Visualizations & NLP

Dae Hyun Kim, Vidya Setlur

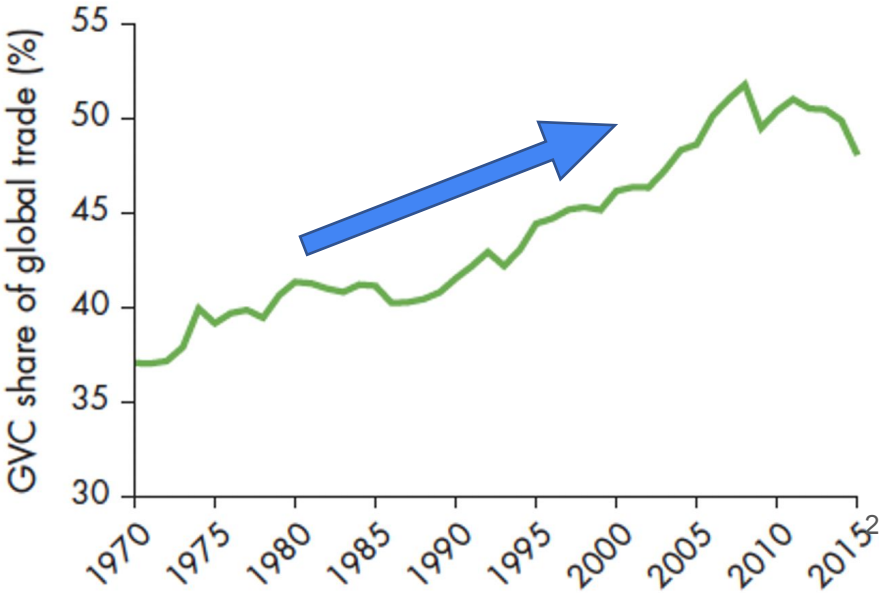
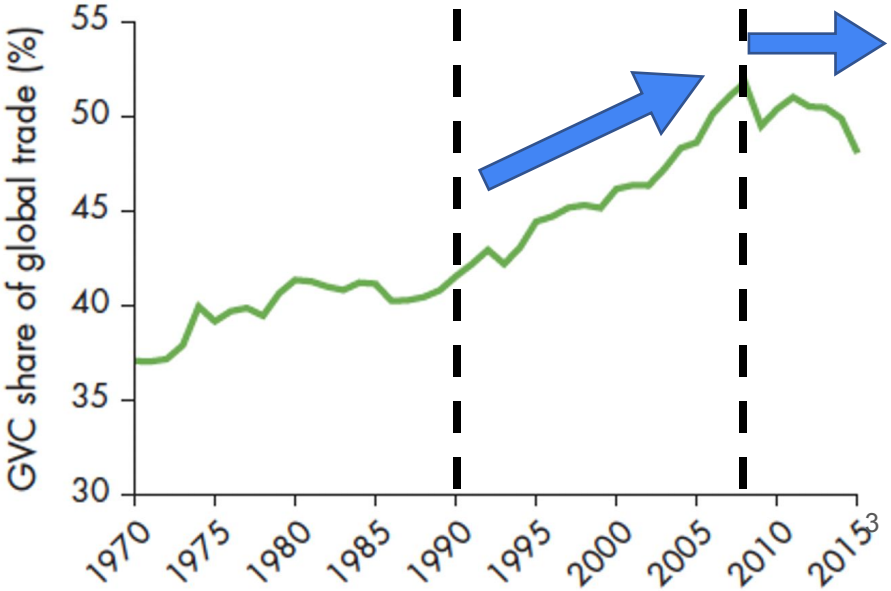

GVC share of global trade (%)
55
50
45
40
35
30
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

Figure 1.2 GVC trade grew rapidly in the 1990s but stagnated after the 2008 global financial crisis



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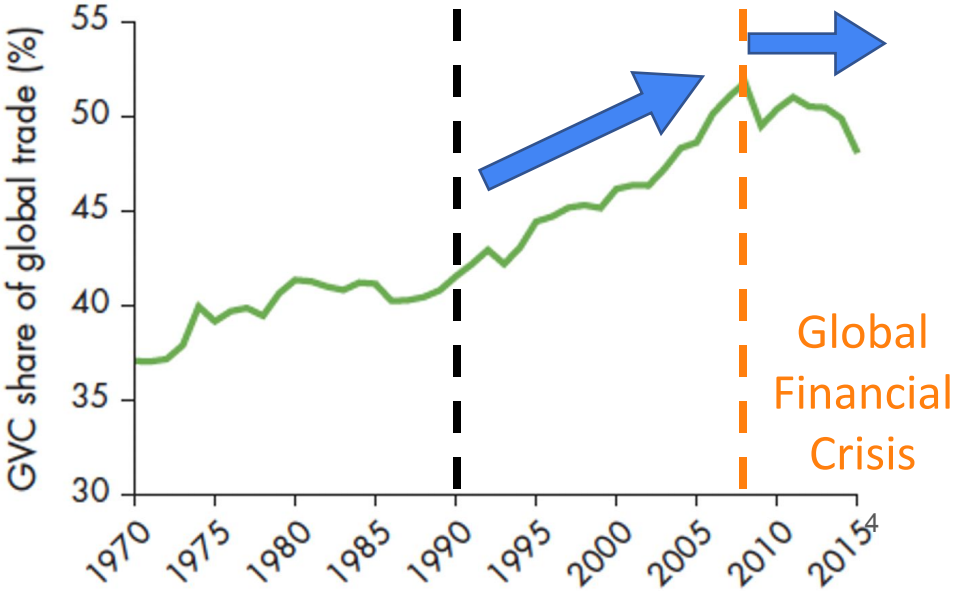

The evolution of GVC participation

The overall share of GVC trade in total world trade—encompassing both forward and backward linkages—grew significantly in the 1990s and early 2000s, but it appears to have stagnated or even declined in the last 10 years (figure 1.2). Still, about half of world trade appears to be related to GVCs.

What explains the remarkable rise in GVC participation in the 1990s and 2000s? And why has this process stalled since the financial crisis?

The global wave of fragmentation of production in the 1990s and 2000s was driven by a combination of factors. The information and communication technology (ICT) revolution brought forth cheaper and more reliable telecommunications, new information management software, and increasingly powerful personal computers (figure 1.3, panel a). Manufacturing firms then found it easier to outsource and coordinate complex activities at a distance and ensure the quality of their inputs. In addition, firms were able to disperse production across the world because transport costs fell significantly (figure 1.3, panel b). Declining air and sea freight costs boosted the trade in goods, while services benefited from cheaper communication costs.

Successive rounds of trade liberalization have resulted in rapidly falling barriers to trade and investment for both developed and developing countries. Tariffs have declined, especially for manufactured goods, and the gradual, although still insufficient, lowering of nontariff barriers has facilitated the international trade of goods and services (figure 1.4). Finally, the creation of the European single market—together with the integration of China, India, and the Soviet Union into the global economy—created huge new product and labor markets, and so firms could sell the same goods to more people and take advantage of economies of scale leading to the further deepening of GVCs. The new supply of cheap labor encouraged profit-seeking companies to either reallocate their production facilities or find local suppliers in low-wage countries.[3]

Since the global financial crisis in 2008, the dynamics of GVC expansion have changed. Trade has bounced back from its deep crisis level, but it has grown only marginally faster than output. Trade in parts and components also stalled after the financial crisis and even fell between 2011 and 2014, with a modest increase since then.

The factors behind the trade and GVC slowdown are both cyclical and structural in nature. On the one hand, trade growth is lower because global output growth is lower in economies that account for large shares of global trade and global output, such as Europe and China. Trade has also grown at a slower pace because the trade-to-income elasticity—defined as the amount of trade generated as output rises—has decreased. This is especially true in large trading countries, including China and the United States. China is producing more at home, thereby becoming less reliant on imported components for its exports. The share of intermediate imports in exports of Chinese goods dropped from about 50 percent in the 1990s to a little over 30 percent in 2015. In the United States, a boom-

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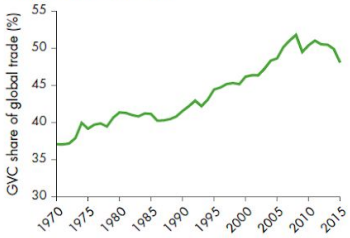

Sources: WDR 2020 team, using data from Eora26 database; Borin and Mancini (2015, 2019); and Johnson and Noguera (2017). See appendix A for a description of the databases used in this Report.

Note: Unless otherwise specified, GVC participation measures used in this and subsequent figures throughout the Report follow the methodology from Borin and Mancini (2015, 2019). The Eora26 database is used because it offers the largest country coverage: 190 countries between 1990 and 2015. GVC participation corresponds to the share of world exports that flow

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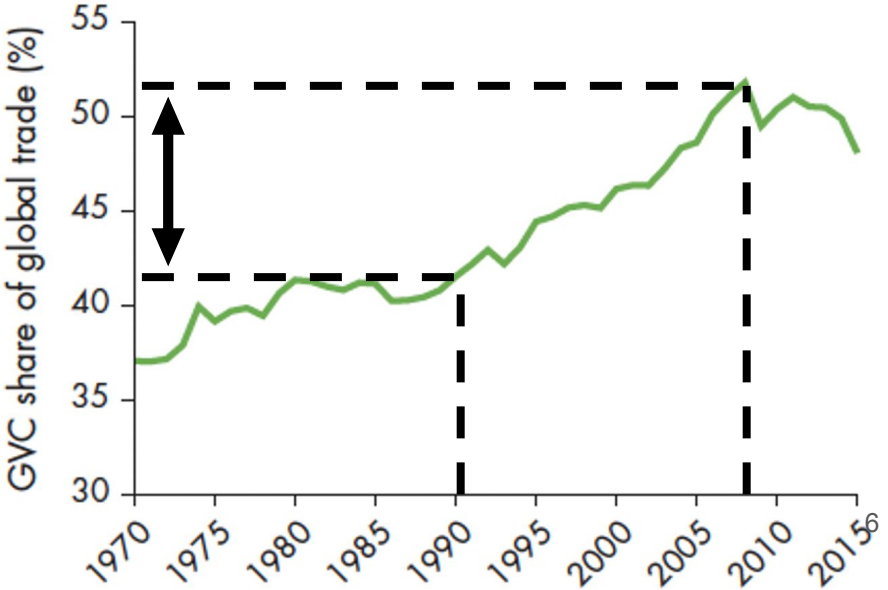
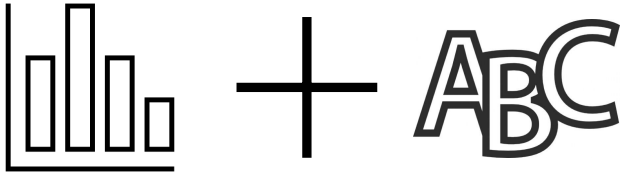


Question: *How much did the GVC share rise between 1990 and 2008?*



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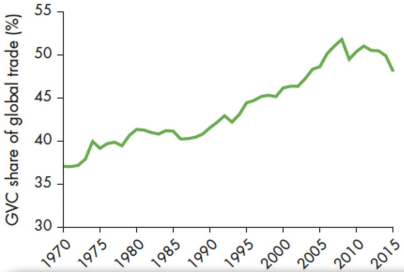
Communicative Documents



Q: How much did the GVC share rise between 1990 and 2008?

