Scaling up to the rest of language without rules

March 3rd, 2025

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What are people trying to do?

Understand messages, given forms (comprehension)

&

Choose forms, given intended messages (production)

&

Conform to the conventions of their communities

- **Need to learn and use form ~ function pairings:**

CONSTRUCTIONS

People learn mappings that cluster together → emergent generalizations (constructions)

- We avoid combining constructions with incompatible functions

- Context can influence degree of compatibility

- We make our contributions helpful (not only efficient, but also expressive, appropriate, polite)

Current LMs do the same. Without rules

Our knowledge of language emerges from clusters of lossy (imperfect) memories that relate form and function;

combined on the fly as needed

a tiny corner of data

The data is specific,
the implications are not

Which order do you prefer?

a. table and chairs
b. chairs and table

a. sun and moon
b. moon and sun

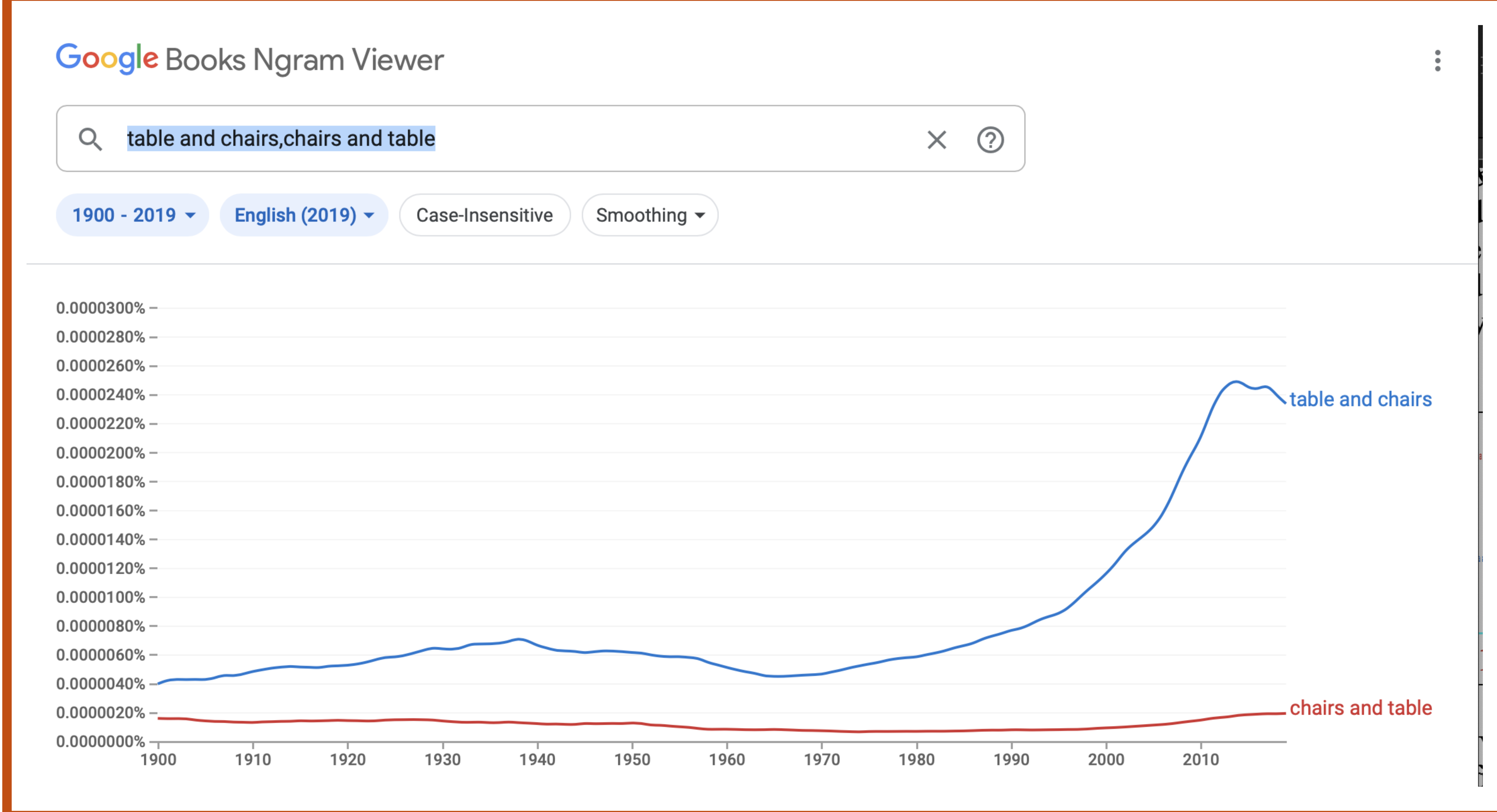
Benor & Levy 2006; Cooper & Ross 1975; Fenk-Oczlon 1989; Iliev & Smirnova 2016; Lohmann & Takada 2014; Malkiel 1959; Mollin 2014; Morgan & Levy 2016; Onishi, Murphy, & Bock, 2008; Wright, Hay, & Bent, 2005

Binomial preferences tend to be stable across people

Benor & Levy 2006; Cooper & Ross 1975; Fenk-Oczlon 1989; Iliev & Smirnova 2016; Lohmann & Takada 2014; Malkiel 1959; Mollin 2014; Morgan & Levy 2016; Onishi, Murphy, & Bock, 2008; Wright, Hay, & Bent, 2005

Binomial preference tends to remain stable across people

And across time


Google Books Ngram Viewer
table and chairs,chairs and table
1900 - 2019
English (2019)
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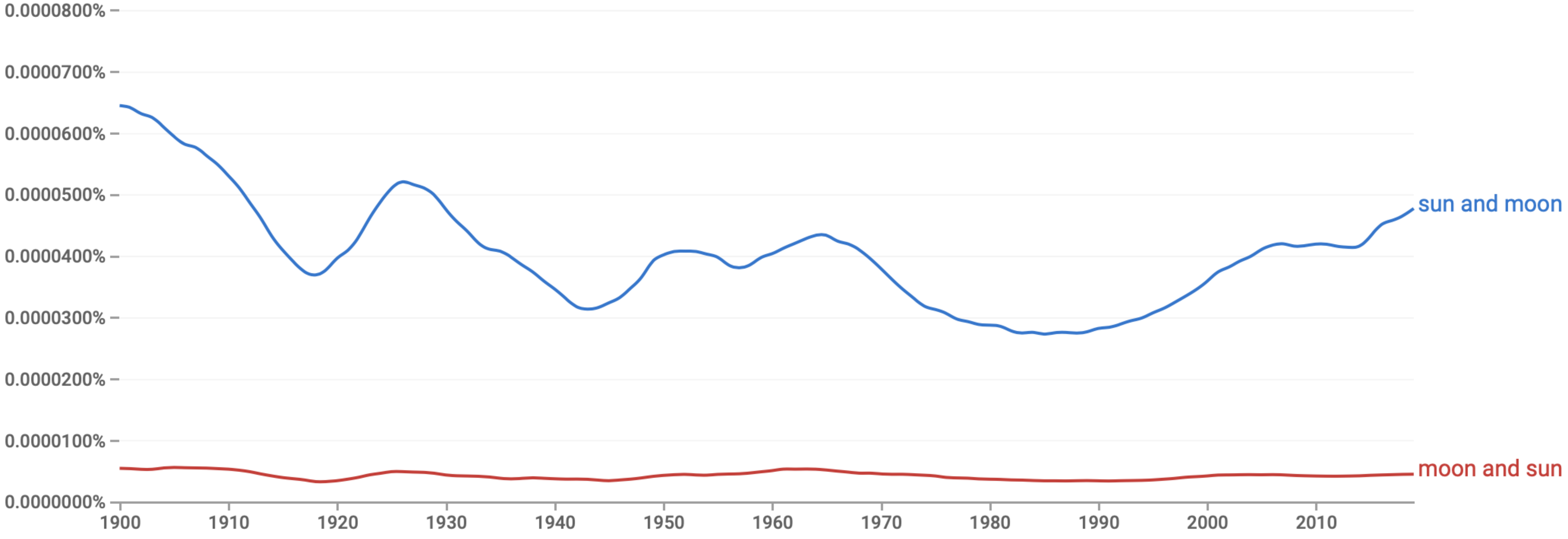
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sun and moon
moon and sun

Phrases are conventional (are learned)

day and night

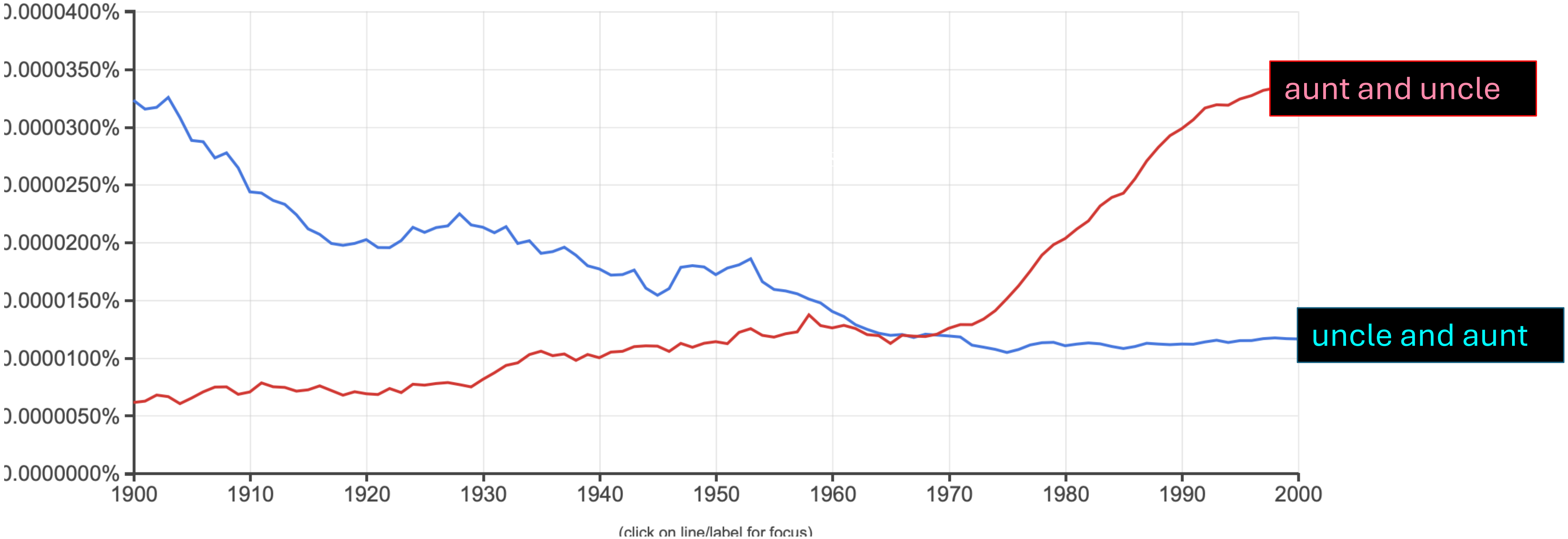
night and day

Phrases are conventional (are learned)

They're as different as___________ day and night

They worked _______________ night and day

The puzzle



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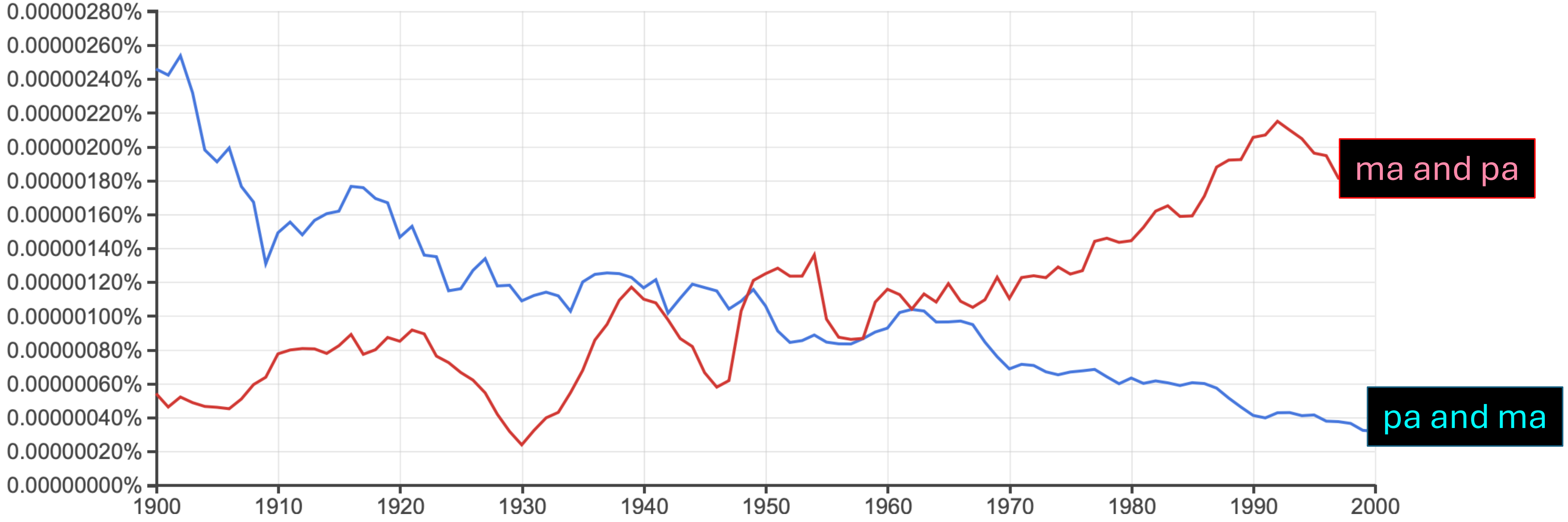
aunt and uncle
uncle and aunt

The puzzle



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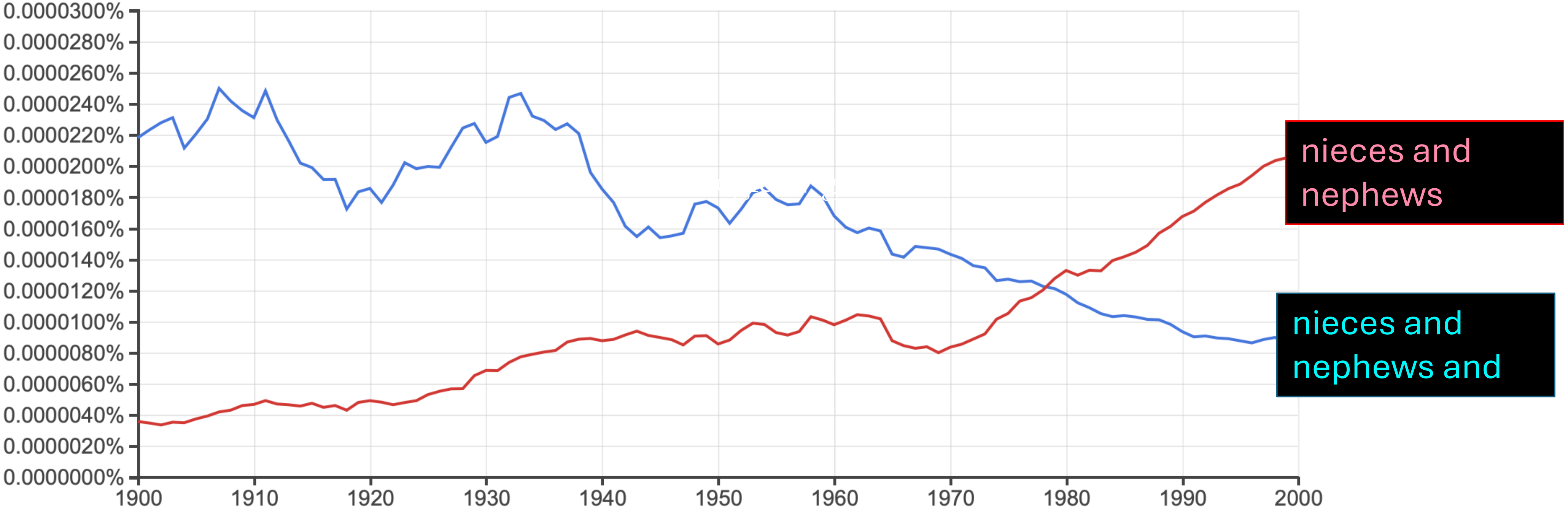
pa and ma

