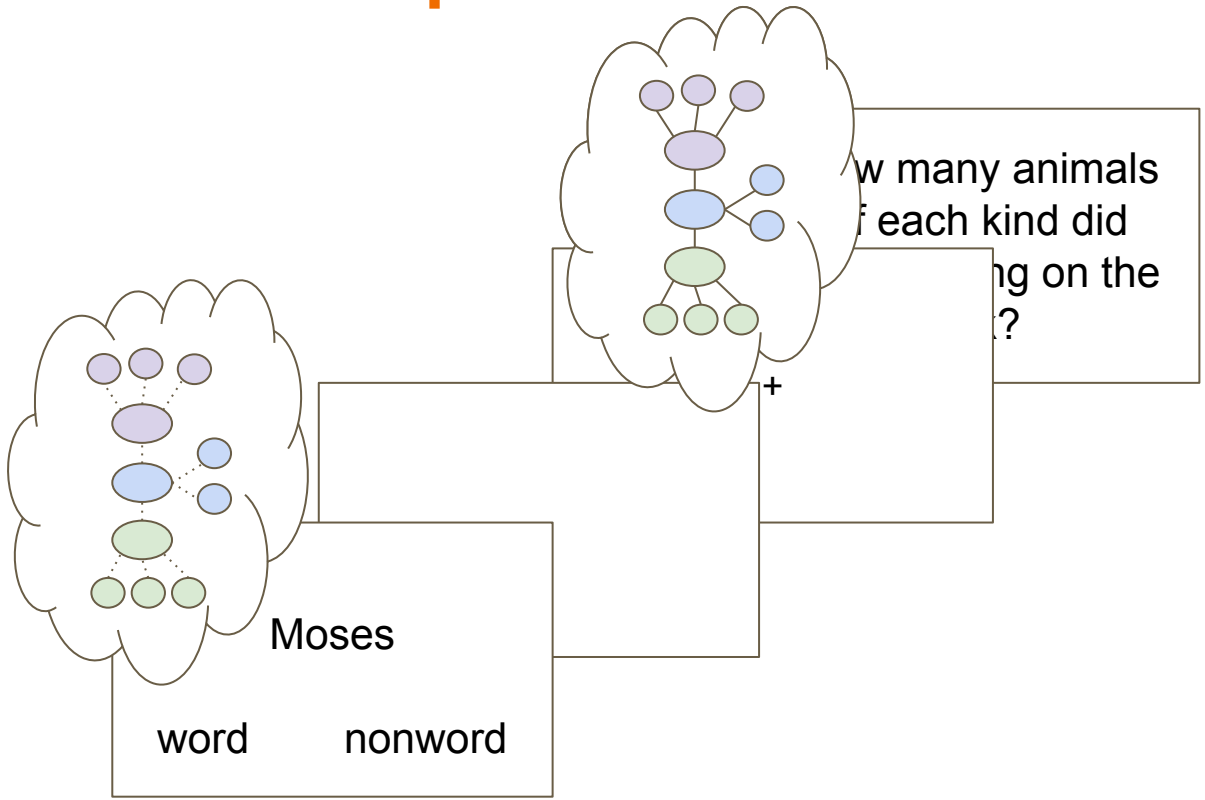


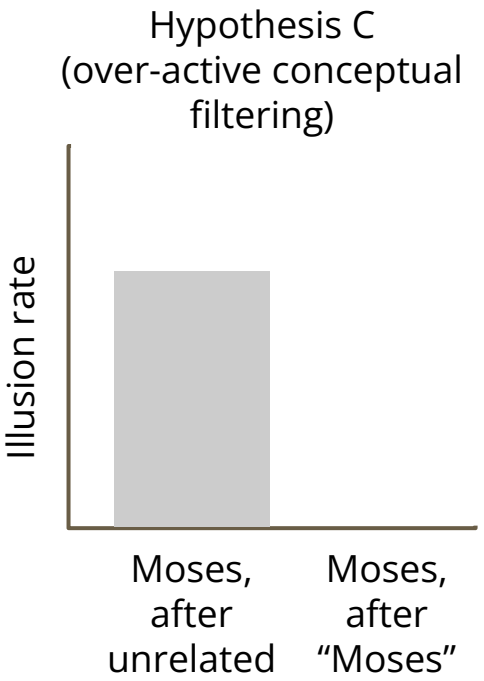
Planned experiment: Moses illusions and priming