Natural Language Interfaces

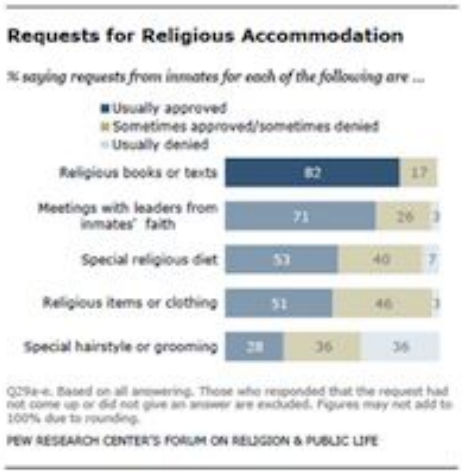
“Words and pictures belong together.”

[Tufte, 1983]

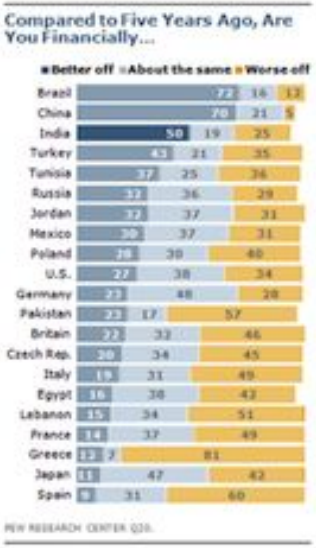
Facilitating Document Reading by Linking Text and Tables

[Kim et al. 2018]

An overwhelming majority of chaplains who responded to these questions say that inmates' requests for religious texts (82%) and for meetings with spiritual leaders of their faith (71%) are usually approved. And about half of chaplains say that requests for a special religious diet (53%) or for permission to have sacred items or religious clothing such as crucifixes, eagle feathers and turbans (51%) also are usually granted.



People may think their personal situation is better than economic conditions in their nation, but only in Brazil (72%) and China (70%) do large majorities think their families are better off than they were five years ago. On balance, Indians (50%) and Turks (43%) also say their situations have improved.

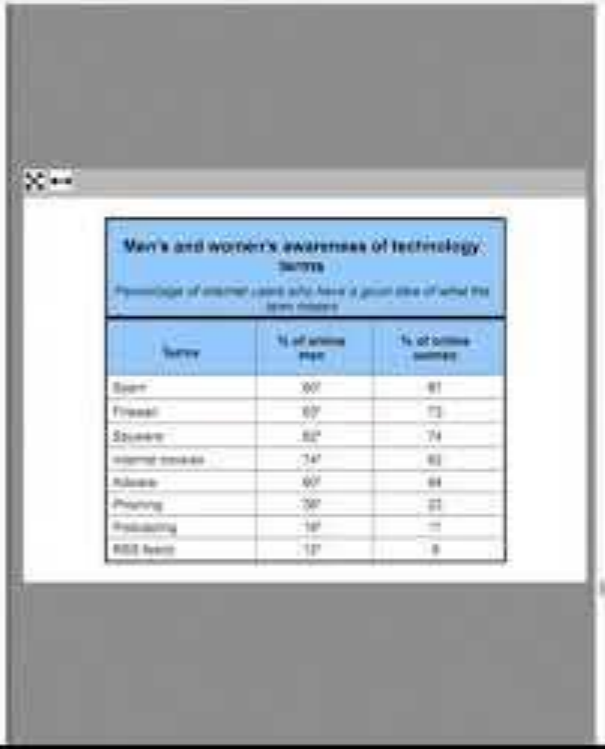


[Kong et al. 2014]

Part 6:

Issues about computers and the internet: Awareness, interest, attitudes, aptitude, self-confidence

Tech terminology and issues: More men than women are familiar with tech terms and issues.



Men's and women's awareness of technology terms

Percentage of internet users who have a good idea of what the term means

Terms	% of online men	% of online women
Spam	80*	81
Firewall	69*	73
Spyware	82*	74
Internet browser	74*	83
Adware	60*	64
Phishing	39*	23
Podcasting	18*	11
RSS feeds	13*	8

Automatically extract references between sentences and tables

Automatic Reference Extraction Pipeline

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Women are more likely than men to cite some reasons for not using the internet		
Major reasons	**% of online men**	**% of online women**
Don't need it	45	58
Don't have time	29	29
Too expensive	25	34

Equal numbers of men and women said they lack time.

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Table Structure Extraction

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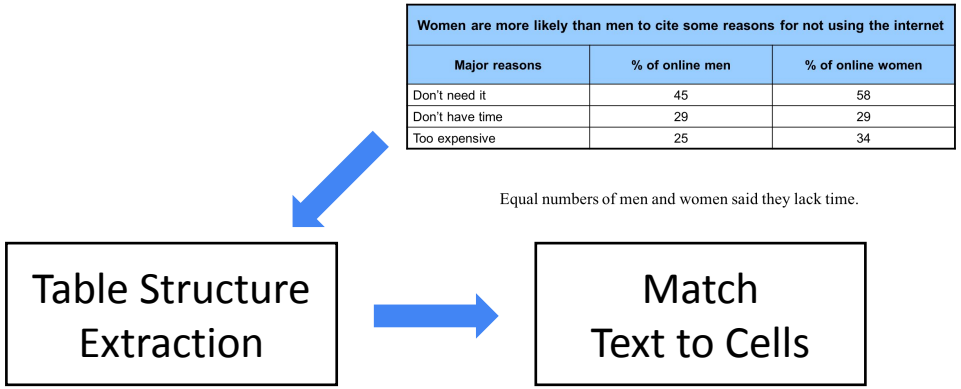

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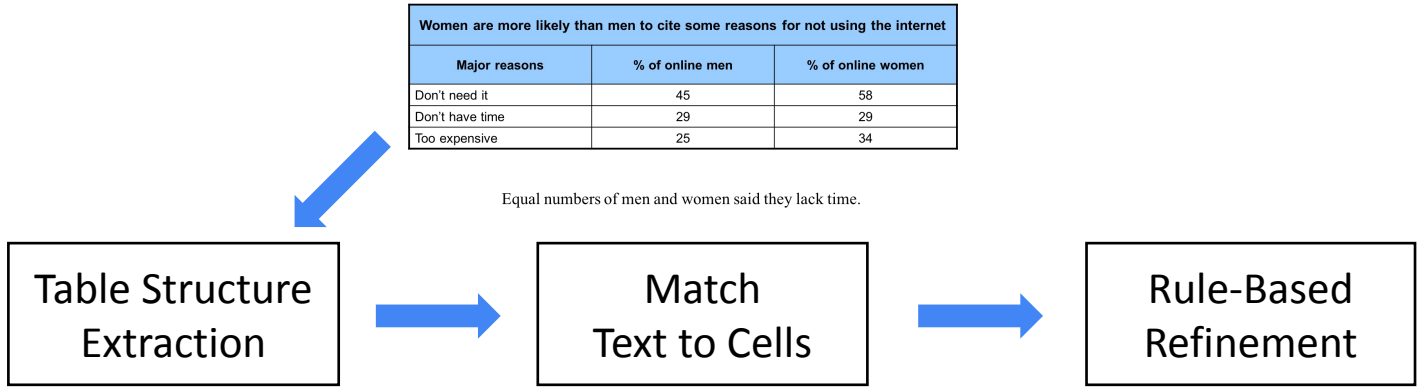

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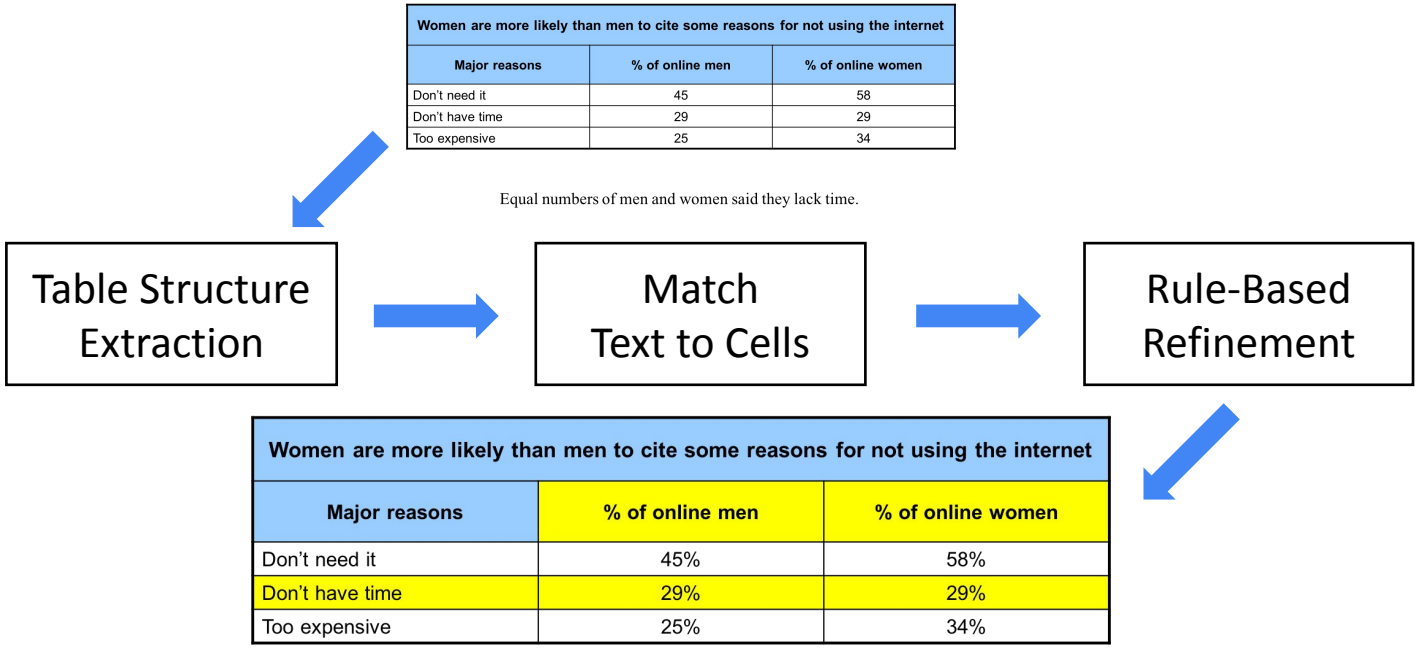