The puzzle



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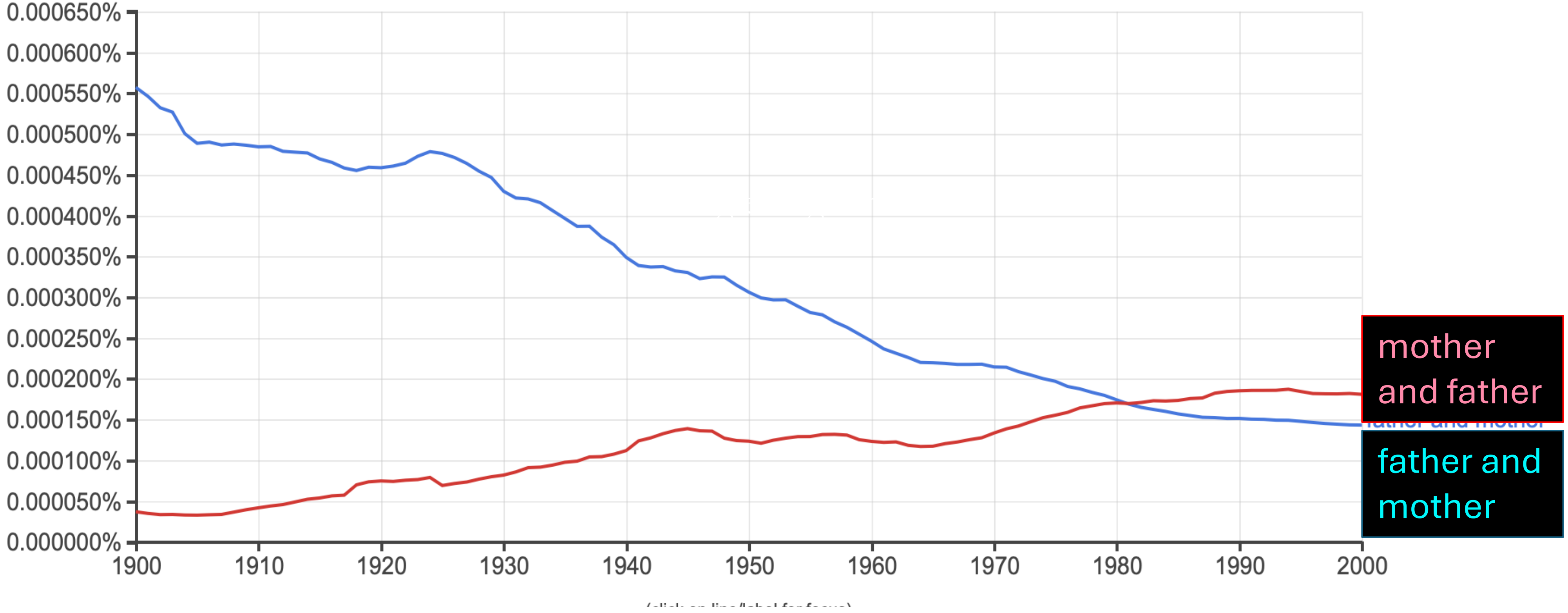
nieces and nephews
nieces and nephews and

The puzzle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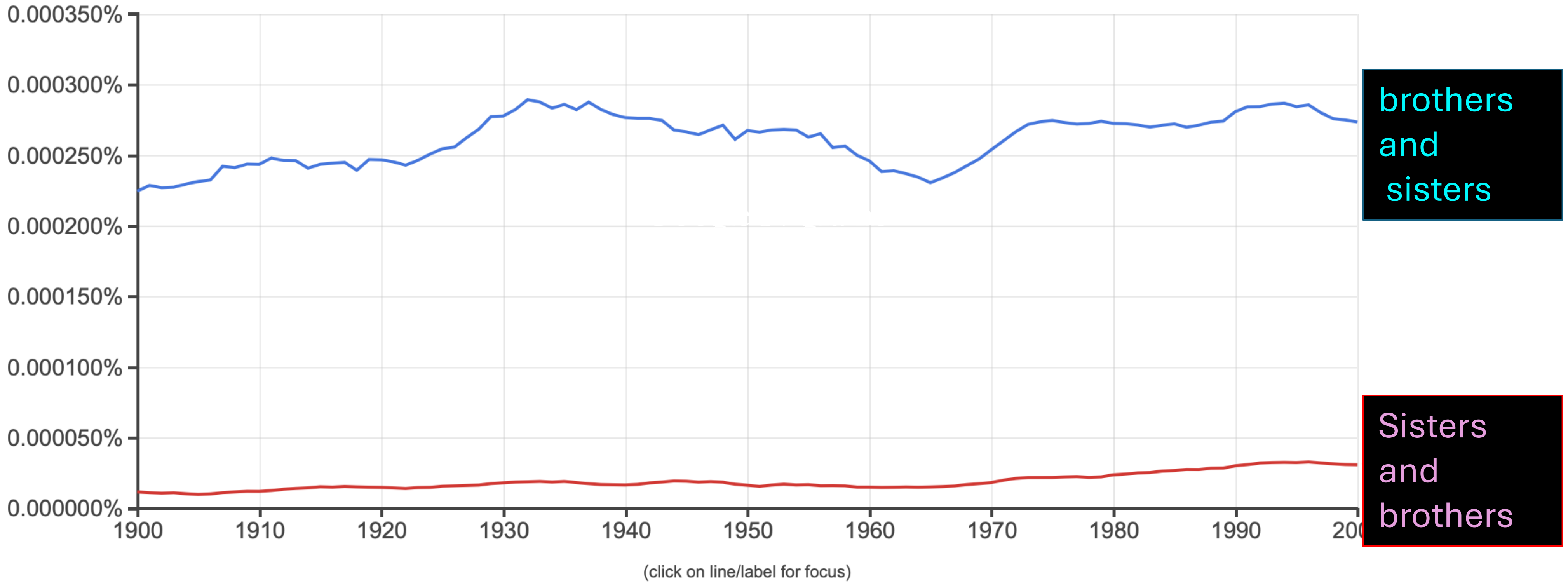
mother and father
father and mother

The puzzle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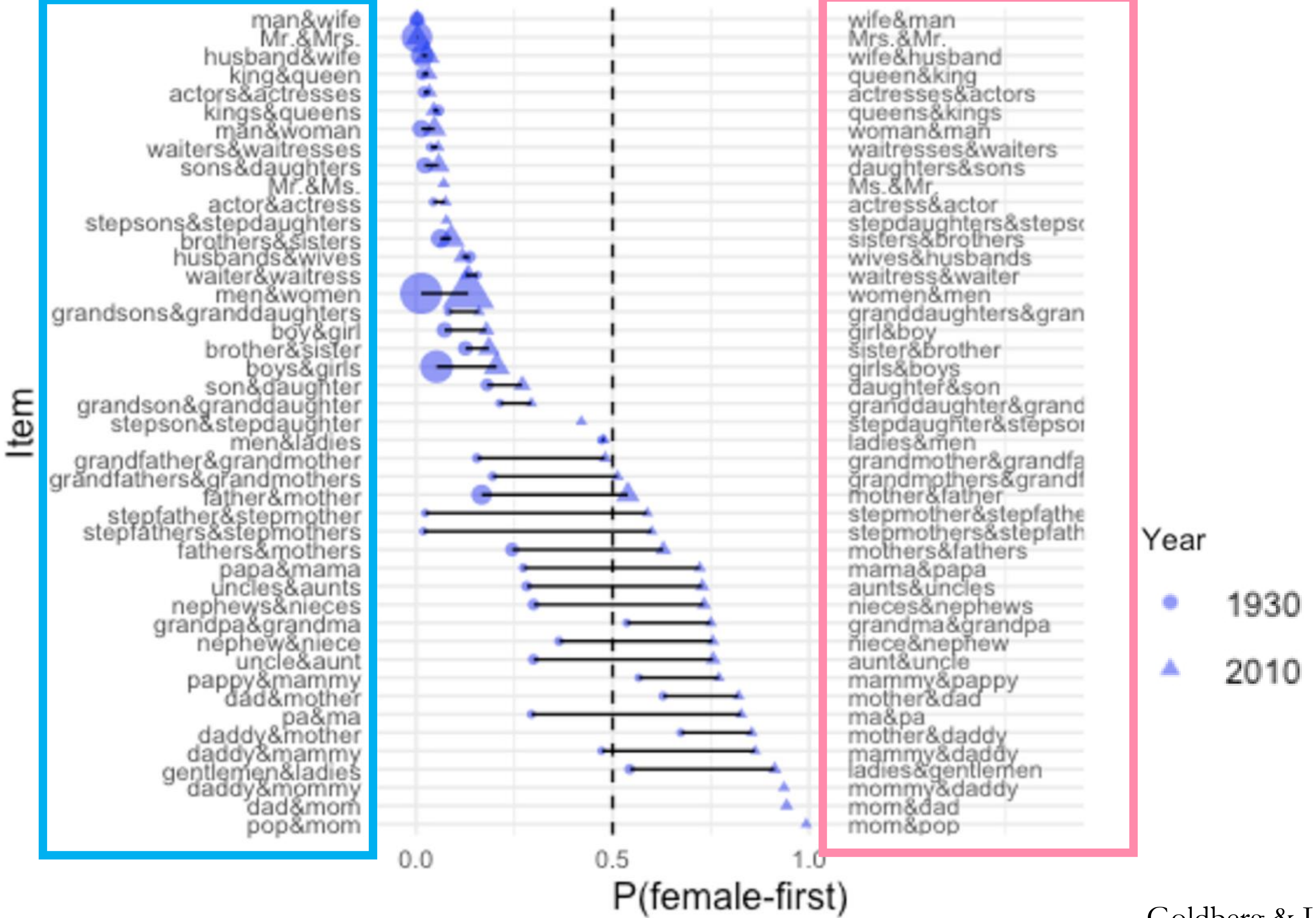
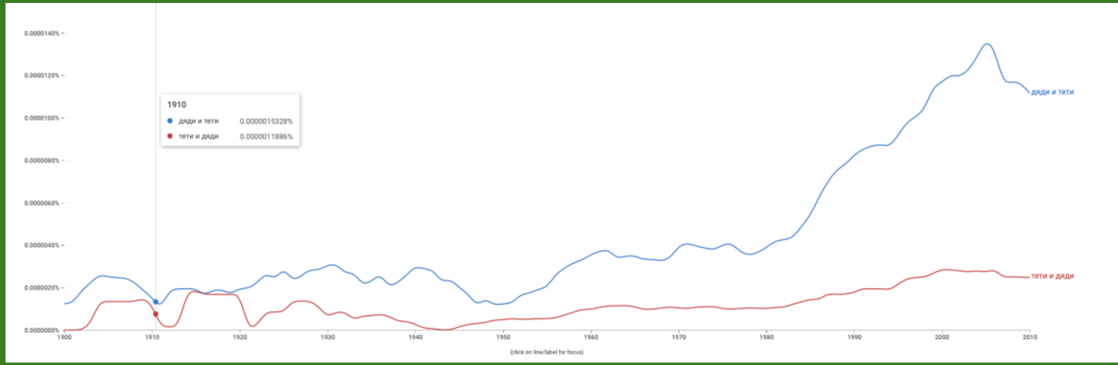
brothers and sisters
Sisters and brothers