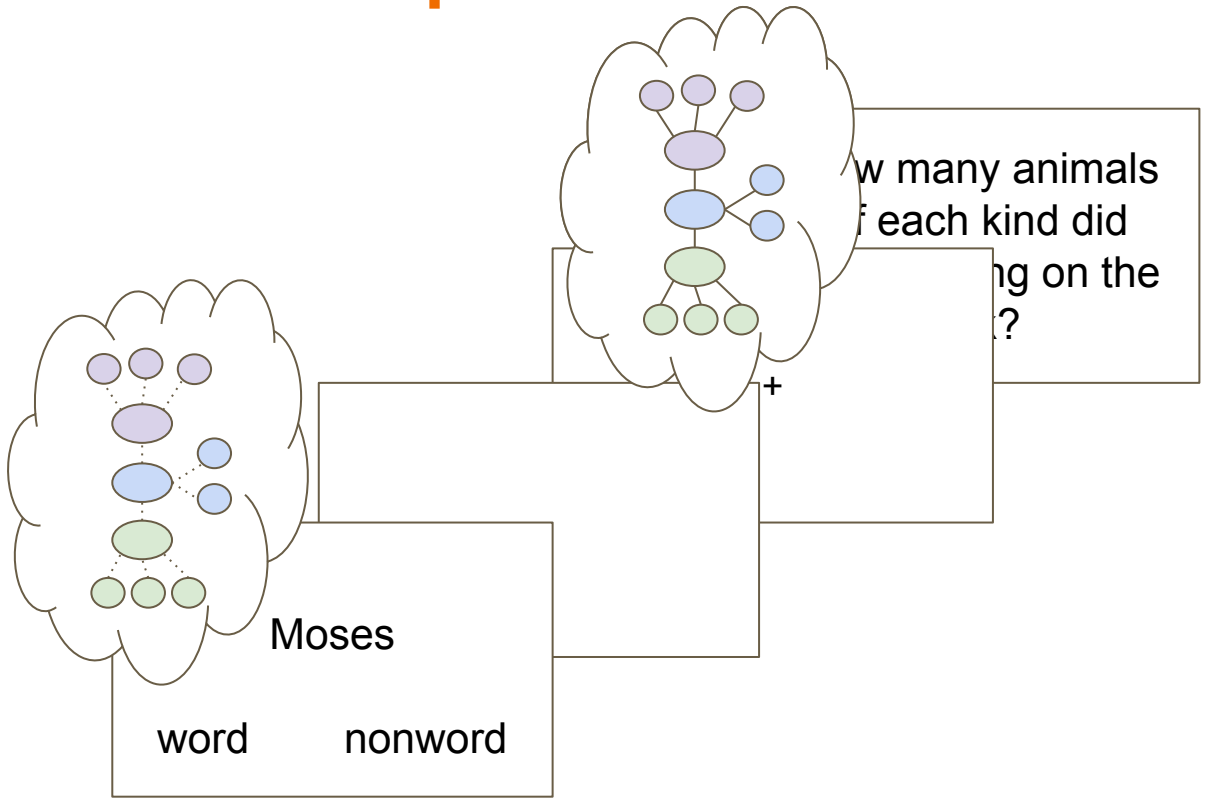


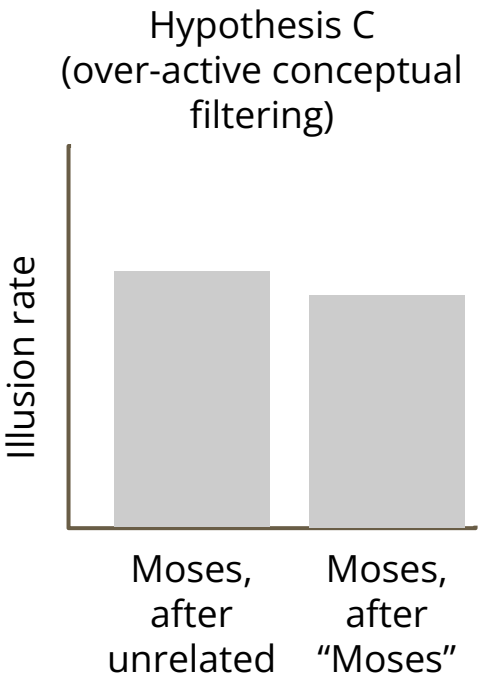
Planned experiment: Moses illusions and priming





Planned experiment: Moses illusions and priming





Planned experiment: Moses illusions and priming

Stay tuned!

Thank you!