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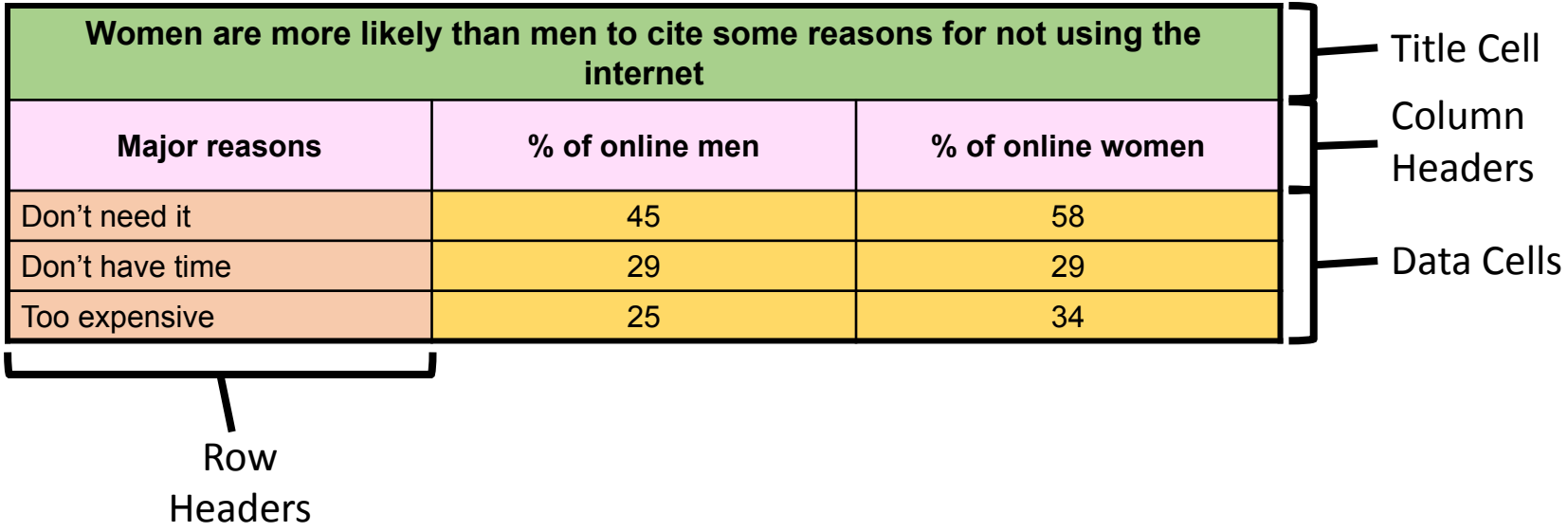

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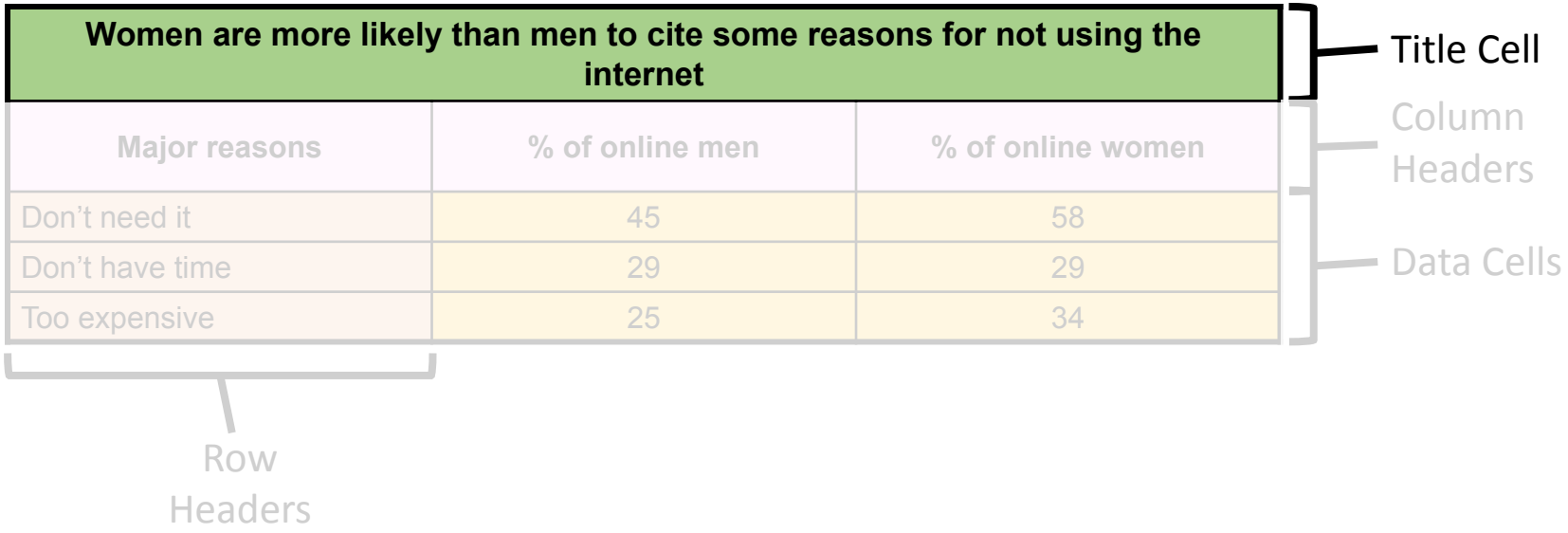

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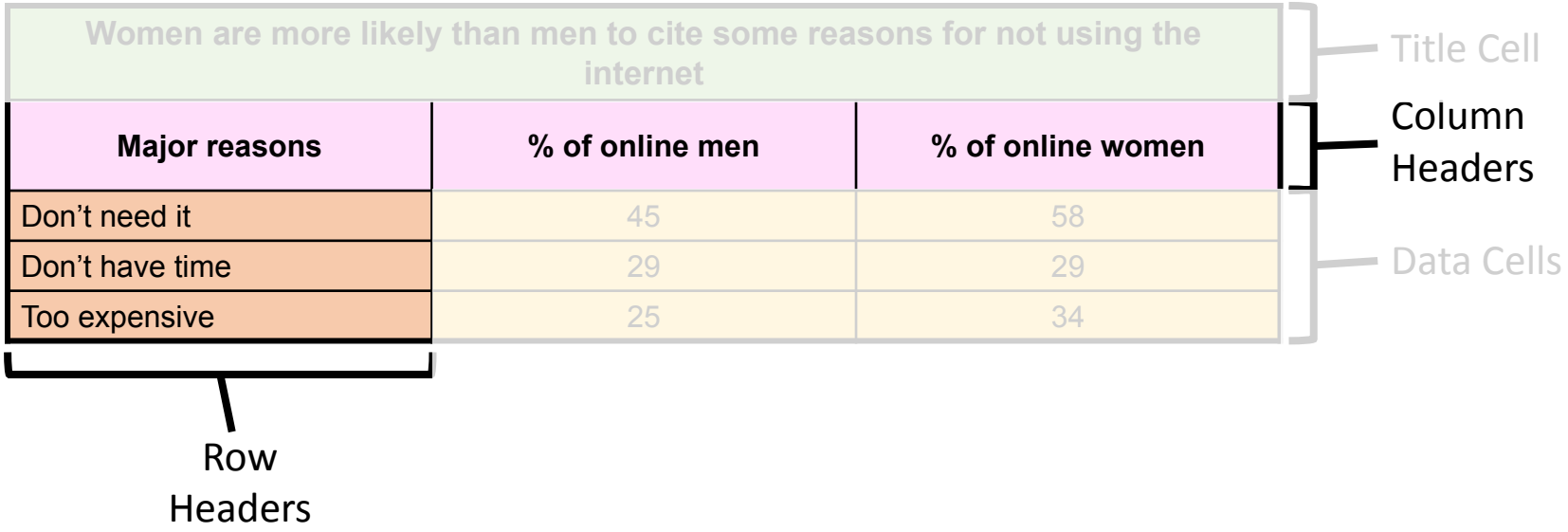

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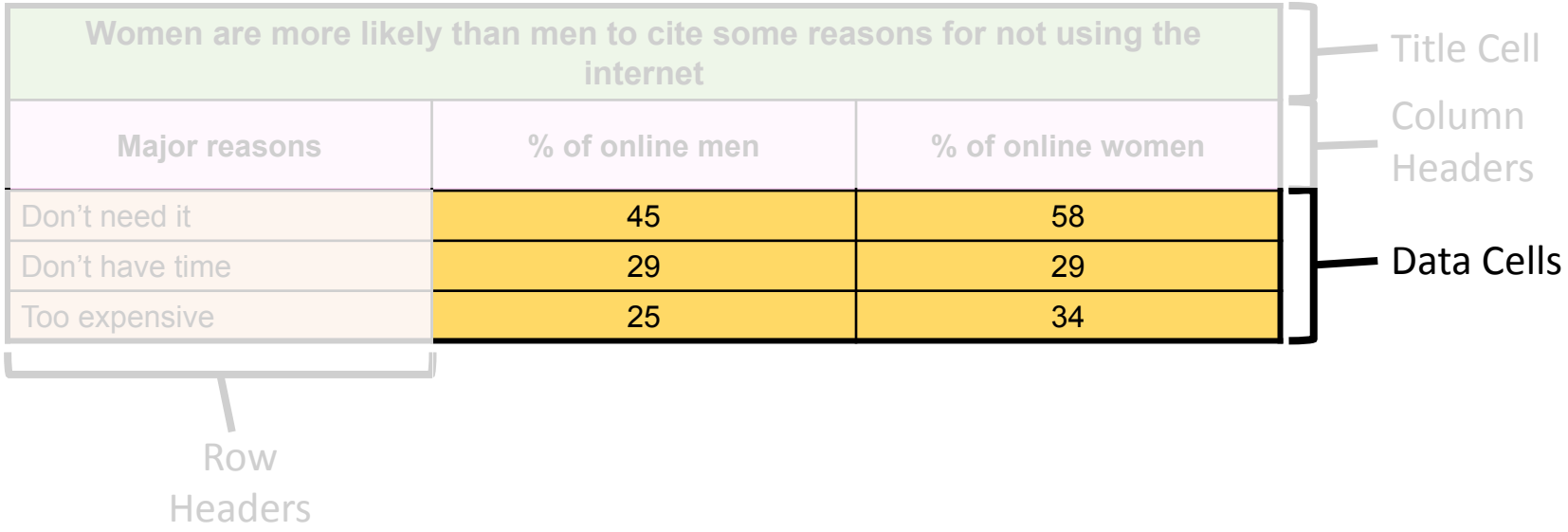