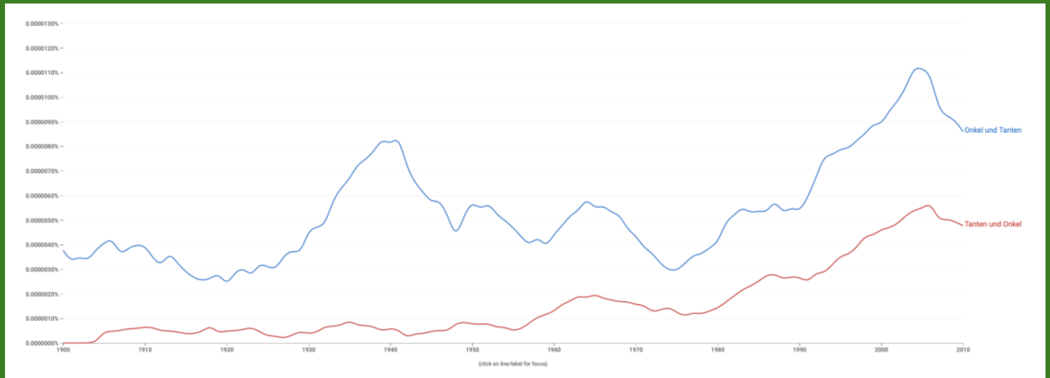
Goldberg & Lee, 2021

uncles and aunts vs *aunts and uncles* in Russian, German, Italian, Spanish

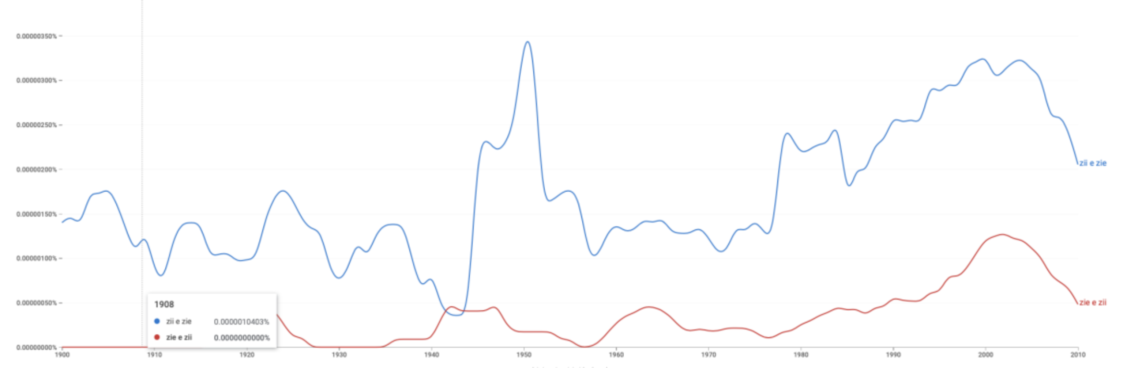
Russian



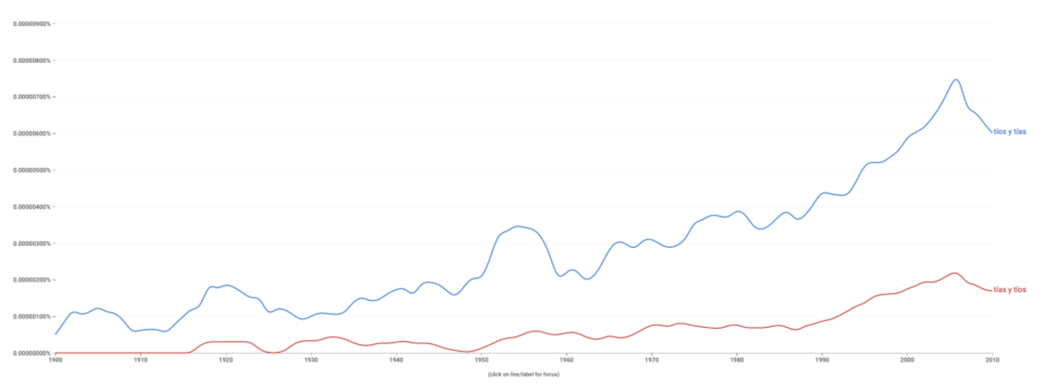
German



Italian

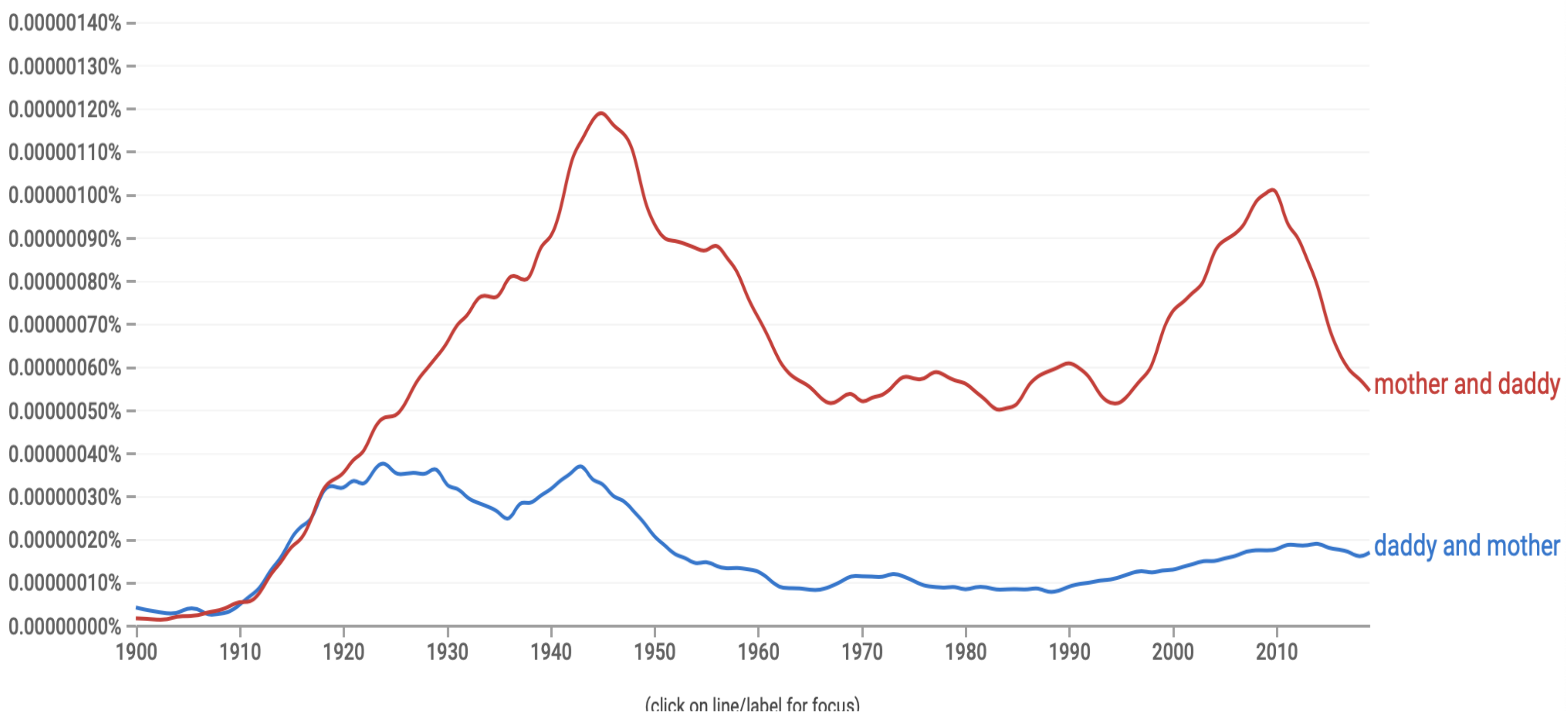


Spanish

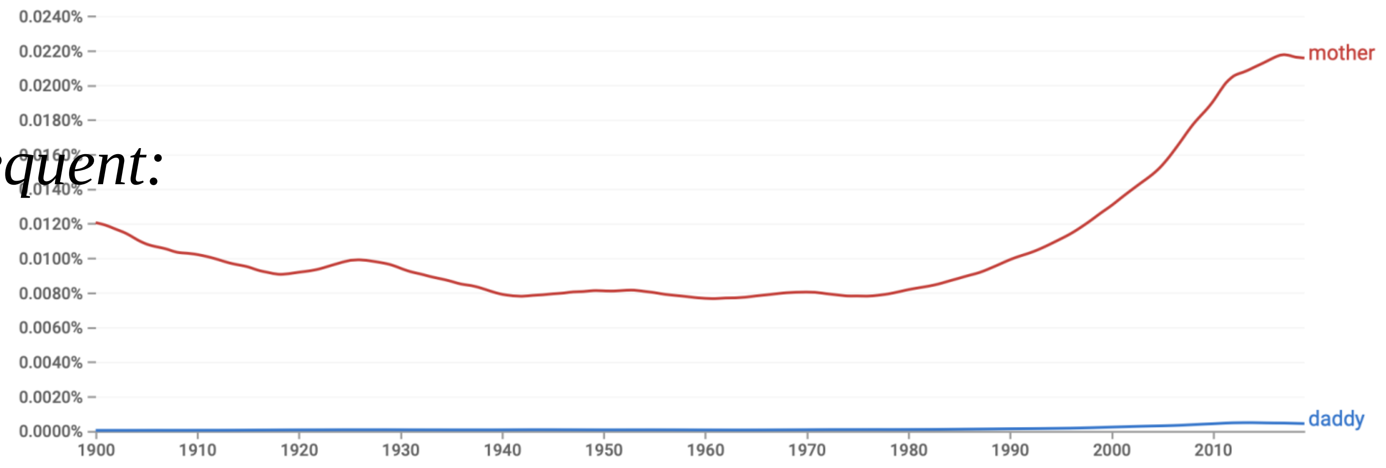


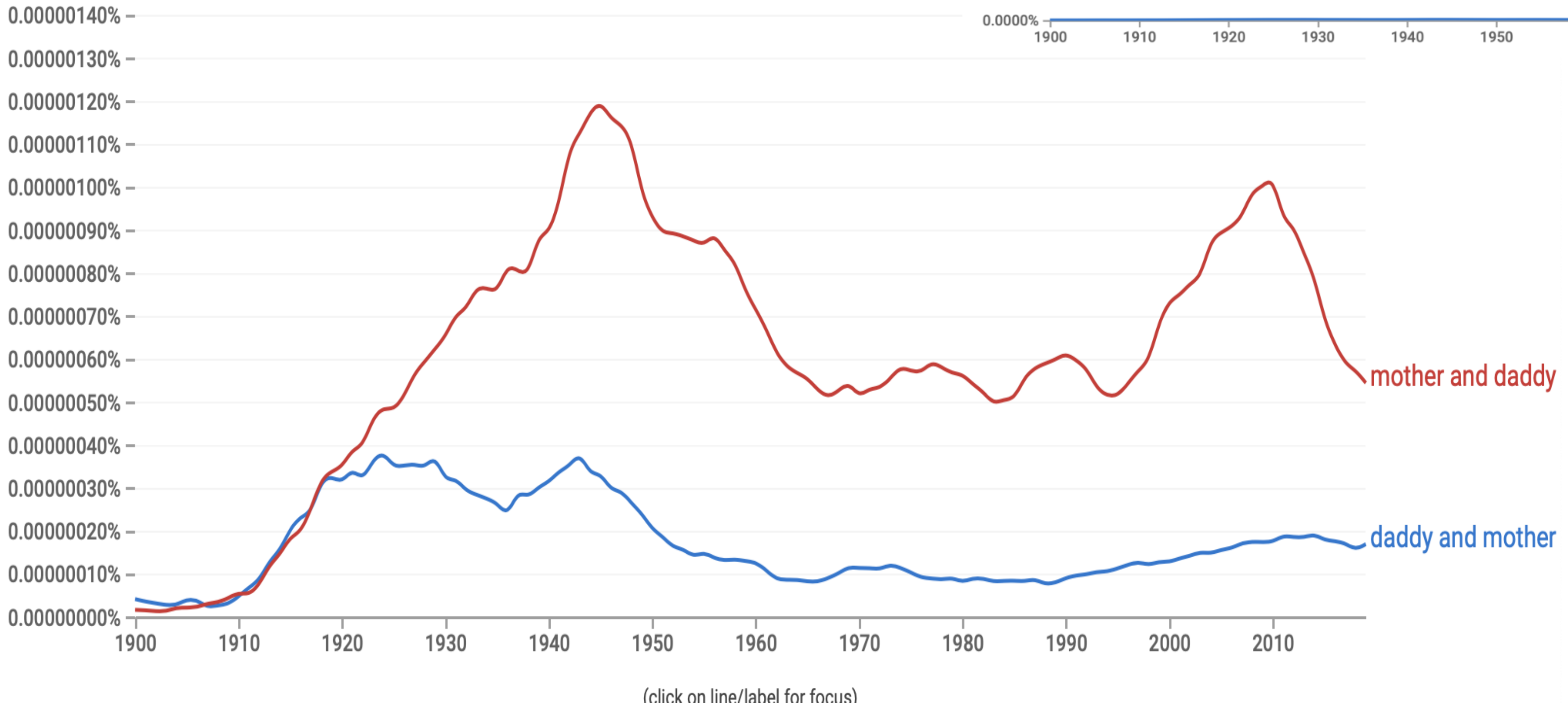
Q: *Why* was this order was preferred?

Ground Zero: *Mother and daddy*



Ground Zero: *Mother 150x more frequent:*





Factors that encourage accessibility (Tulving & Pearlstone, 1966; Bock & Kelly 1993; Bock & Warren 1985; Carroll 1958; Bock 1982, 1987; Bock & Levelt 1994; Ferreira & Dell 2000; MacDonald, 2013, Tanaka et al. 2011; Levelt 1989; McDonald, Tomlin 1995; Downing & Noonan 1995)

Matches intended message

Binomial order does not *usually* change meaning:

aunt and uncle = *uncle and aunt*

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Matches intended message

Type of meaning: agentivity, importance, salience to speaker

sun and moon > *moon and sun*

table and chairs > *table and chairs*

Princeton and Yale > *Yale and Princeton*

Factors that encourage accessibility (Tulving & Pearlstone, 1966; Bock & Kelly 1993; Bock Warren 1985; Carroll 1958; Bock 1982, 1987; Bock & Levelt 1994; Ferreira & Dell 2000; MacDonald 2013, Tanaka et al. 2011; Levelt 1989; McDonald, Tomlin 1995; Downing & Noonan 1995)

Intended MESSAGE

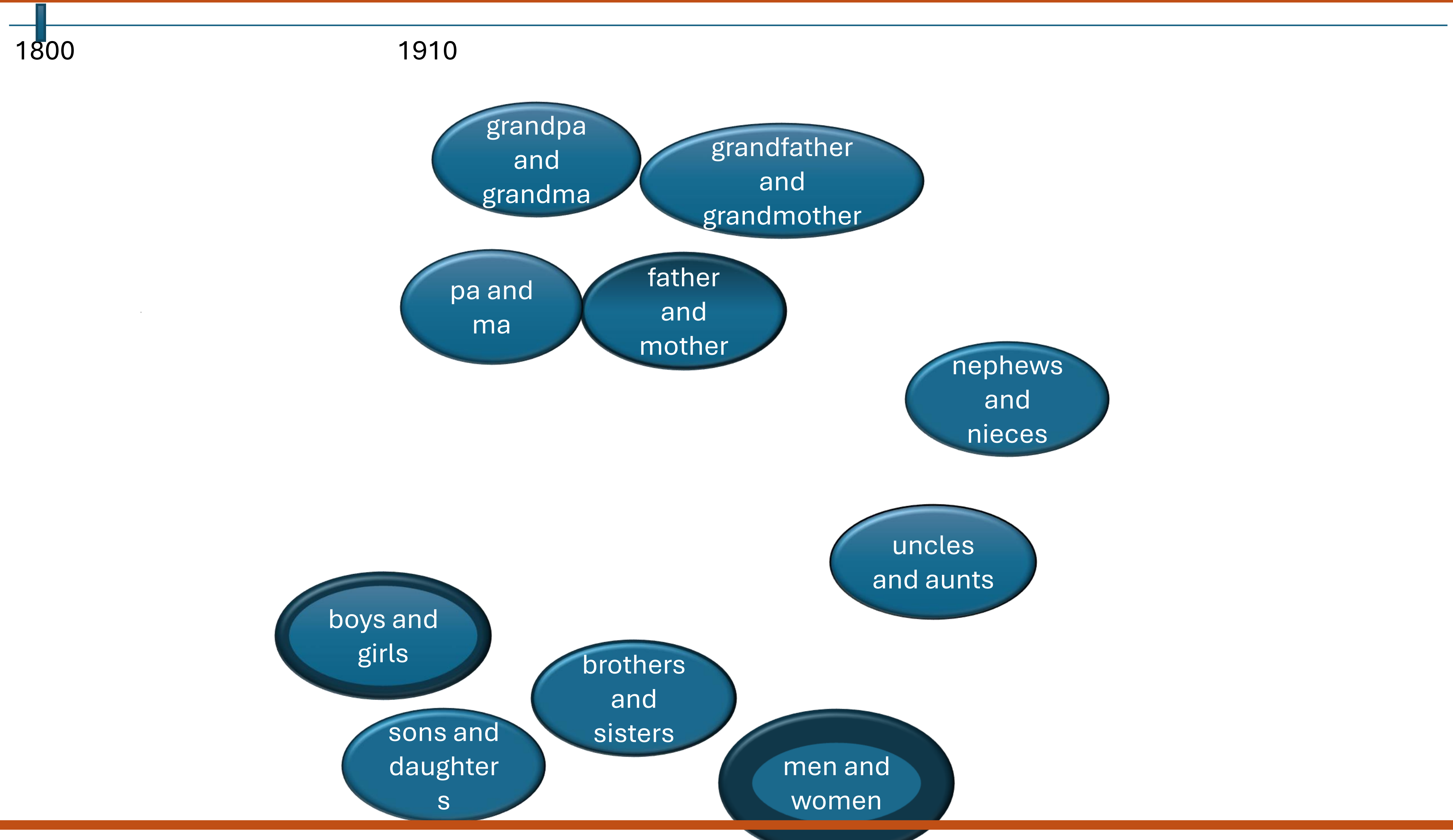
Type of meaning: agentivity, important, salience to speaker

Token frequency

Priming

Lack of interference, competition

Neighborhood effects


1800
1910
grandpa and grandma
grandfather and grandmother
pa and ma
father and mother
nephews and nieces
uncles and aunts
boys and girls
brothers and sisters
sons and daughters
men and women

1800

1910

grandpa and grandma

grandfather and grandmother

pa and ma

father and mother

nephews and nieces

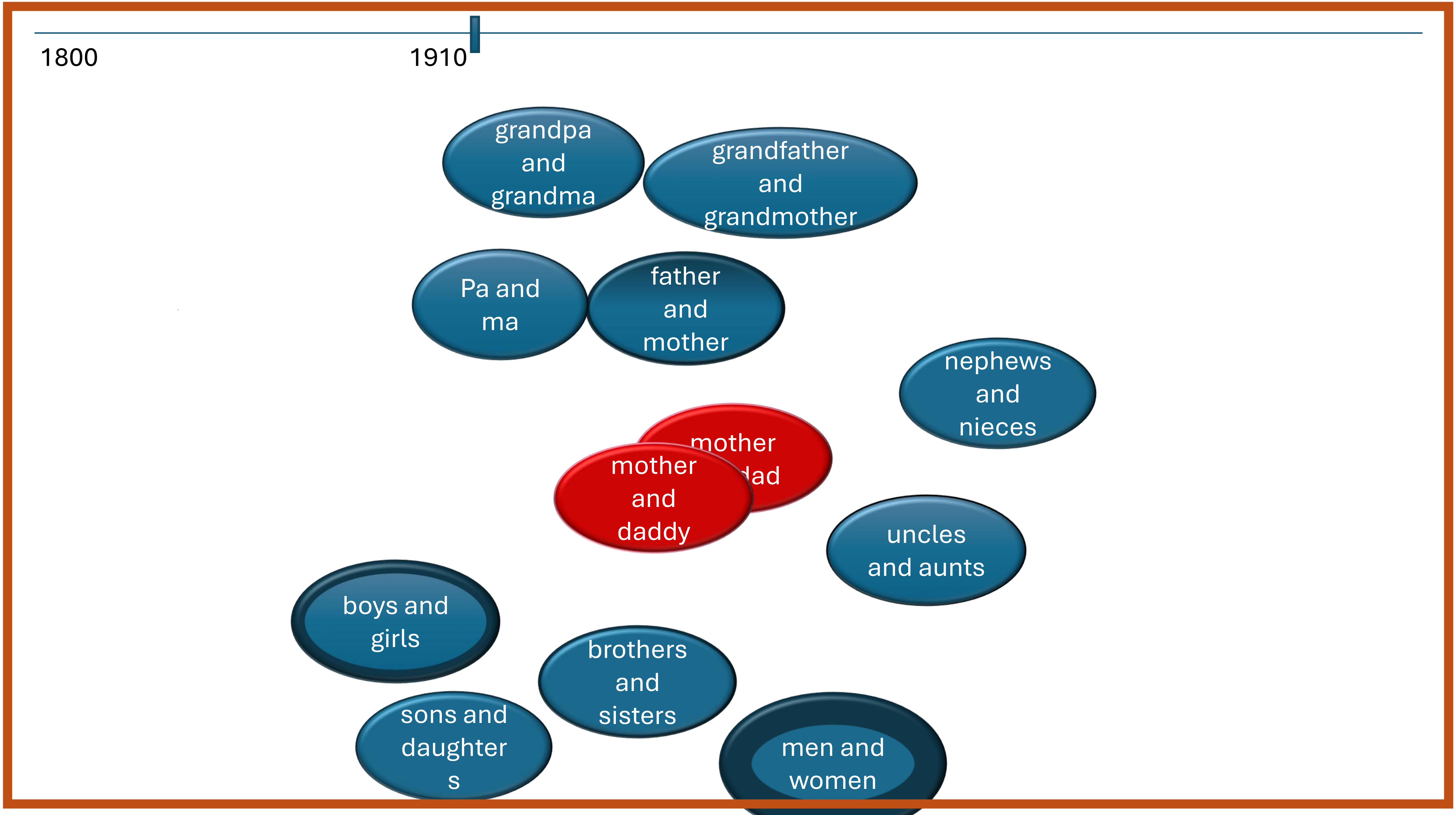
uncles and aunts

boys and girls

brothers and sisters

sons and daughters

men and women



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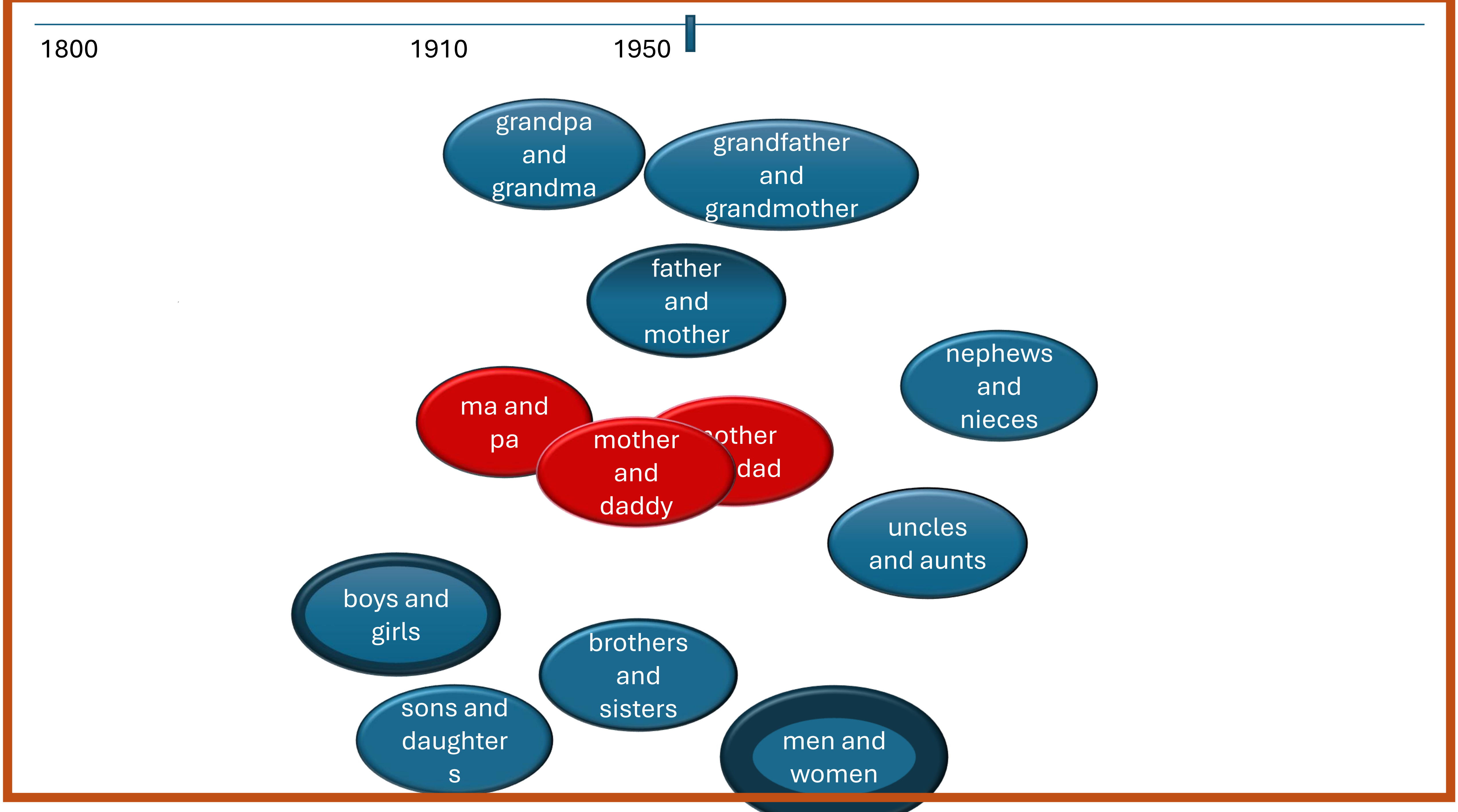
men and women



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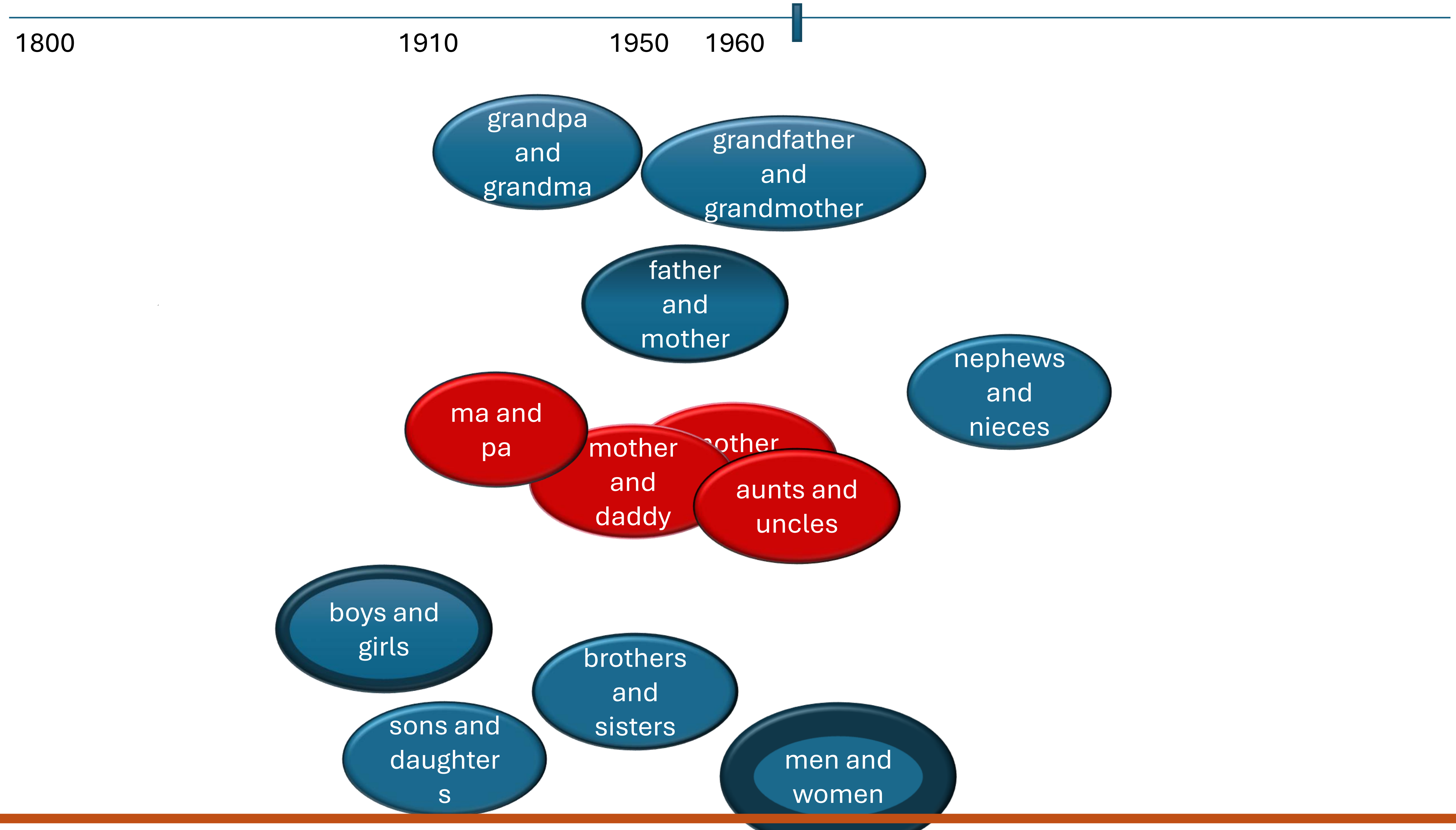
men and women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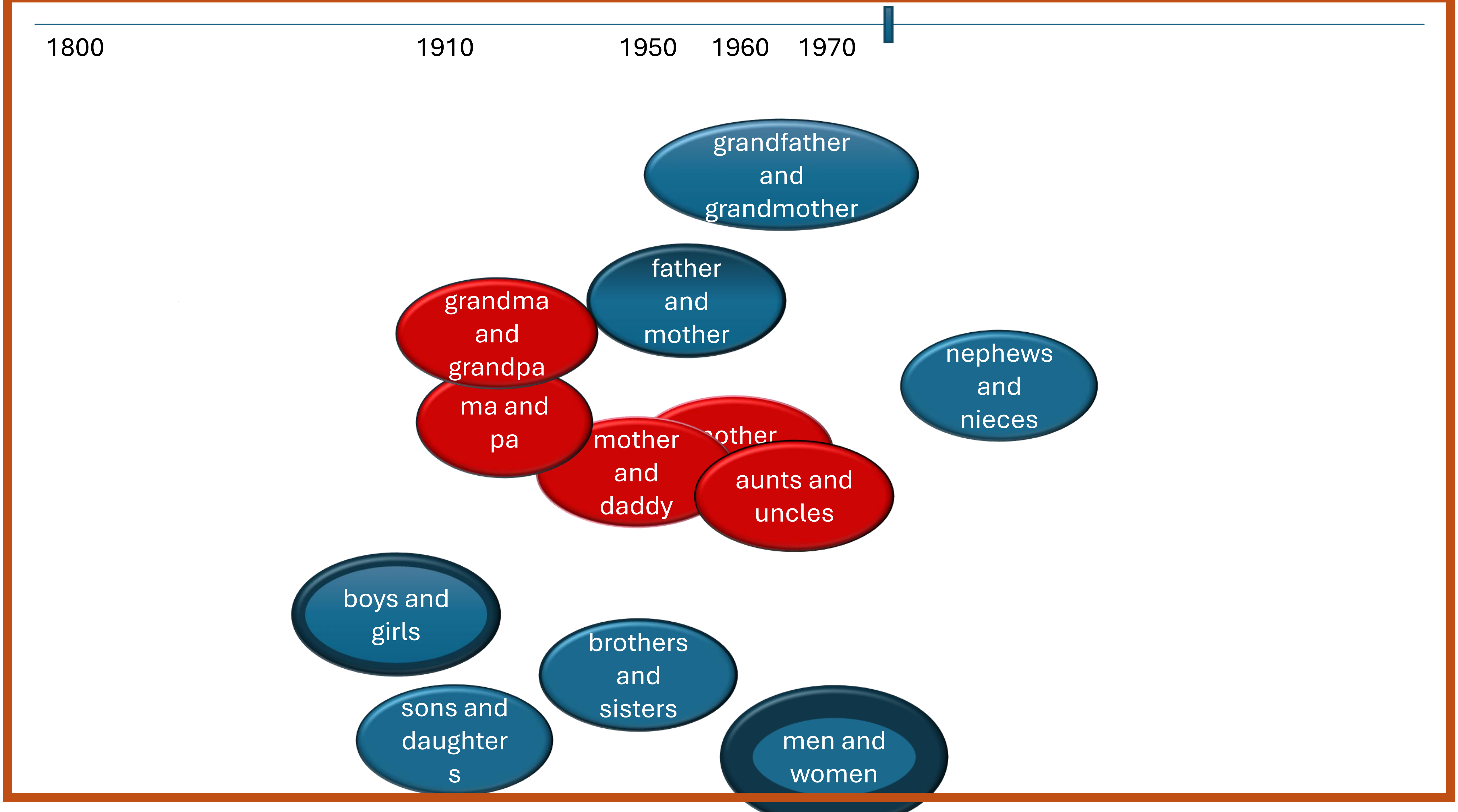
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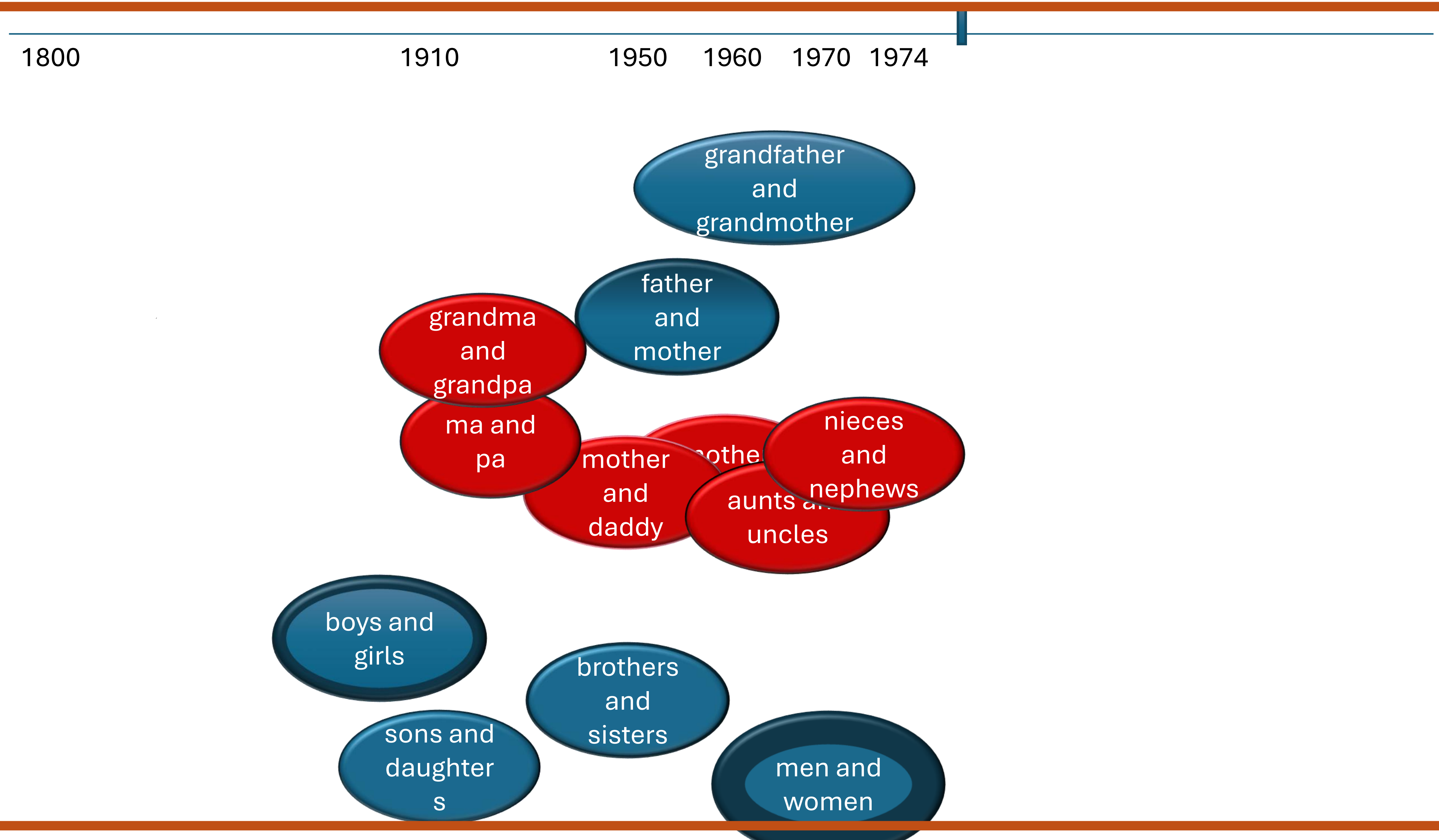
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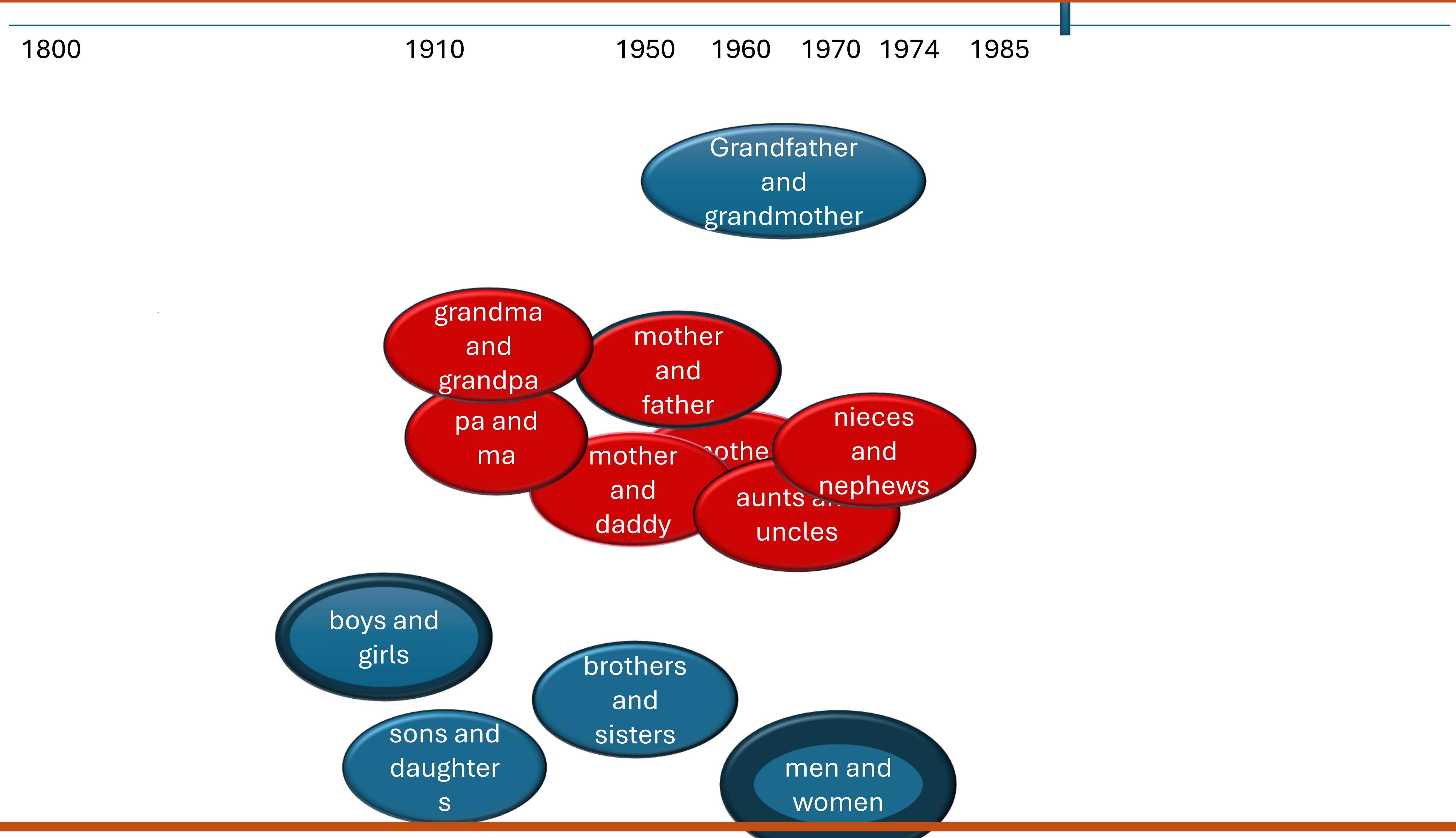
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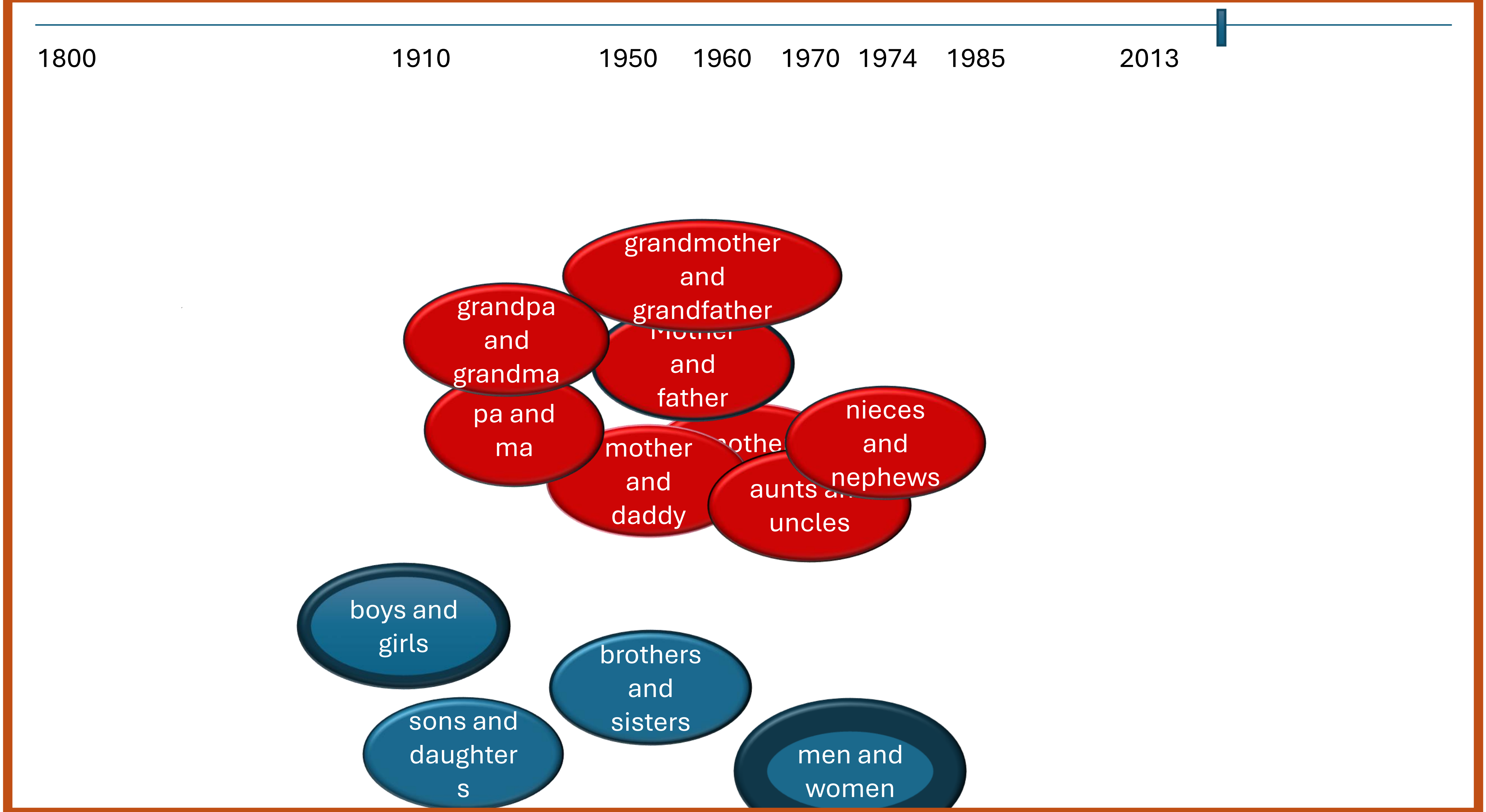
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grandmother and grandfather
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sons and daughter s
men and women