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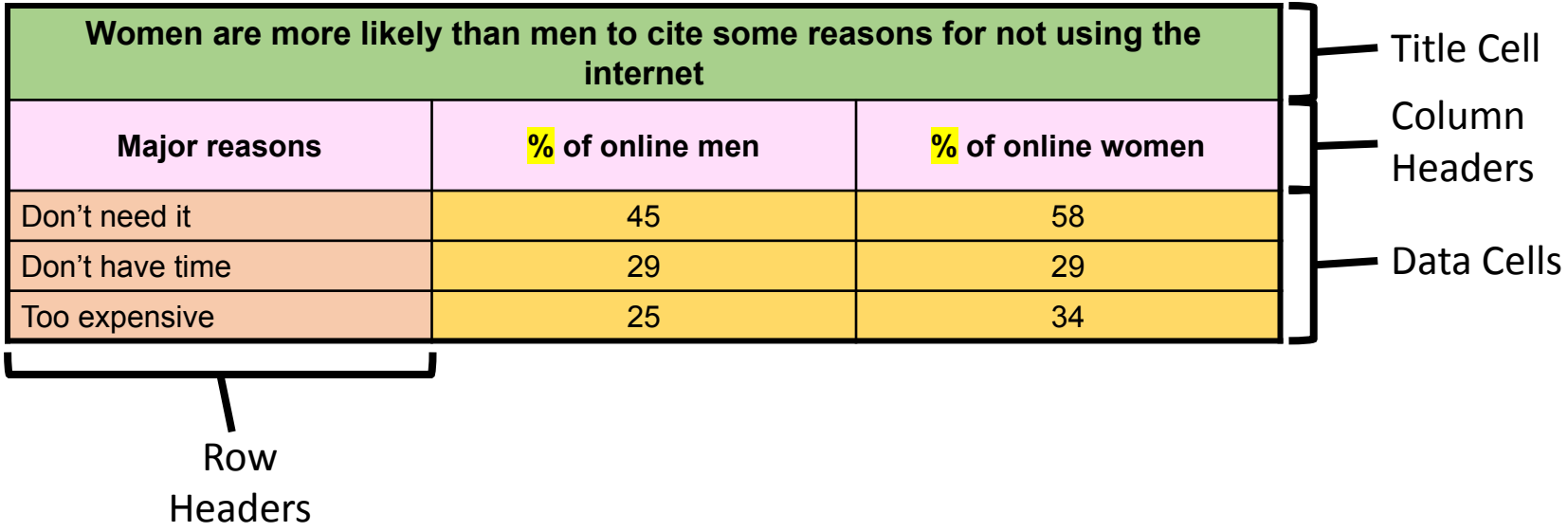

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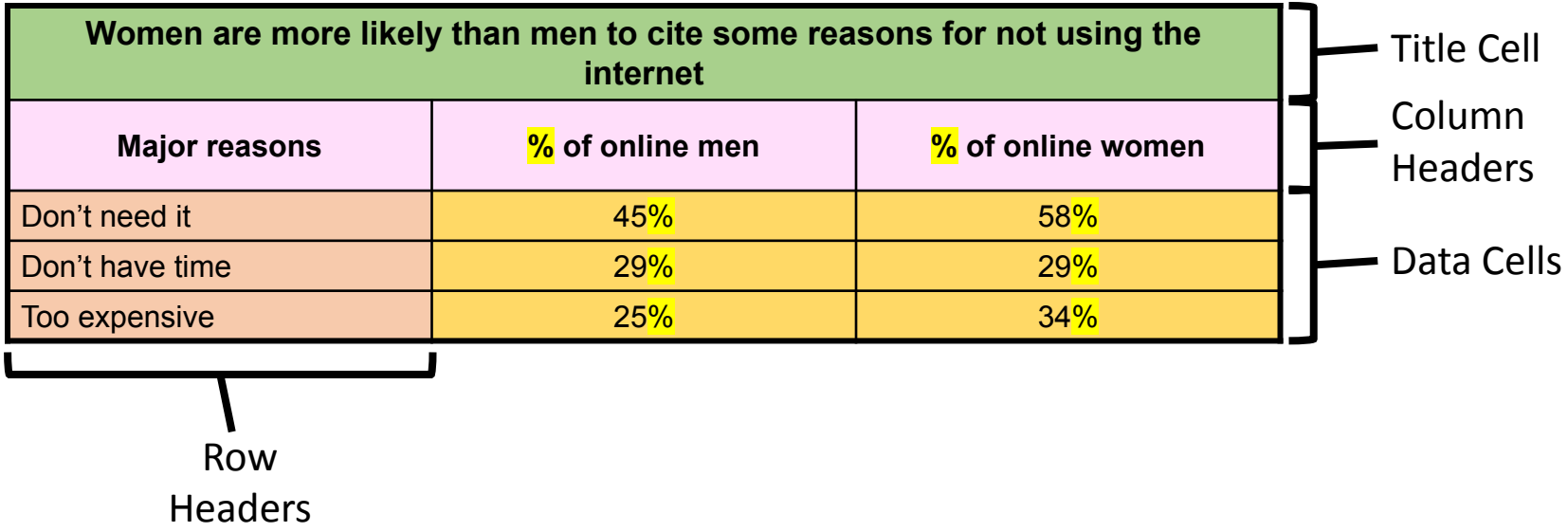

Stage 2: Match Sentence Text to Table Cells

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Pipeline Evaluation

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- Corpus
  - Pew Research Reports
  - ACL and CVPR papers

Pipeline Evaluation

- Corpus
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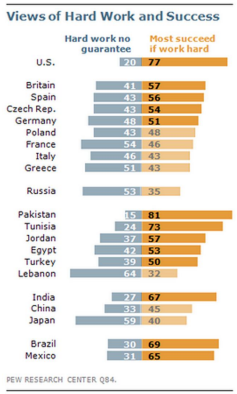
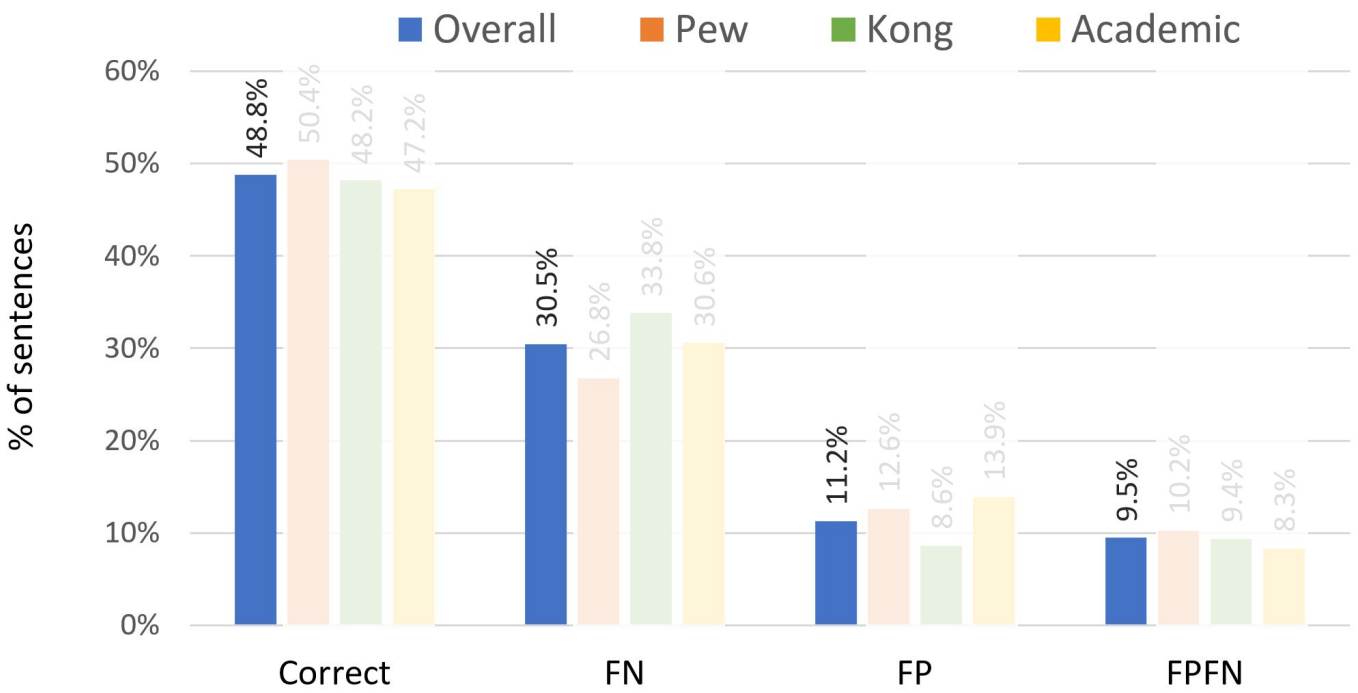
  - ACL and CVPR papers
  - Kong et. al (2014)