Data:

20 binomials for male and female relatives at each decade, 1920 : 2020

Frequency data from Google-N-grams

P(A&B) ~ Cognitive accessibility of A relative to B

- Competition from B&A

+ Cluster strength of cases related to A&B (A'& B')

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- Competition from B&A

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P(A&B) ~ [cog_acc.(A)] - [cog_acc(B)]

- logfreq(B&A)

+ Cluster strength of cases related to A&B (A'& B')

Novel Binomials

P(A&B) ~ Cognitive accessibility of A relative to B

- Competition from B&A

+ Cluster strength of cases related to A&B (A'& B')

P(A&B) ~ [cog_acc.(A)] - [cog_acc(B)]

- logfreq(B&A)

+ Cluster strength of cases related to A&B (A'& B')

Familiar Binomials

P(A&B) ~ Cognitive accessibility of A relative to B

- Competition from B&A

+ Cluster strength of cases related to A&B (A'& B')

P(A&B) ~ [cog_acc.(A)] - [cog_acc(B)]

- logfreq(B&A)

+ Cluster strength of cases related to A&B (A'& B')

P(F&M) ~

$$\beta_1 \left[(logFreq(F) - \#syll(F)) - (logFreq(M) - \#syll(M) + 1)\right]$$

$$- \beta_2 \left[logFreq(M\&F)\right]$$

$$+ \sum_{i=1}^{n} (\beta_3 Sem\_sim(F\&M, F_i\&M_i) + \beta_4 Morph\_sim(F\&M, F_i\&M_i))$$

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$$\beta_1 \left[(logFreq(F) - \#syll(F)) - (logFreq(M) - \#syll(M) + 1)\right]$$

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Random effects:

Groups	Name	Variance	Std.Dev.
item	(Intercept)	0.034974	0.18701
Residual		0.005747	0.07581

Number of obs: 215, groups: item, 21

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept)	4.769e-01	6.996e-02	1.955e+01	6.817	1.42e-06	***
log_freq	-3.071e-02	5.788e-03	2.110e+02	-5.305	2.84e-07	***
accs	6.855e-02	4.859e-02	1.846e+01	1.411	0.175	
cluster	1.601e-02	8.616e-04	1.928e+02	18.588	< 2e-16	***

P(F&M) ~

$$\beta_1 [(logFreq(F) - \#syll(F)) - (logFreq(M) - \#syll(M) + 1)]$$

$$- \beta_2 [logFreq(M\&F)]$$

$$+ \sum_{i=1}^{n} (\beta_3 Sem\_sim(F\&M, F_i\&M_i) + \beta_4 Morph\_sim(F\&M, F_i\&M_i))$$

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P(F&M) ~

$$\beta_1 [(logFreq(F) - \#syll(F)) - (logFreq(M) - \#syll(M) + 1)]$$

$$- \beta_2 [logFreq(M\&F)]$$

$$+ \sum_{i=1}^{n} (\beta_3 Sem\_sim(F\&M, F_i\&M_i) + \beta_4 Morph\_sim(F\&M, F_i\&M_i))$$

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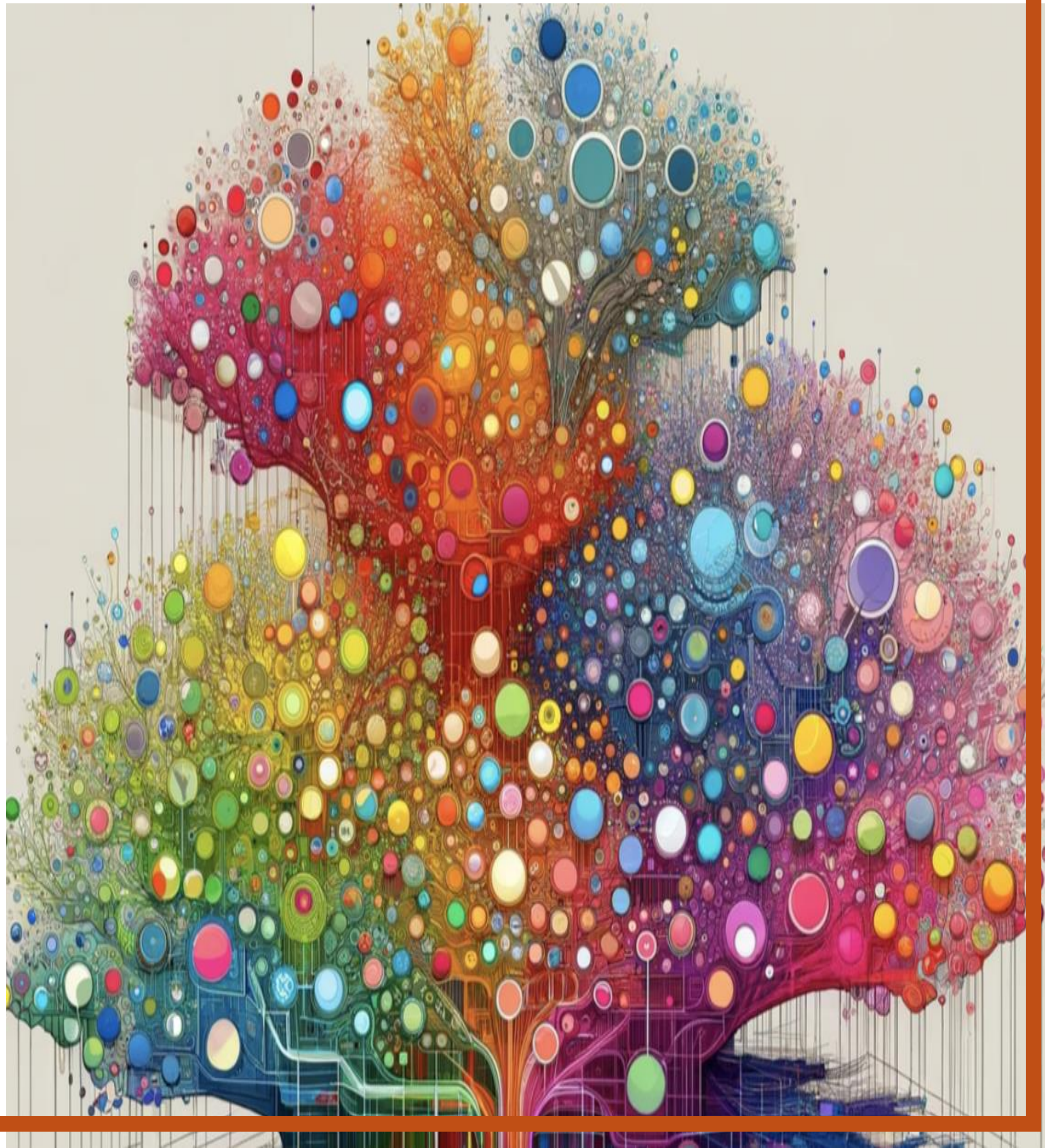
```

We choose linguistic constructions on the basis of:



We choose linguistic constructions on the basis of:

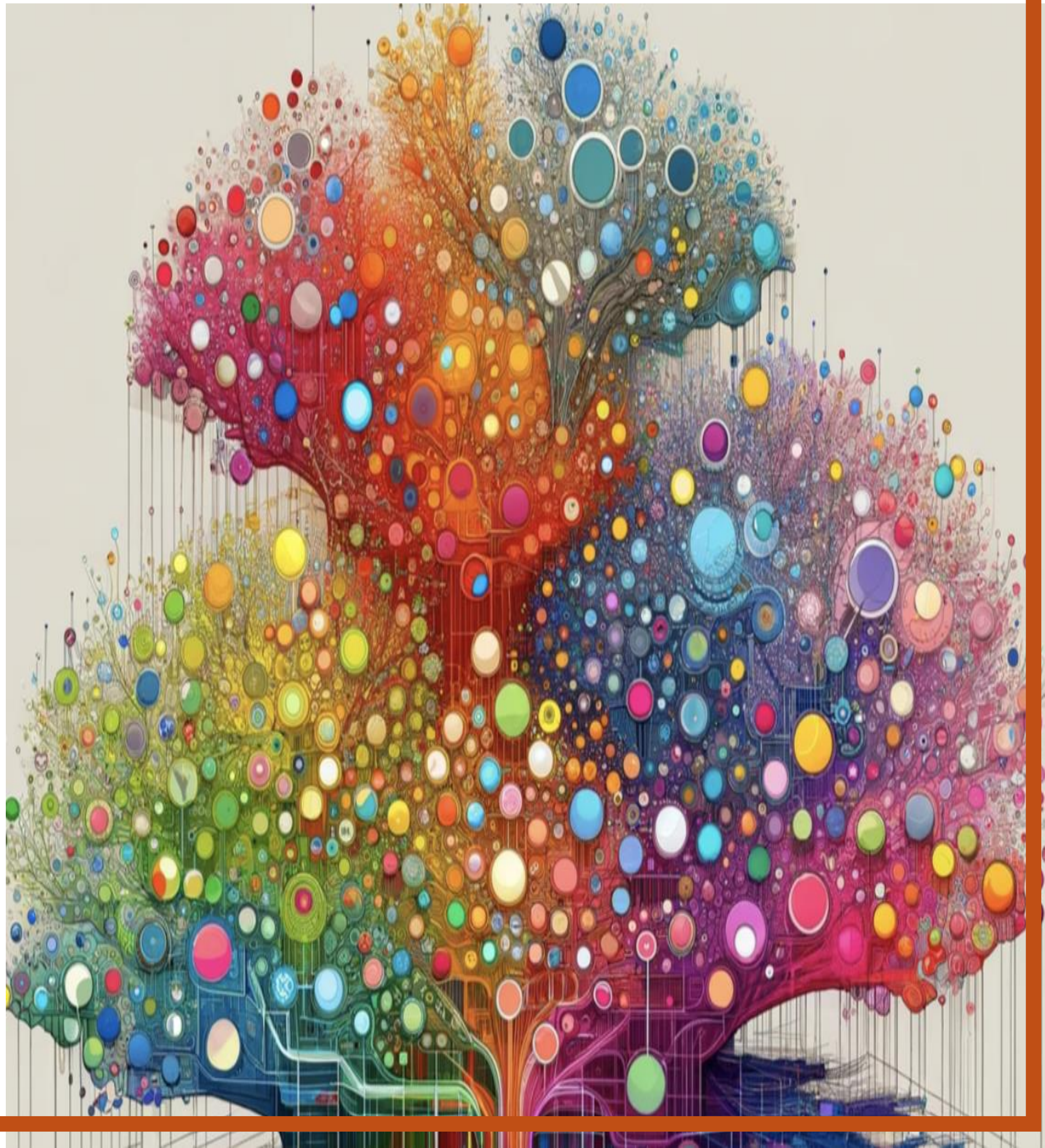
- **Intended message**
- Accessibility:

  Accessibility of whole (for familiar combinations)

  Accessibility of parts (for novel combinations)

  Interference from competitor with same function

- Similar constructions cluster together, lead to emergent regularities



People learn mappings that cluster together → emergent generalizations (constructions)

- We avoid combining constructions with incompatible functions
- Context can influence degree of compatibility
- We make our contributions helpful (not only efficient, but also expressive, appropriate, polite)

Current LMs do the same. Without rules

CONSTRUCTIONS w/ varying levels of complexity and abstraction	**Examples**
Words	*break, skeet, course, one*
Words with open slots	*N-ness, #-th* (*e.g., gazillionth, (n+1)th*)
Unfilled lexical Cx	$[N\ N]_N$ (*e.g., Monday pm NEU class presentation*) (recursive)
Phrasal cx, lexically specified	*not the sharpest tool in the shed*
Phrasal cx with open slots	*nice and <easy/warm/clean/quiet/soft/neat…>*
Phrasal cx with mostly open slots	*The* $[comparative_1]\ S_1$, *The* $[comparative_2]\ S_2$ *The more you think about it, the less you understand*
Argument structure constructions	<Subj> Verb <object1> <obj2> (e.g., *she gave him something; he baked her something*)
Passive construction (minimally lexically filled)	e.g., *He was given something.*
Topicalization (lexically unfilled unfilled)	*Language, I love*

People learn mappings that cluster together → **emergent generalizations (constructions)**

- ➢We avoid combining constructions with incompatible functions

- ➢Context can influence degree of compatibility

- ➢We make our contributions helpful (not only efficient, but also expressive, appropriate, polite)

Current LMs do the same. **Without rules**

Rules

- Include open variables, constrained only by grammatical categories (N, A, V)
- Context-free
- Insensitive to similarity & frequency
- Unstructured list

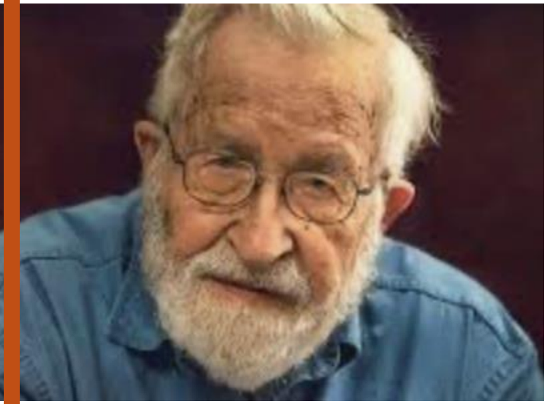
algebra, logic, programming

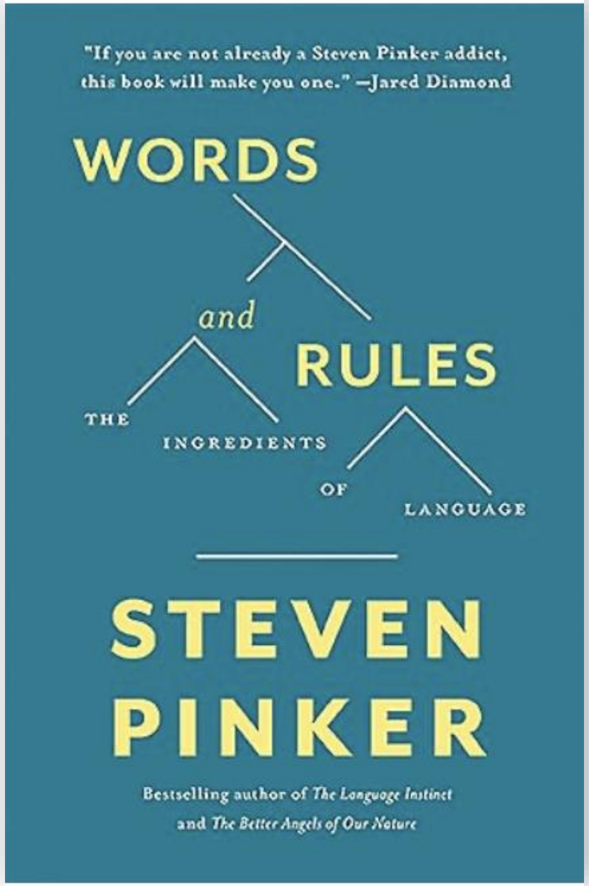
$P \rightarrow Q$ for any P, Q

$-Q \rightarrow -P$

$i + j = j + i$ for all i, j

Does language use symbolic rules?





Chomsky, Fodor, generative linguistics, formal semantics, much current work in ML

Symbolic rules assumed in syntax

Word order: [Adj Noun] for any Adj, N

Productive inflectional morphology V-ed

Rule based Compositionality

“The meaning of an expression is a function of the meanings of its parts and the way they are syntactically combined” Partee (1984: 153)

Meaning is determined by the meanings of immediate constituents via a semantic operation that corresponds directly to the relevant syntactic operation Dowty 1979; 2006

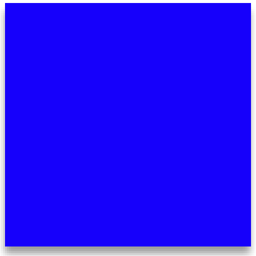
Standard argument for rule-based compositionality

We understand sentences we've never heard before

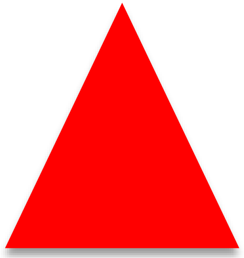
UnWarRaNted asSumPtioNs:

(1) sentences are generated by syntax (= algebraic rules)

(2) We determine meaning based on words + syntactic rules

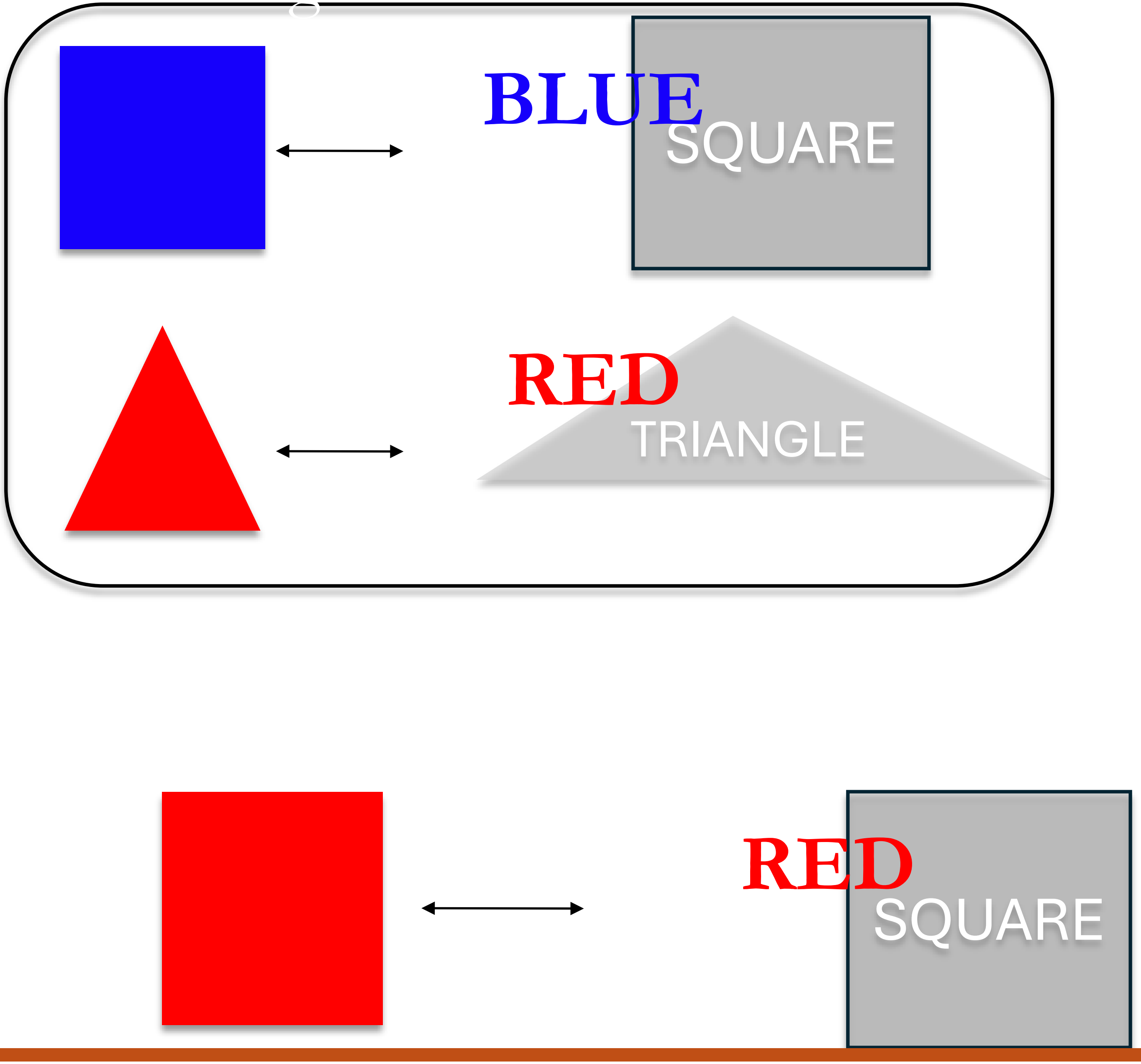


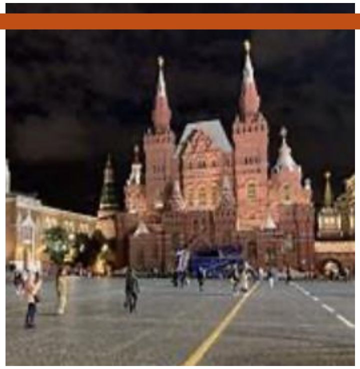
Blue square



Red triangle

$< color > \cap$ ”noun”





Red Square

$< \mathit{color} \not> \cap$ ”noun”

red book

red pen

red states

Alabama
Alaska
Arkansas
Florida
Idaho
Indiana
Iowa
Kansas
Kentucky
Louisiana
Mississippi
Missouri
Montana
Nebraska
North Carolin
North Dakota
Ohio
Oklahoma
South Carolin
South Dakota
Tennessee
Texas
Utah
West Virginia
Wyoming

red hair

red meat

red grapefruit

Red Sox, Red Cross, red flag, red line, red tape…

Rule-compositionality: training should generalize to *all* new instances

VERB twice

"A compositional model trained on the meanings of novel words: *dax*, *flug*, and *flug twice* should be able to interpret the meaning of *dax twice*" (Lake & Baroni 2018)

Is that how language works?

What does *dax twice* mean?

VERB twice

Corpus of Contemporary Ameri

SEARCH | FREQU

N CLICK: CONTEXT | TRANSLATE (??) | ENTIRE PAGE

HELP			ALL FORMS (SAMPLE): 100 200 500
1			THINK TWICE
2			SHOT TWICE
3			SCORED TWICE
4			THOUGHT TWICE
5			WORK TWICE
6			LOOK TWICE
7			WON TWICE
8			MARRIED TWICE
9			THINKING TWICE
10			GOING TWICE
11			PAY TWICE
12			MET TWICE

Is that how language works?

VERB twice

think twice =

work twice =