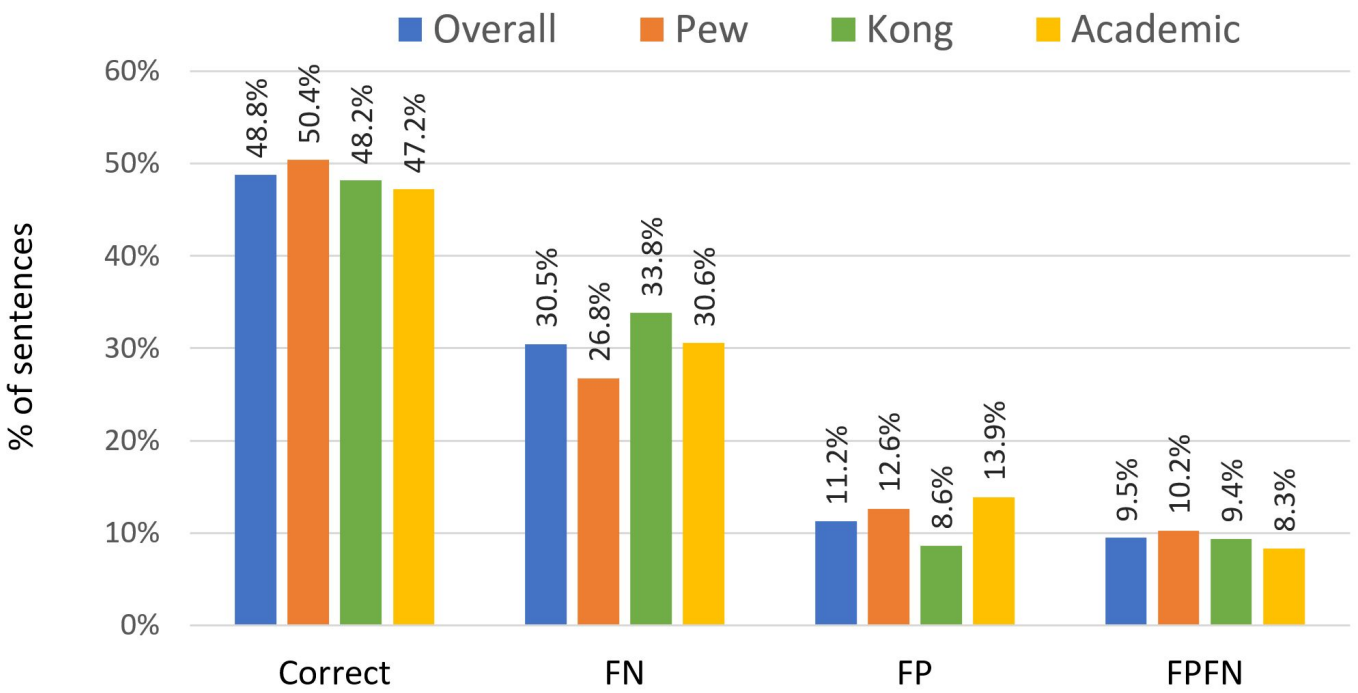
Half or more in 13 of the 21 nations surveyed believe that most people can succeed if they are willing to work hard. This includes Pakistan (81%) and the U.S. (77%). It also includes Tunisia (73%), Brazil (69%), India (67%) and Mexico (65%).



Results


Overall
Pew
Kong
Academic
% of sentences
60%
50%
40%
30%
20%
10%
0%
48.8%
50.4%
48.2%
47.2%
30.5%
26.8%
33.8%
30.6%
11.2%
12.6%
8.6%
13.9%
9.5%
10.2%
9.4%
8.3%
Correct
FN
FP
FPFN

Results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26.8%
33.8%
30.6%
11.2%
12.6%
8.6%
13.9%
9.5%
10.2%
9.4%
8.3%
Correct
FN
FP
FPFN

User Study

User Study

- Hypothesis

Our interface facilitates reading documents with tables

User Study

- Within-subject study
- 14 adult volunteers, all fluent in English
- Task: Annotate references with/without our interface

Findings of User Study

- Hypothesis

  Our interface facilitates reading documents with tables

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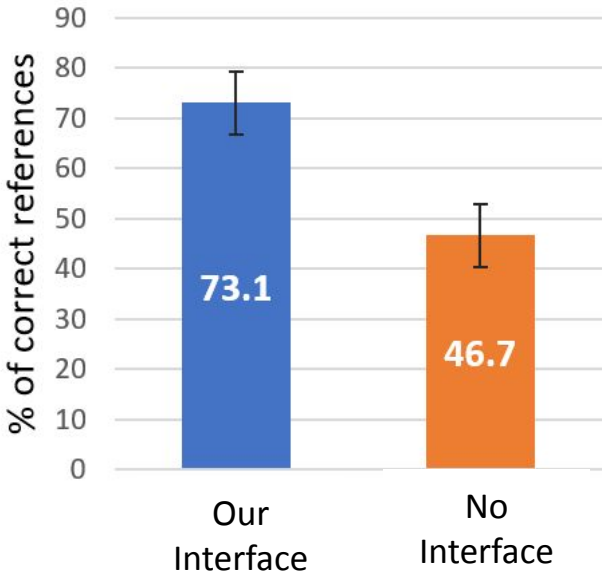

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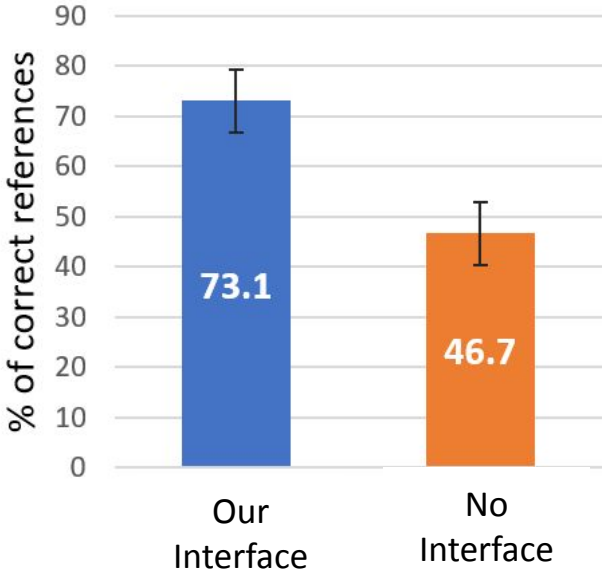

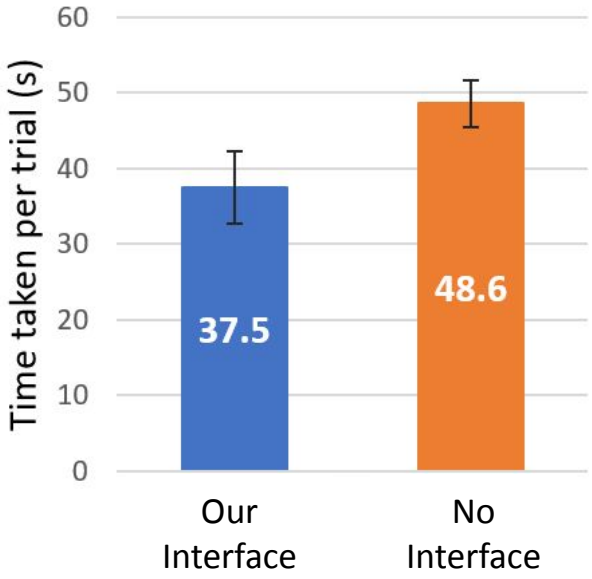

Findings of User Study

“The interface allows me to read the table while reading the text …”

PRINCIPLE 1

A mutation to a place is a mutation to all conflicting places.

THEOREM 3.1

Let:

- $\pi_{\text{mut}} = \pi_{\text{mut}}{}^{\square}[x], \sigma$ *where* $\sigma \vdash \pi_{\text{mut}} \Downarrow \_ \times \mathcal{V}$
- $v, \vec{\sigma} = \sigma[x \mapsto \mathcal{V}[v]]$
- π_{any} *be any place*

Then $\sigma(\pi_{\text{any}}) \neq \vec{\sigma}(\pi_{\text{any}}) \implies \pi_{\text{any}} \sqcap \pi_{\text{mut}}$.

As described in Section 3.3, a mutation to a place is represented by updating a variable x in a stack σ by plugging a value v into a value context $\mathcal{V}$. To denote a conflict, we reuse the notation from Oxide that $\pi_1 \# \pi_2$ means "π_1 and π_2 do not conflict", or more formally:

$$x_1.q_1 \# x_2.q_2 \stackrel{\text{def}}{=} x_1 \neq x_2 \vee ((q_1 \text{ is not a prefix of } q_2) \wedge (q_2 \text{ is not a prefix of } q_1))$$

Conversely, we use the shorthand $\pi_1 \sqcap \pi_2 \stackrel{\text{def}}{=} \neg(\pi_1 \# \pi_2)$. So if a place π_{any} is changed when π_{mut} is mutated, then it must be that $\pi_{\text{any}} \sqcap \pi_{\text{mut}}$.

Part of Nota's inspiration was my attempts to visually encode correspondences between objects (see page 10 of the PDF). LaTeX's brittle abstractions made it frustratingly hard to do something as simple as "draw a colored underline beneath a piece of math."

By contrast, implementing this feature was trivial in HTML/CSS/Javascript. And we could extend the idea with interactions like drawing attention to corresponding objects on hover.

[Crichton 2021]

How Readers Integrate Information in Visualizations & Text

[Kim et al. 2020]


30 Year Fixed Mortgage Rate
18.00%
16.00%
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
1975
1980
1985
1990
1995
2000
2005
2010
2015

The 30-year fixed mortgage rate increased slightly from 1997 to 1999.

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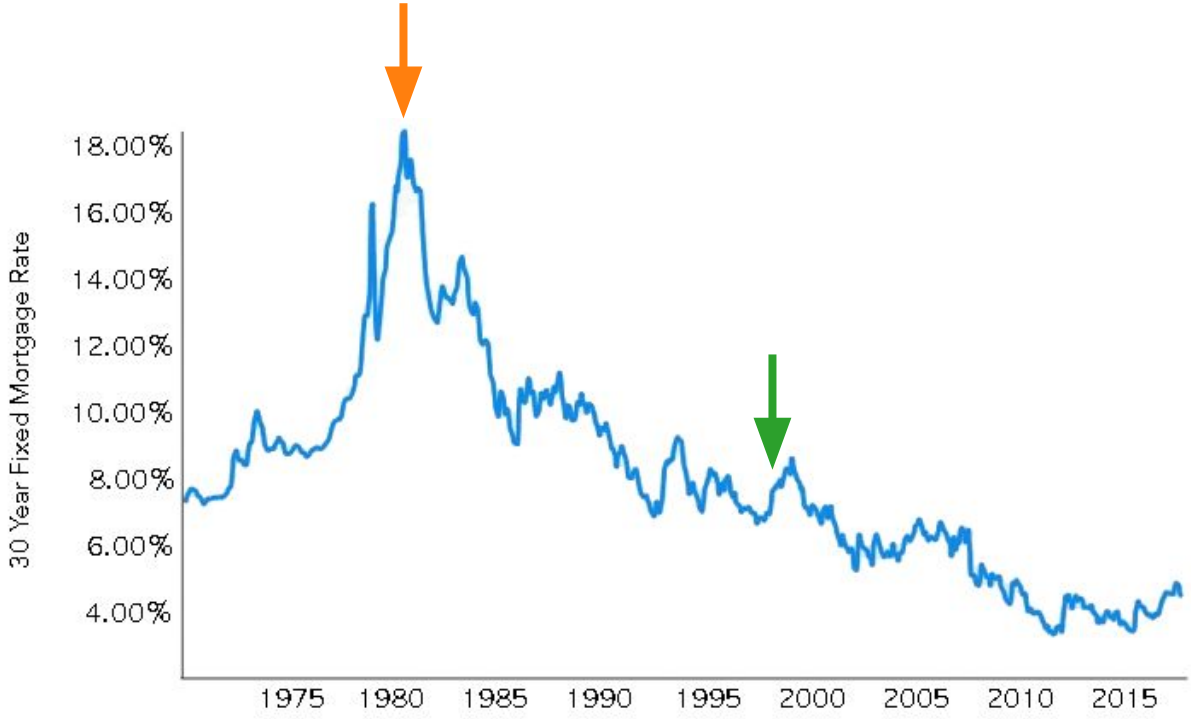
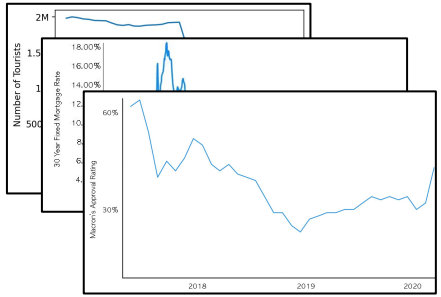


The 30-year fixed mortgage rate increased slightly from 1997 to 1999.