going twice =

From top dozen *VERB twice* examples on COCA

Is that how language works?

VERB twice

think twice = hesitate (≠ think a second time)

work twice =

going twice =

From top dozen *VERB twice* examples on COCA

Is that how language works?

VERB twice

think twice = hesitate (≠ think a second time)

work twice = work twice as hard/much (≠ work a second time)

going twice =

From top dozen *VERB twice* examples on COCA

Is that how language works?

VERB twice

think twice = hesitate (≠ think a second time)

work twice = work twice as hard/much (≠ work a second time)

going twice = auction context: last chance to buy (≠ going twice somewhere)

From top dozen *VERB twice* examples on COCA

Is that how language works?

VERB twice

shot twice

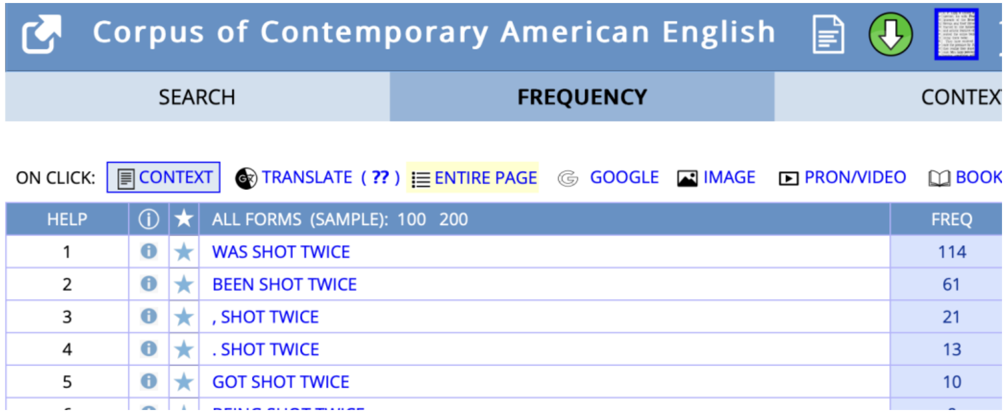
met twice

From top dozen *VERB twice* examples on COCA

Is that how language works?

VERB twice

shot twice (likely passive)



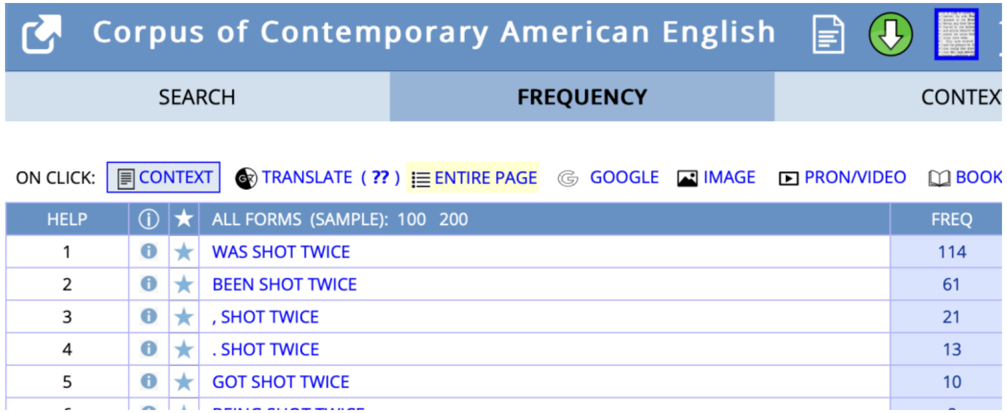
met twice

From top dozen *VERB twice* examples on COCA

Is that how language works?

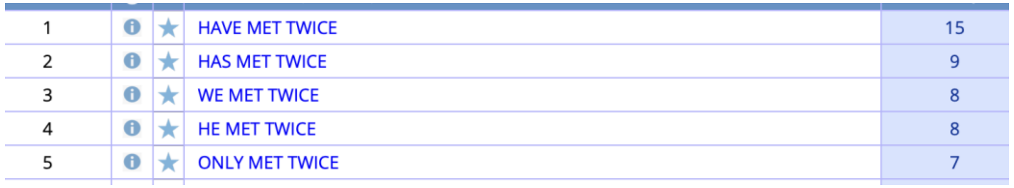
VERB twice

shot twice (likely passive)



HELP			ALL FORMS (SAMPLE): 100 200	FREQ
1			WAS SHOT TWICE	114
2			BEEN SHOT TWICE	61
3			, SHOT TWICE	21
4			. SHOT TWICE	13
5			GOT SHOT TWICE	10

met twice (not passive)



1			HAVE MET TWICE	15
2			HAS MET TWICE	9
3			WE MET TWICE	8
4			HE MET TWICE	8
5			ONLY MET TWICE	7

From top dozen *VERB twice* examples on COCA

"[humans know that] if X is more Y than Z, then in general Z is less Y than X irrespective of the specific meanings of X Y, and Z" Dasgupta, Guo, Gershman, Goodman (2020)

Pat is more clever than wise.

? → Wise is less clever than Pat.

Nothing is more important than experience.

? → Experience is less important than nothing.

The car is more trouble than it's worth.

? → It's worth is less trouble than the car.

English Gossip Construction

(It is) <adj> of NP_{agent} VP_{to}

e.g., It's _____ of you to be here.

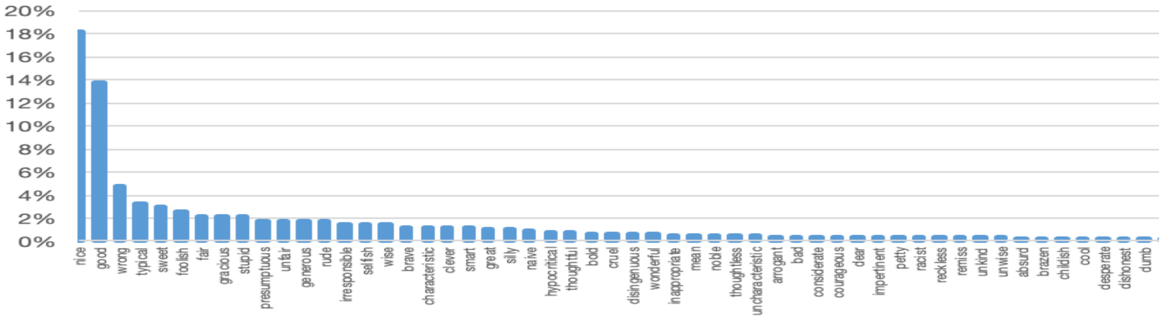
It's nice/good of you to be here.

It's crazy of her to talk about that.

??It's tall of you to reach the top shelf.

It's big of you to reach the top shelf.

??It was good of the dishwasher to save water.



Goldberg and Herbst, 2021, *Linguistics*

LMs offer an alterative to rules	
Lossy compression and interpolation	Every neural net model
Conform to conventions	Pre-training to predict the next word
Complex dynamic network	Structured distributed representations at varying levels of complexity and abstract are learned from massive amounts of input text
Context dependent interpretations	via thousands of words of preceding text
Relationships among discontinuous elements	Attention heads
Goal is to be helpful	Fine-tuning from Instruct GPT

People learn mappings that cluster together → **emergent generalizations (constructions)**

- We avoid combining constructions with incompatible functions
- Context can influence degree of compatibility
- We make our contributions helpful (not only efficient, but also expressive, appropriate, polite)

Current LMs do the same. **Without rules**

She said that Alex ate the pies.

She said that Alex ate the pies.

She grumbled that Alex ate the pies.

She said [that Alex ate <u>the pies]</u>.

What did she say [that Alex ate______]?

She grumbled [that Alex ate <u>the pies.]</u>

?? What did she grumble [that Alex ate ______]?

Ross 1967

Islands: constituents that resist combination w/ long-distance dependency (LDD) constructions to varying degrees

She said [that Alex ate the pies].

What did she say [that Alex ate______]?

She grumbled [that Alex ate the pies.]

?? What did she grumble [that Alex ate ______]?

Ross 1967

Why do island effects exist?

Hypothesis: island effects arise from a clash of discourse functions

"Island" constructions **background** information to varying degrees

Long Distance Dependency (LDD) constructions make a constituent **Prominent**

→ Backgrounded Constructions are Islands (BCI)

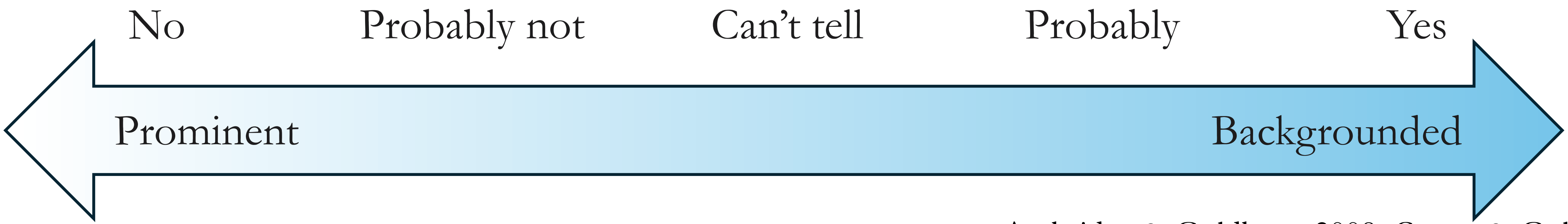
Abeille et al. 2024; Ambridge & Goldberg, 2008; Cuneo & Goldberg, 2023; Dabrowska 2013
Goldberg, 2006, 2013; Lu, Pan, Degen, LSA '24; Namboodiripad et al. 2022

Measuring backgroundedness: Negation Task

She <u>didn't</u> **say** [that Alex ate the pies].

She <u>didn't</u> **grumble** [that Alex ate the pies].

Did she eat the pies?



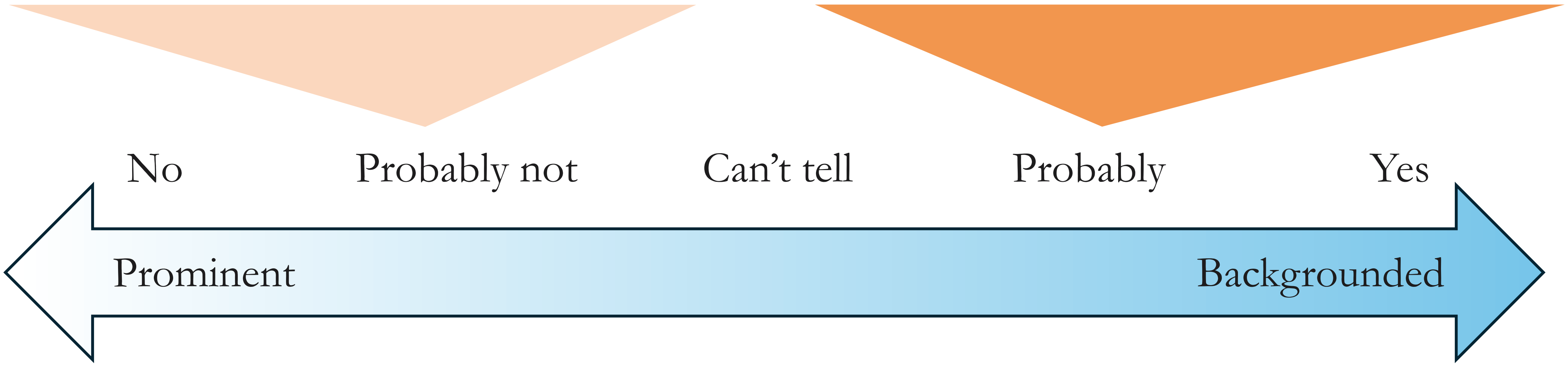
Ambridge & Goldberg, 2008; Cuneo & Goldberg, 2023; Liu et al. 2021; Fergus et al. submitted

Measuring backgroundedness: Negation Task

Did she eat the pies?

She didn't **say** [that Alex ate the pies].

She didn't **grumble** [that Alex ate the pies].



Judgments are subtle and non-binary

1st task: acceptability ratings ("syntactic")
2nd task: degree of presupposition ("semantic")

144 stimuli constructed by hand (Nov 2023)

Stimuli

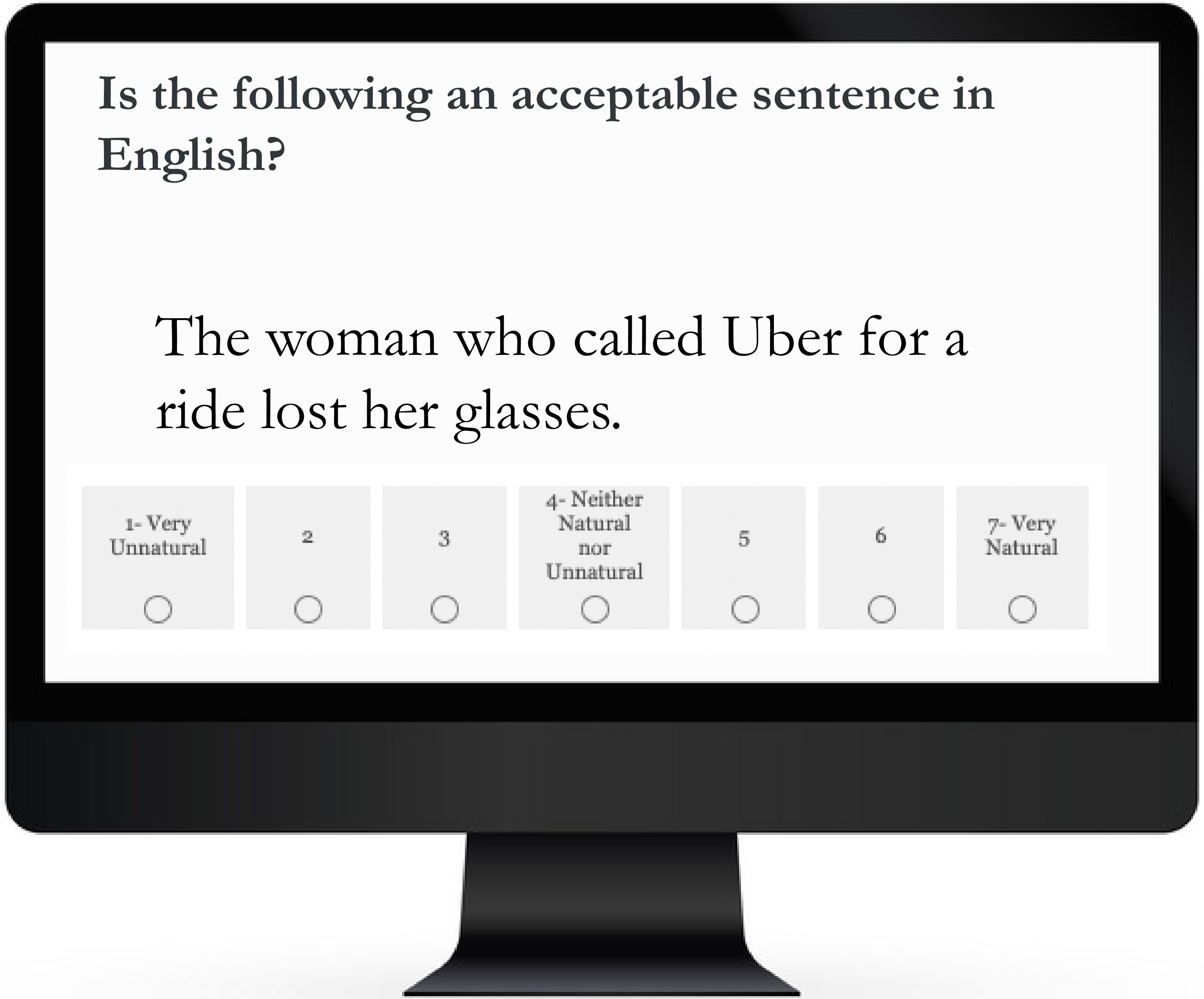
144 base items

Cuneo & Goldberg, 2023, *Cognition*

Constructions	Sample Base sentences	Example Wh-Question
Main Clauses	The woman who called Uber for a ride lost her glasses.	What did the woman who called Uber for a ride lose __?
Relative Clauses	The woman who lost her glasses called Uber for a ride.	What did the woman who lost __called Uber for a ride?
Non-finite Adjuncts	He researched it by/after/while comparing prices.	What did he research the question by/after/while comparing __?
DO Recipient	Daisy showed him an insurance policy.	Who did she show __ the portrait?
PO Recipient	Daisy showed an insurance policy to him.	Who did she show the portrait to__?
Verb Complements	Bill said/discovered that Skyler recited a poem.	What did Alicia say/discover that Skyler recited _?
Parasitic Gaps	Saul gossiped about Beth because he hated her.	Who did Saul gossip about __because he hated_ ?
Nonparasitic Gaps Finite adjuncts	Saul gossiped about Beth's husband because he hated her.	Who did Saul gossip about Beth's husband because he hated _?

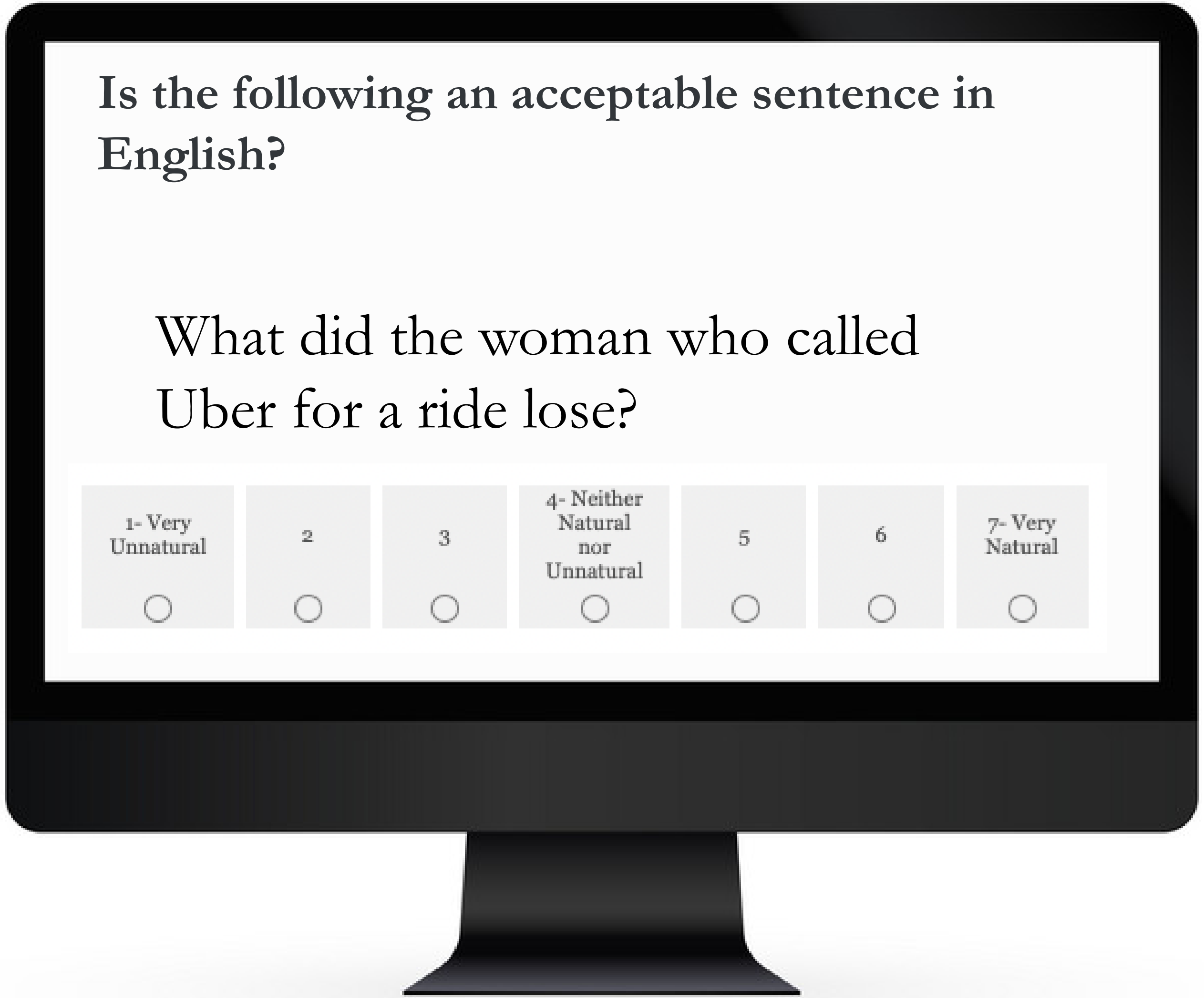
Acceptability Judgments on base sentences

Between subjects;
Prolific, *n= 120*



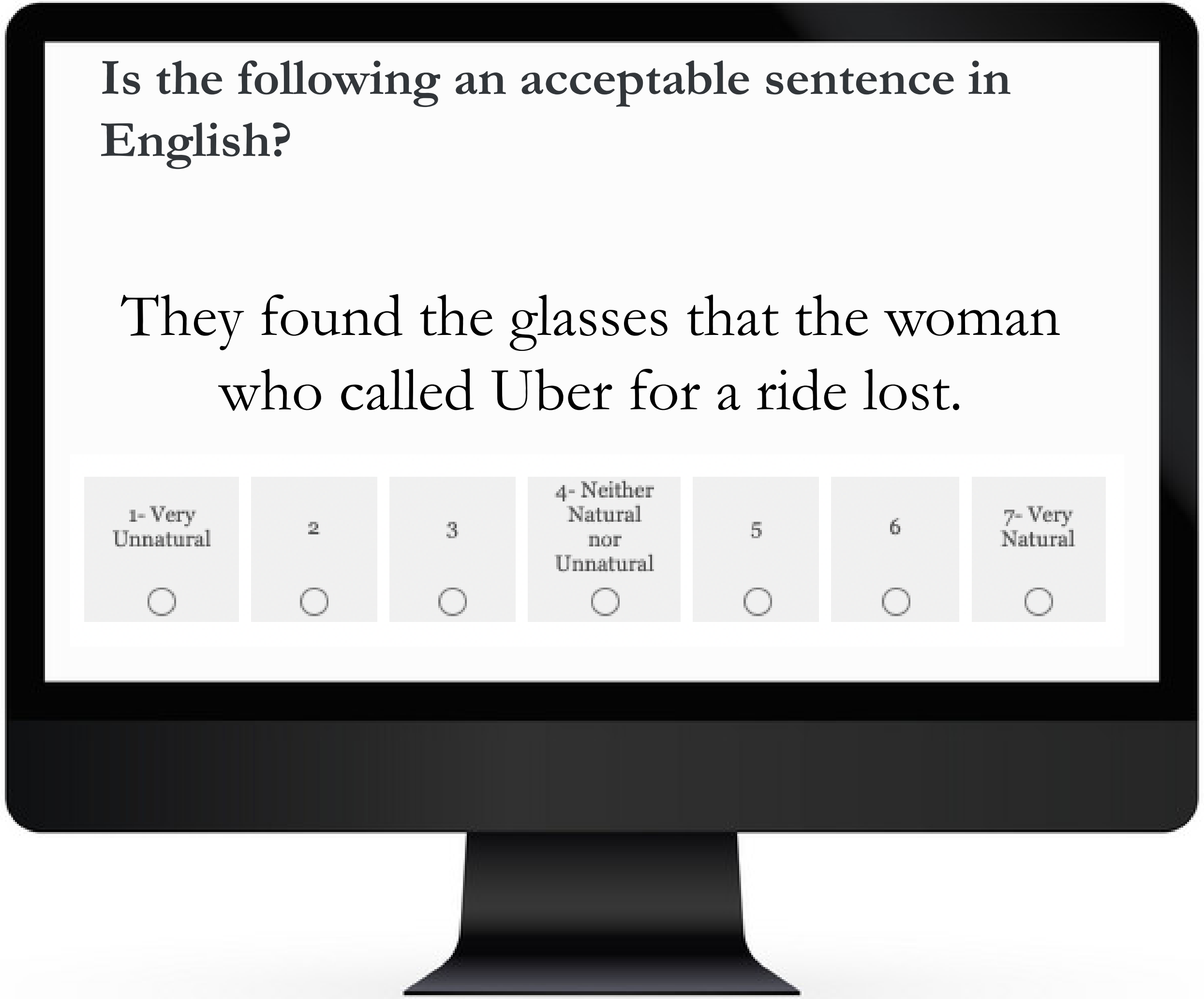
Acceptability Judgments on *wh-* Questions

Between subjects;
Prolific, *n= 120*



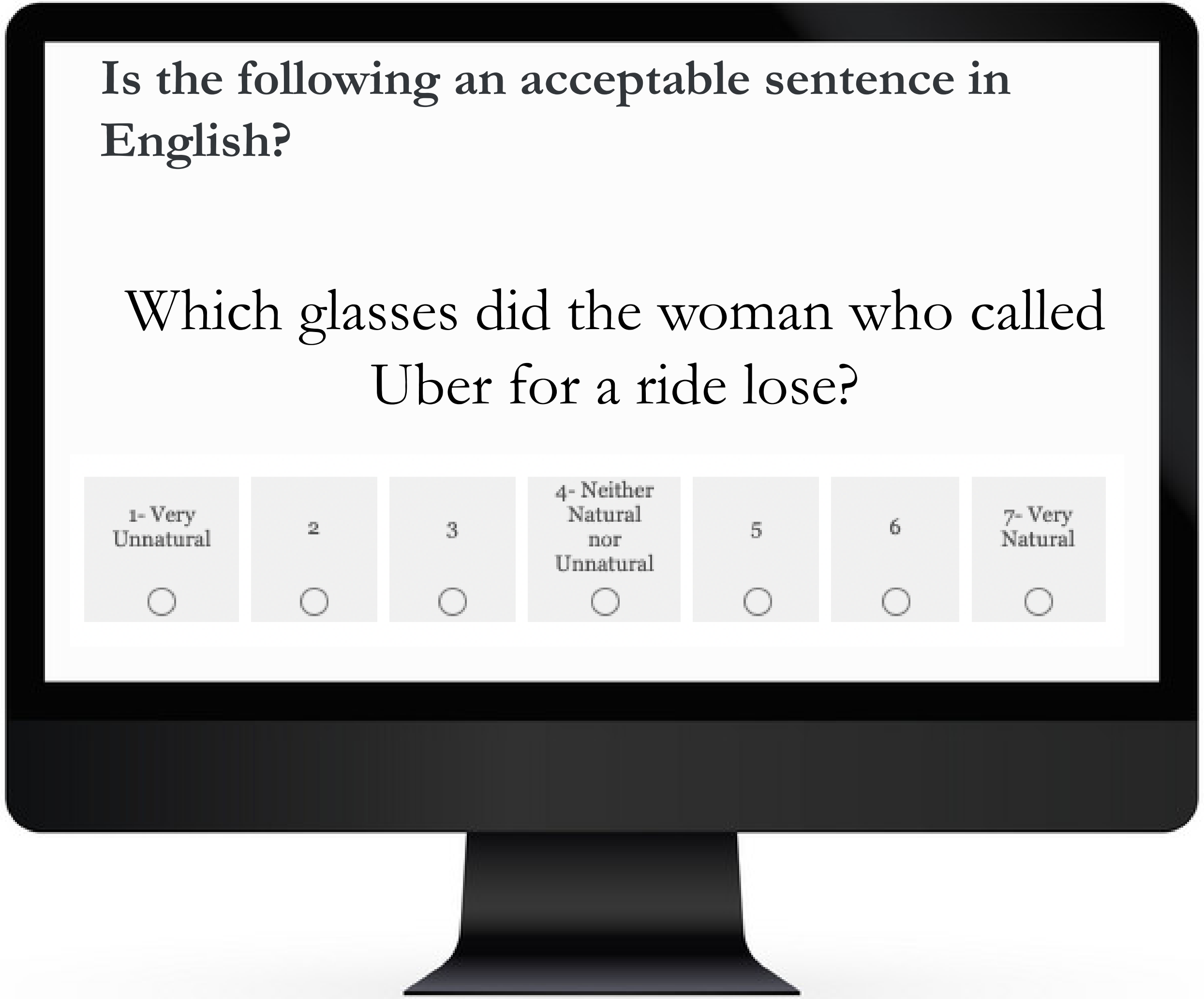
Acceptability Judgments on sentences w/ Relative clause LDDs

Between subjects;
Prolific, *n= 120*



Acceptability Judgments on “discourse-linked” Questions

Between subjects;
Prolific, *n*= *120*



Predicting island effects:
Backgrounded constructions are islands (BCI)

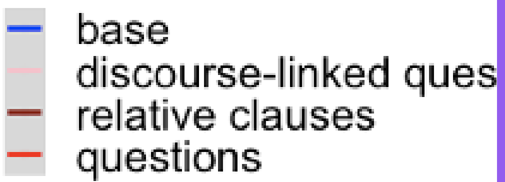
N = 680; between-subjects tasks

- Acceptability judgments on:
  - Base sentences
  - Wh-questions
  - "discourse-linked" wh-questions
  - Relative Clauses

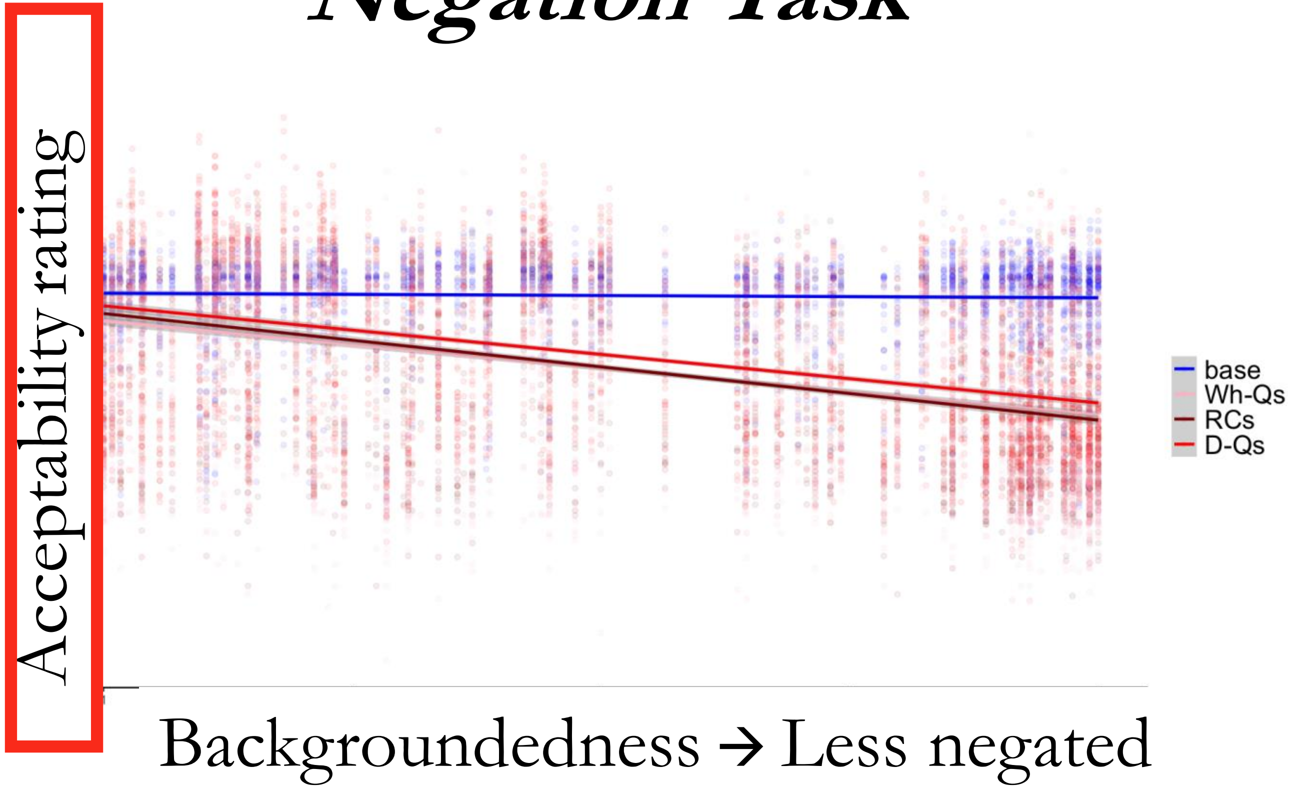
Measuring Backgroundedness

- Negation Task

Cuneo & Goldberg, 2023, *Cognition*



Negation Task



whole experiment replicated

$N = 680$

- Each backgroundness measure predicted judgments for each LDD

- Within *subsets* of data, degree of backgroundedness predicted LDD judgments on:
  - Verbs with clausal complements w/ log frequencies included (24 items)
  - Non-finite adjuncts (24 items) (see also Namboodiripad et al. 2022)
  - Main Clauses and RCs
  - Parasitic and nonparasitic gaps
  - Main clauses and temporal adjuncts

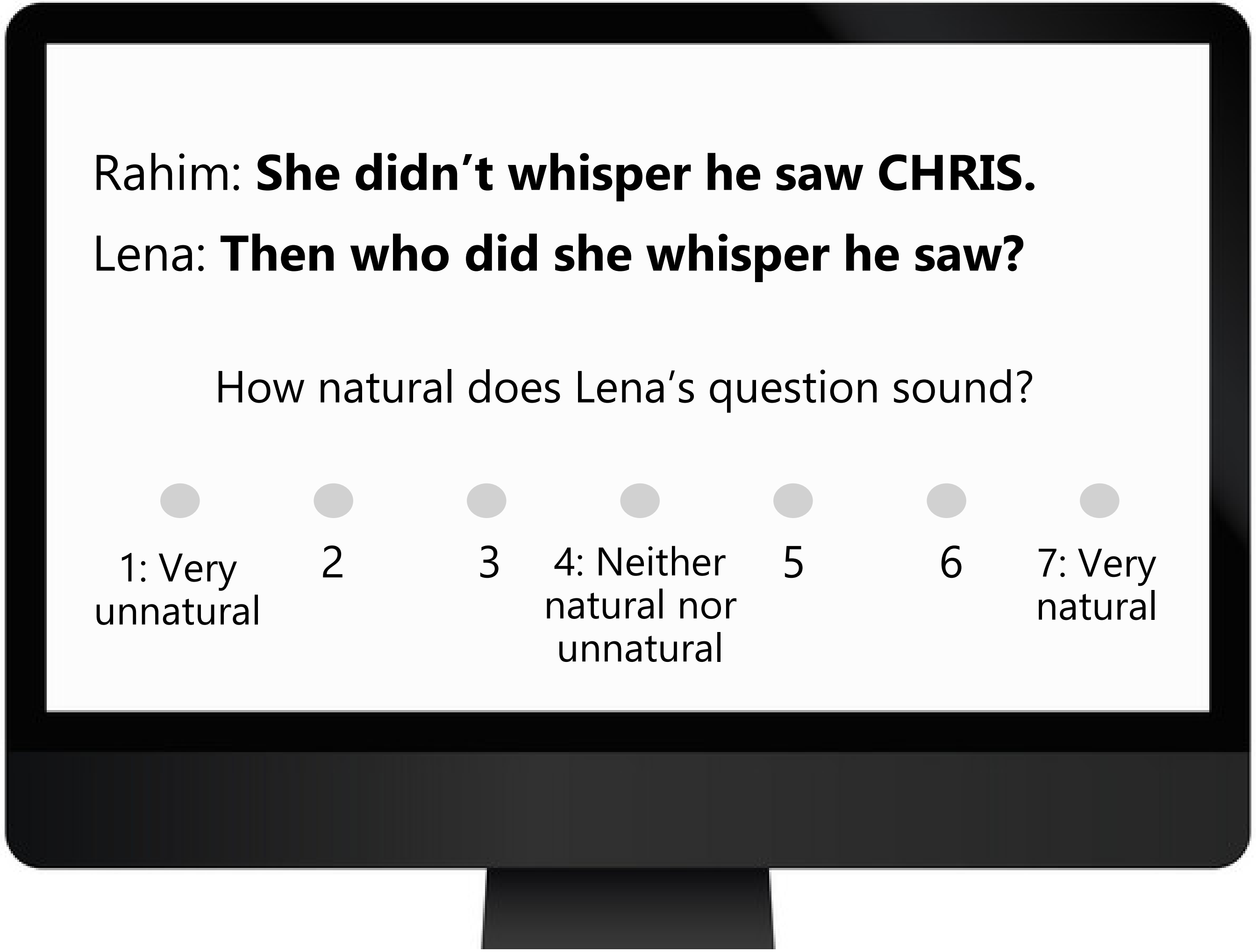
Cuneo & Goldberg 2023, *Cognition*

→Backgrounded constructions are islands

It is infelicitous for speakers to choose to both foreground and background the same element

Manipulating prominence

Is *wh*-Q acceptability improved when the queried constituent is made prominent via lexical stress?

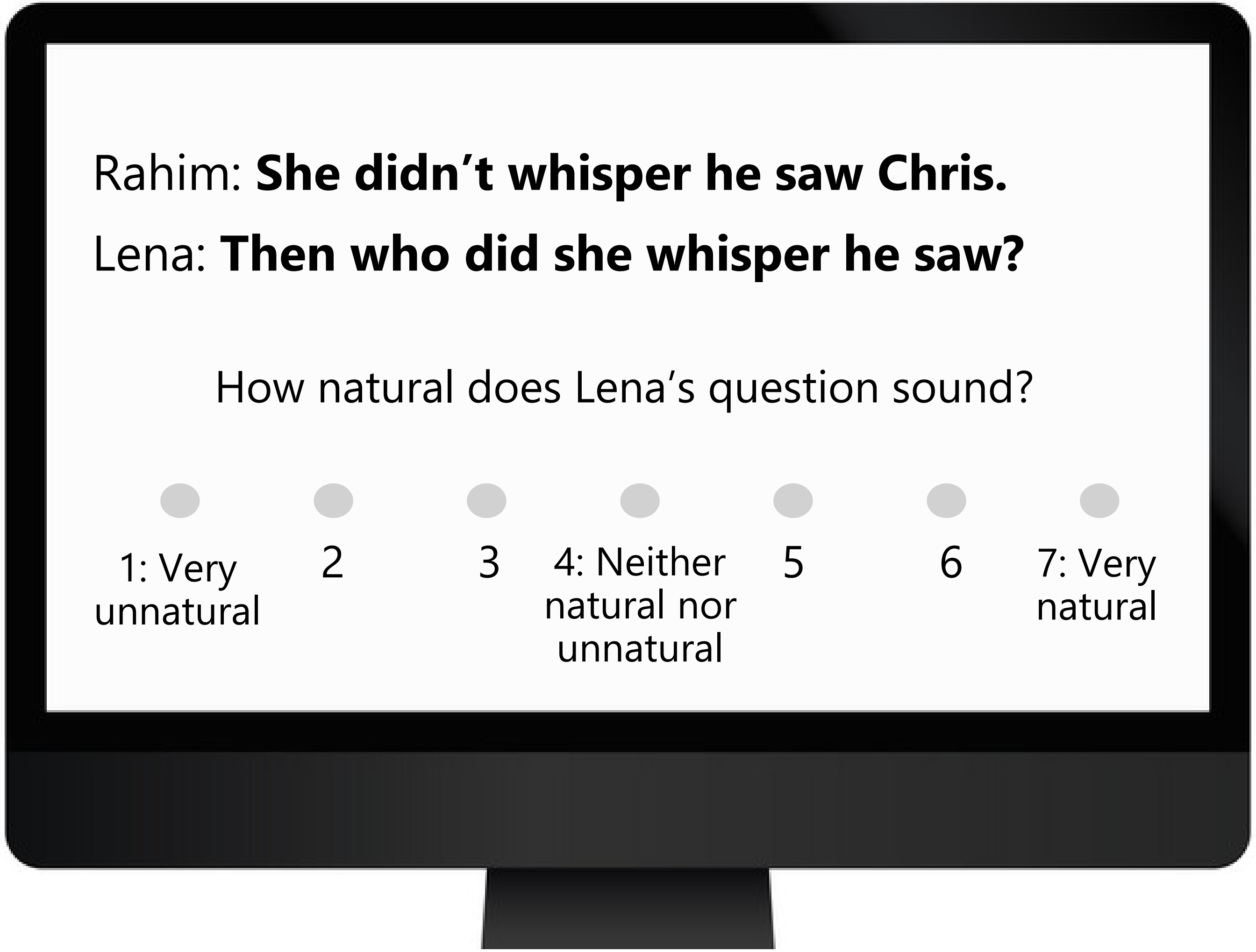


Lu, Pan, Degen, '24

Fergus, Belluck, Cuneo, & AEG, submitted

Manipulating prominence

Is *wh*-Q acceptability improved when the queried constituent is made prominent via lexical stress?



Lu, Pan, Degen, '24

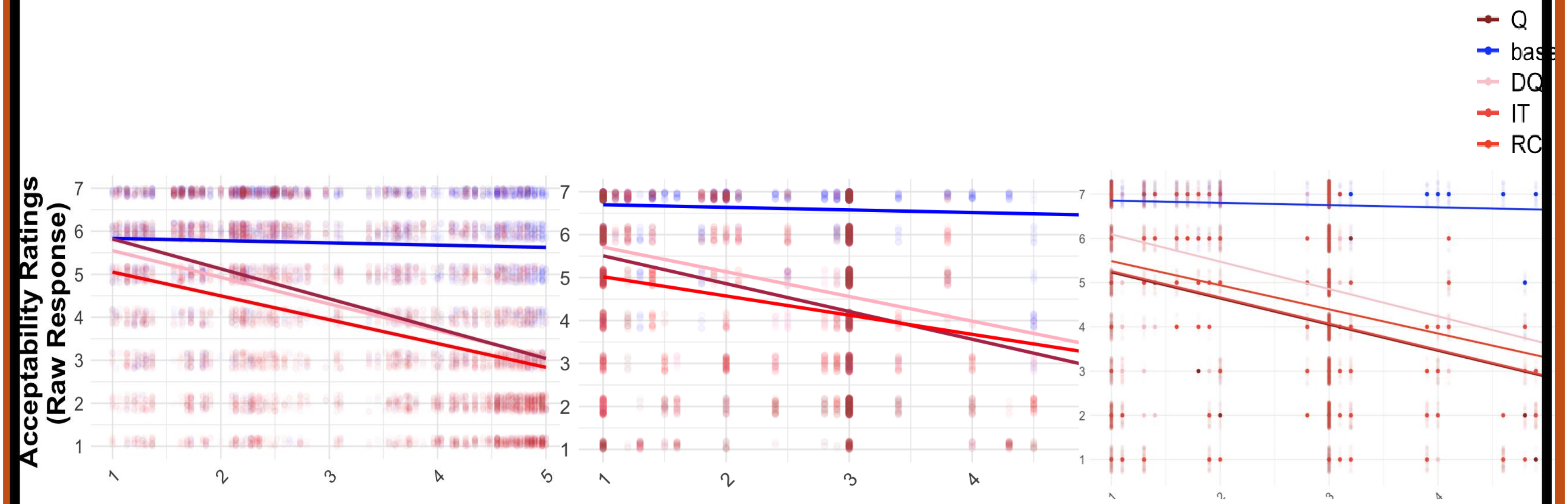
Fergus, Belluck, Cuneo, & AEG, submitted

GPT-4 Prompt **Acceptability judgments**	Is the following an acceptable question in English? Who did Marcus write a letter? Rate it on a scale of 1-7, where 1 is very unnatural and 7 is very natural. Return only an integer rating.

Cuneo, Graves, Raxit, & Goldberg, submitted

GPT-4 Prompt	Assume the sentence below is true and think about what it means: Marcus didn't write her a letter.
Negation task	Now answer the following question with an integer between 1 and 5, where 1 means no, 2 means probably not, 3 means can't tell, 4 means probably yes, and 5 means yes: Did Marcus write someone else a letter?

Cuneo, Graves, Raxit, & Goldberg, submitted



Backgroundedness
Humans
(Cuneo & Goldberg, 2023, *Cognition*)

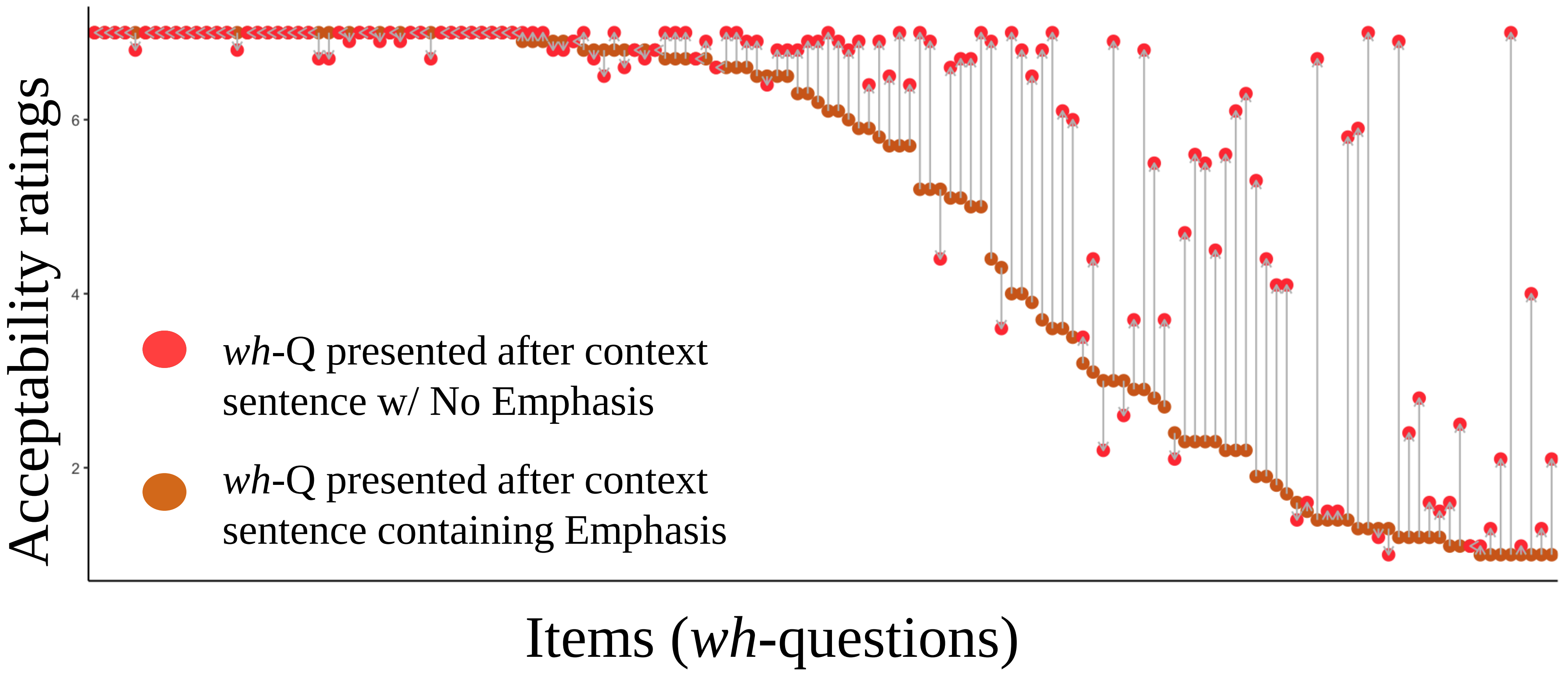
Backgroundedness
GPT-4
replication

Backgroundedness
GPT-4
New stimuli

Cuneo, Graves, Raxit, & Goldberg, submitted

Manipulating emphasis:

GPT-4's ratings on 144 (new) items w/ and w/o emphasis



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Current LMs do the same. Without rules

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