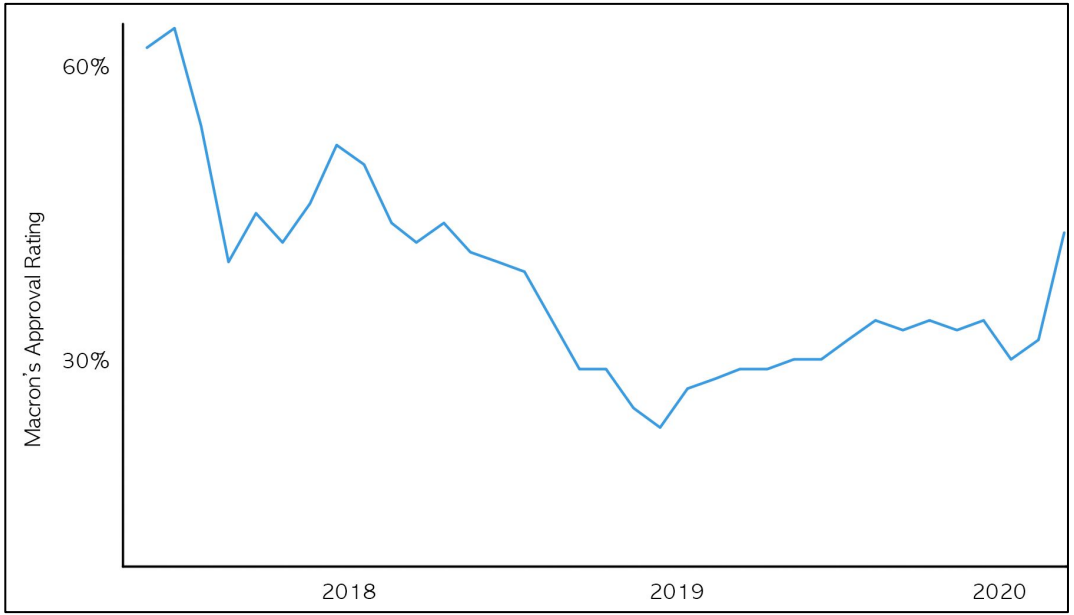
Do readers rely more on the chart or captions for their takeaways?

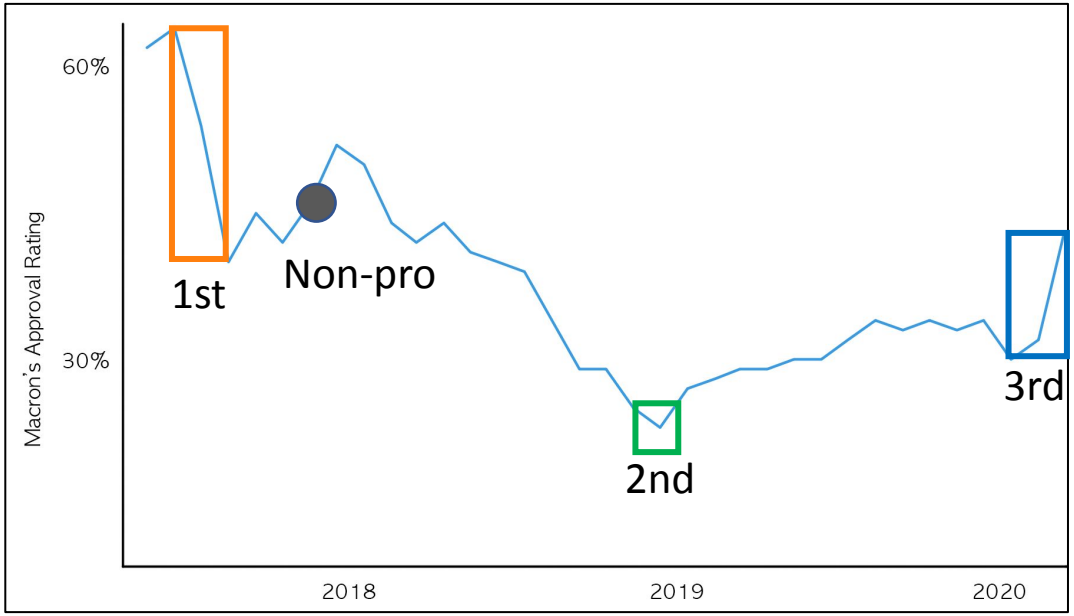
User Study

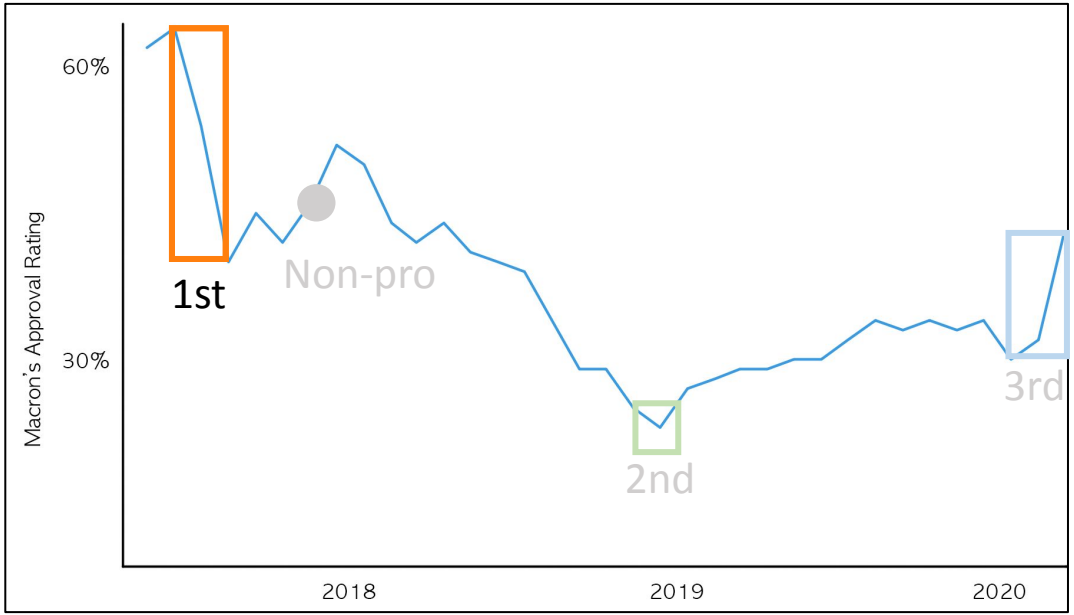


Charts

Identify Visually Prominent Features → Generate Captions → Collect Takeaways for Charts & Captions


60%
30%
Macron's Approval Rating
2018
2019
2020


60%
30%
Macron's Approval Rating
1st
Non-pro
2nd
3rd
2018
2019
2020



[DOMAIN] [FEATURE] between [START DATE] and [END DATE].

↓

Macron's approval rating steeply dropped between June and August of 2017.

Results

Chart Emphasis

≠

Caption Emphasis

↓

Takeaway:
Chart Emphasis

The 30-year fixed mortgage rate increased slightly from 1997 to 1999.

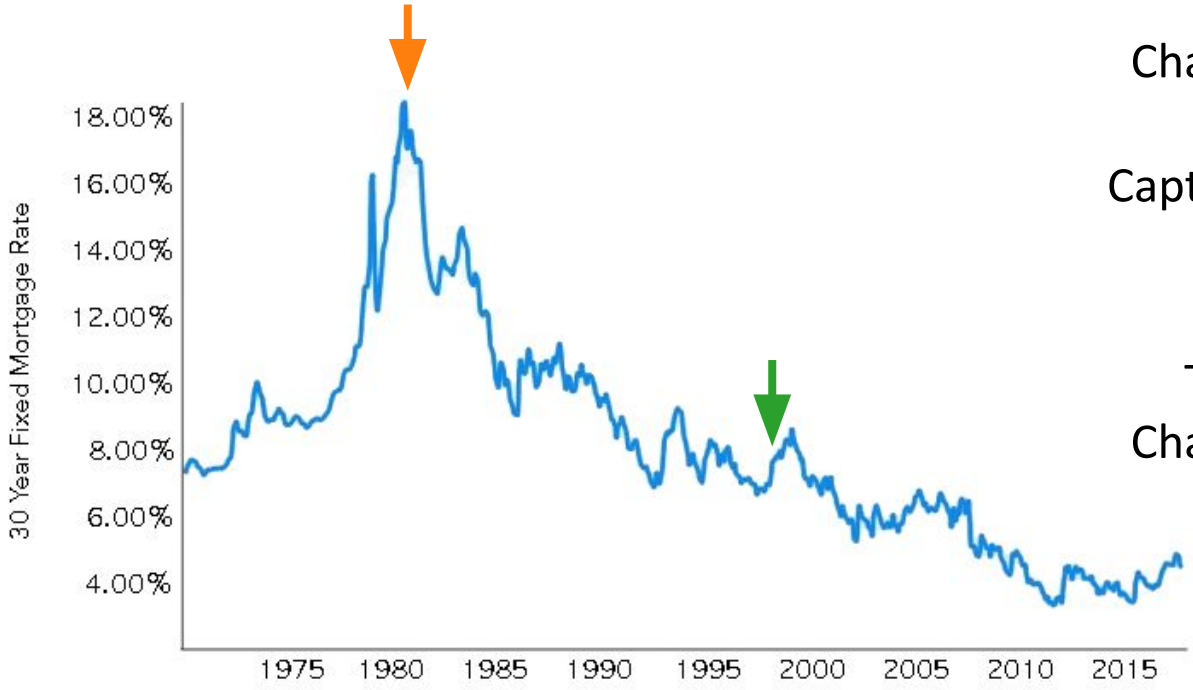


Chart Emphasis

≠

Caption Emphasis

↓

Takeaway:
Chart Emphasis

The 30-year fixed mortgage rate increased slightly from 1997 to 1999.

Chart Emphasis

=

Caption Emphasis

↓

Takeaway:
Chart Emphasis

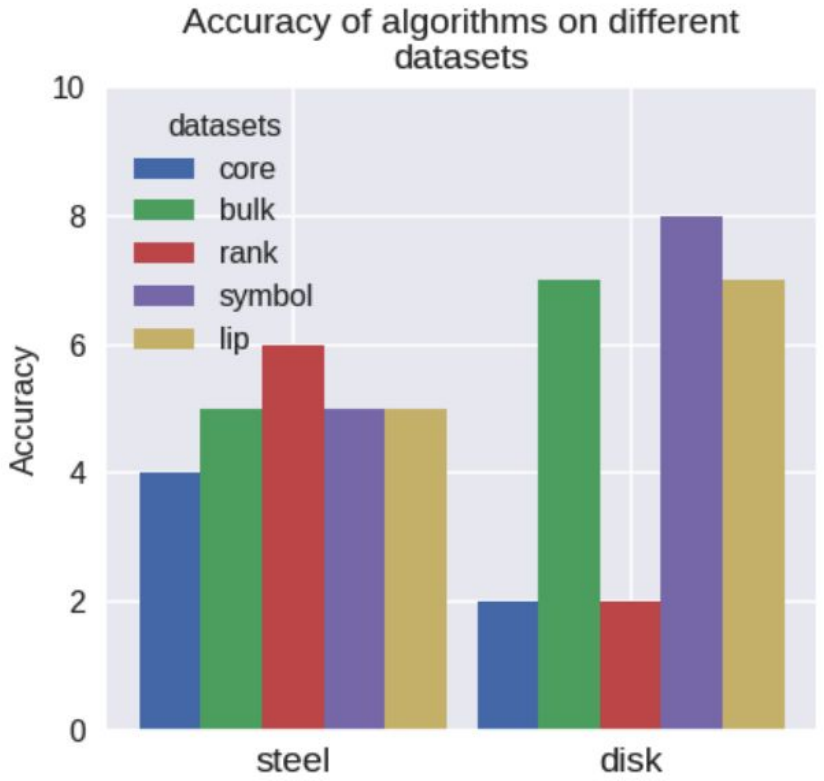
The 30-year fixed mortgage rate reached its peak of 18.5% in 1981.

*When text and visualization emphasis **mismatch**,*
*readers rely **more on the chart** and*
*can **miss information in the caption**.*

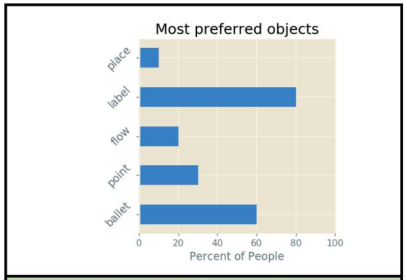
Chart Question Answering with Explanations

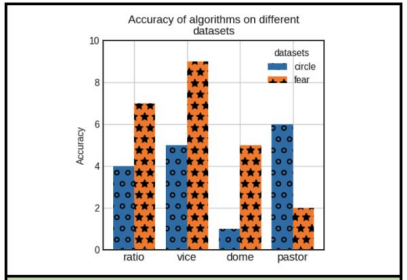
[Kim et al. 2021]

[Kafle et al. 2018]



[Kafle et al. 2018]

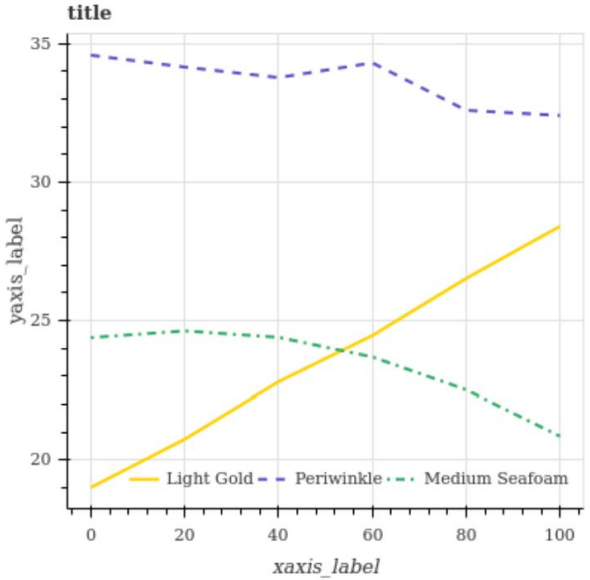




Structure Understanding	Structure Understanding
How many bars are there? Are the bars horizontal?	How many groups of bars are there? Are the bars stacked?
Data Retrieval	**Data Retrieval**
What percent of people prefer the object ballet? What is the label of the third bar from the bottom?	What is the accuracy of the algorithm vice on the dataset fear? Does the chart use logarithmic scale?
Reasoning	**Reasoning**
Is the object flow preferred by more people than the object point? What percent of people prefer the object point or ballet?	Which algorithm has the lowest accuracy across all datasets? How many algorithms have accuracy greater than 5 in at least one dataset?

DVQA

[Kafle et al. 2018]



Q: Does Medium Seafoam intersect Light Gold?
A: Yes

Q: Is Medium Seafoam the roughest?
A: No

Q: Is Light Gold less than Periwinkle?
A: Yes

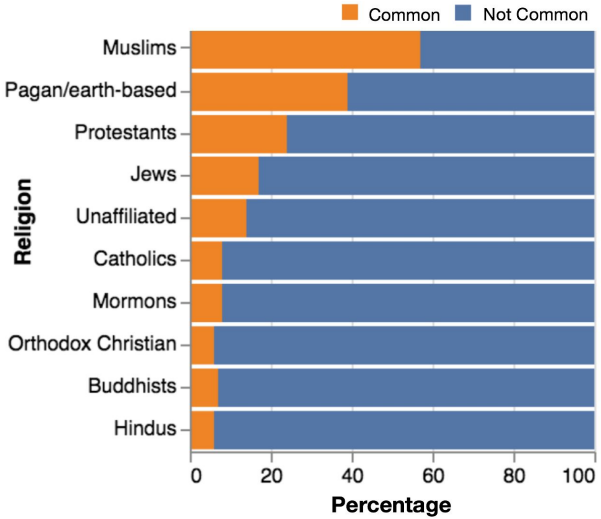
Q: Does Periwinkle have the maximum area under the curve?
A: Yes

Q: Does Medium Seafoam have the lowest value?
A: No

FigureQA

[Kahou et al. 2018]

Chart



Question

For which religion did the fewest chaplains think that religious extremism is common?

Chart

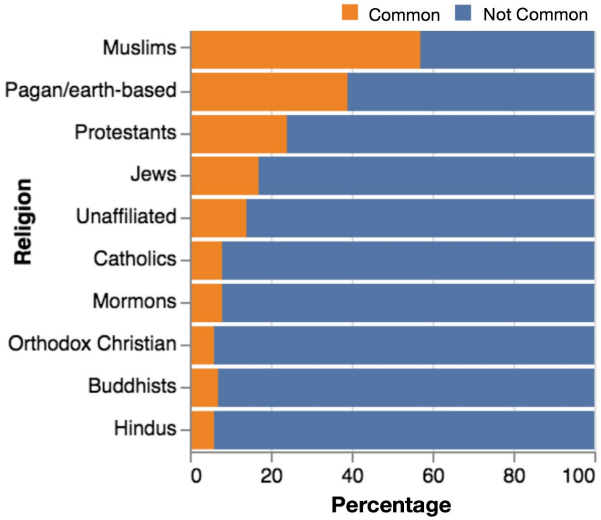


Chart QA

Answer

Orthodox Christians, Hindus.

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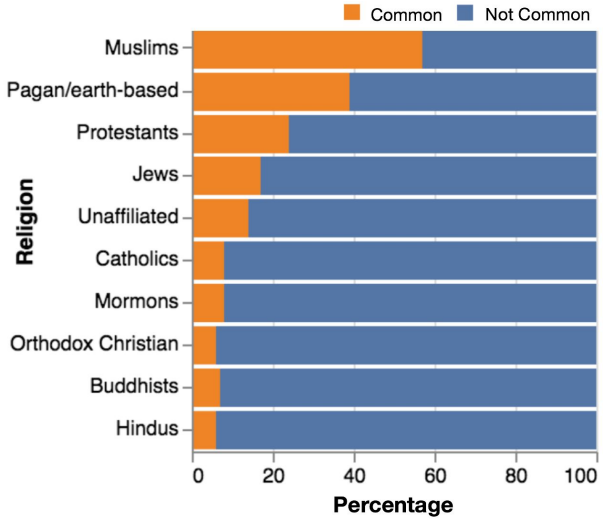

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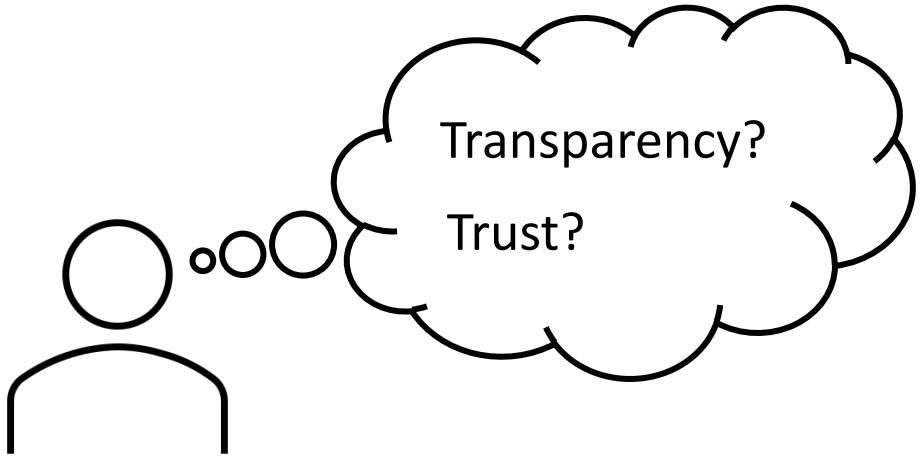

Chart

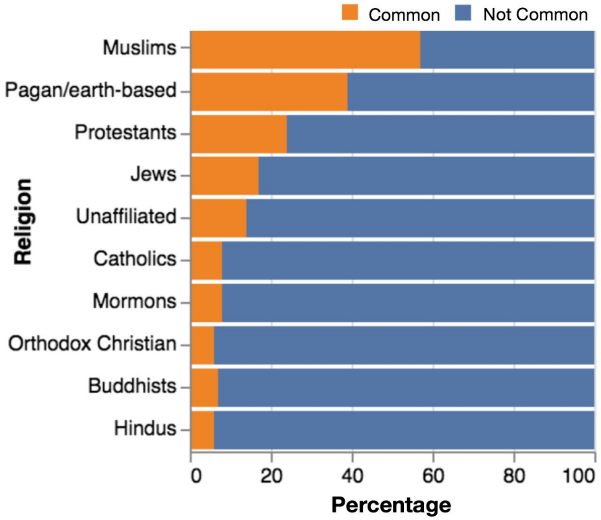

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Chart QA

Answer

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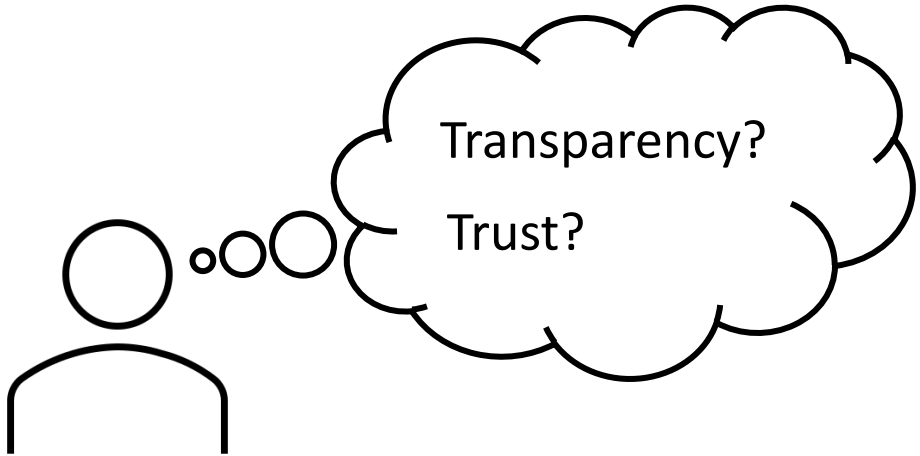
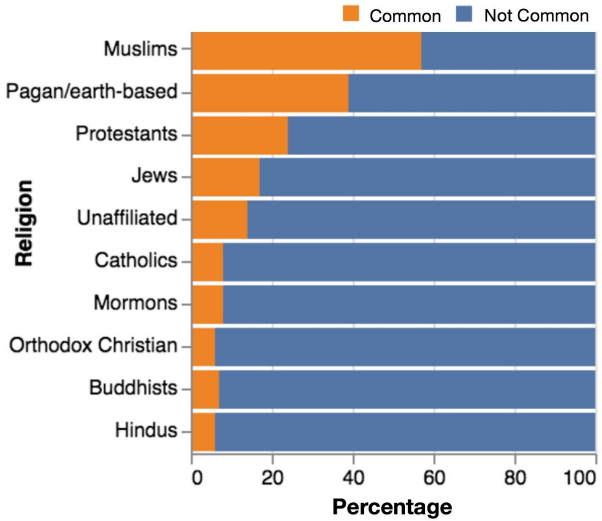
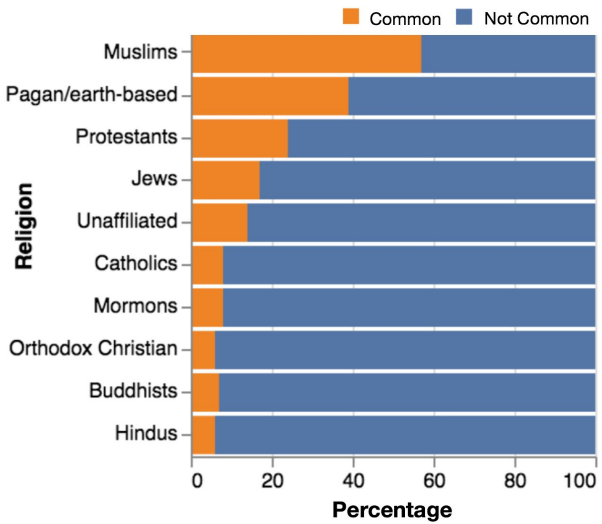
Explanation

I looked up 'Religion' for the shortest orange bars.



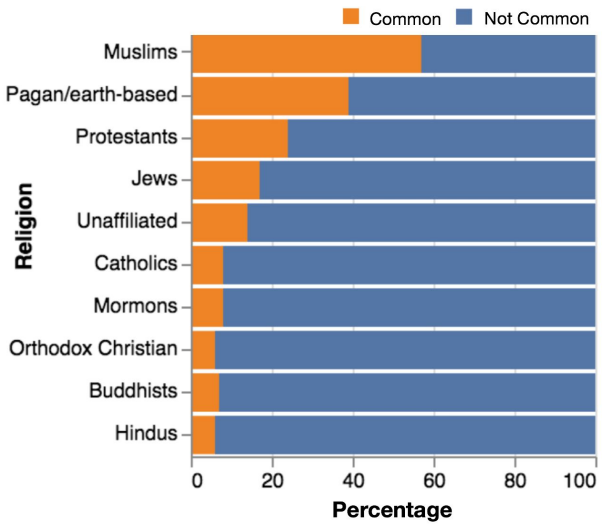
Formative Study


Common
Not Common
Muslims
Pagan/earth-based
Protestants
Jews
Unaffiliated
Catholics
Mormons
Orthodox Christian
Buddhists
Hindus
Religion
0
20
40
60
80
100
Percentage



Question

Which religion has the greatest value for Common?



Question

Which religion has the greatest value for Common?

Answer

Muslims

Explanation

I picked religions with the greatest orange percentage.

Formative Study Results

- Explanations describe procedure for computing answer

- Explanations describe procedure for computing answer
- Half of the explanations referred to visual features of chart

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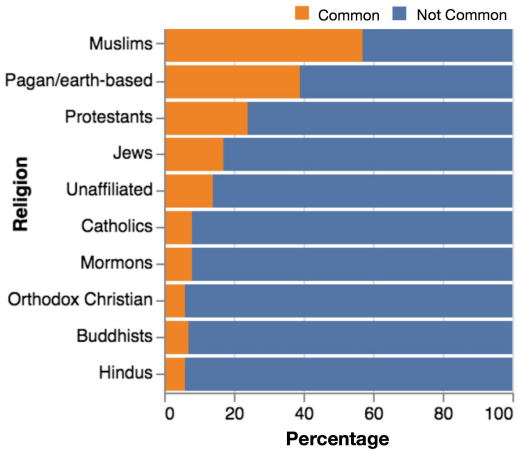
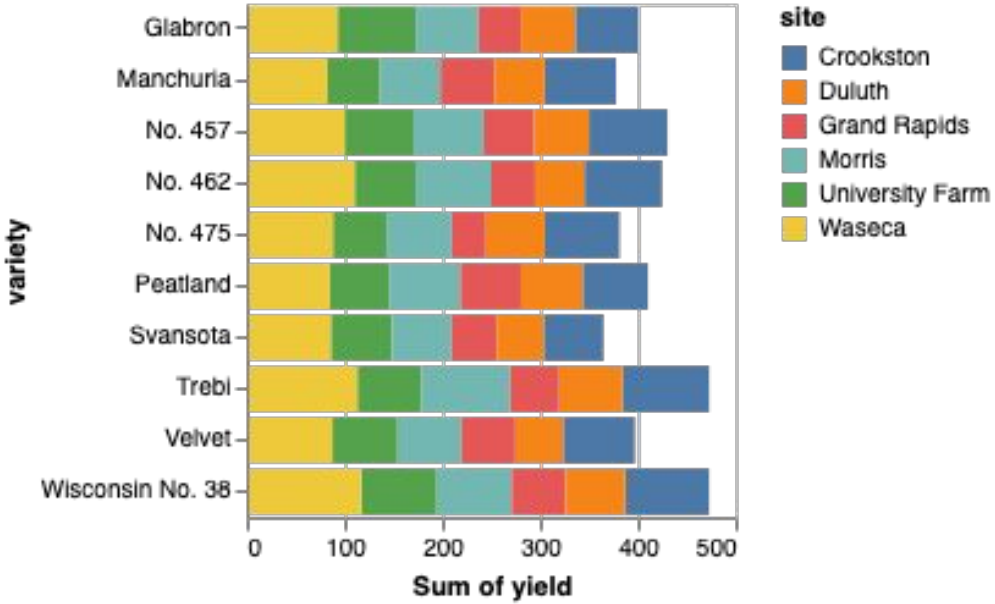
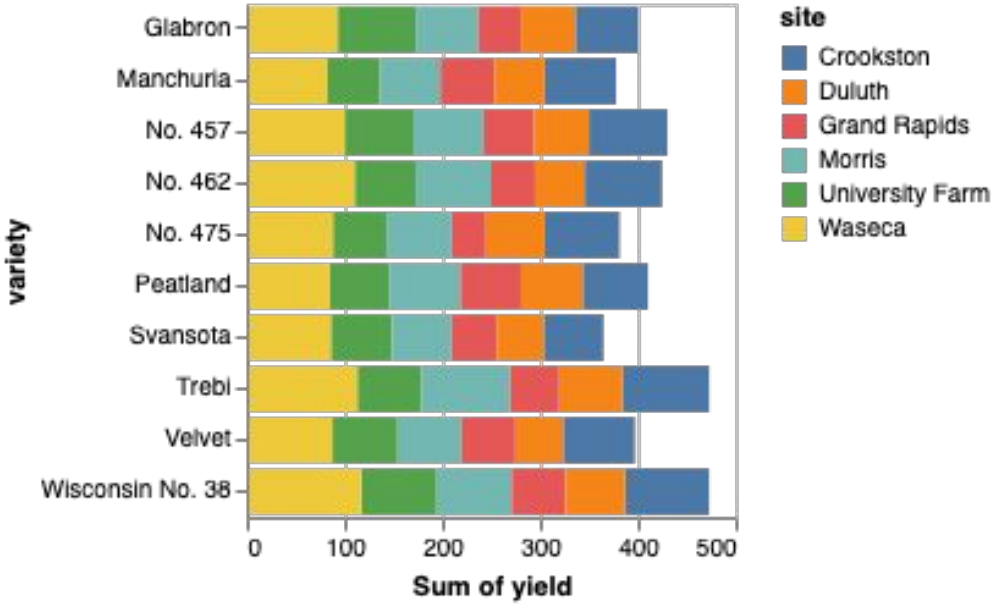
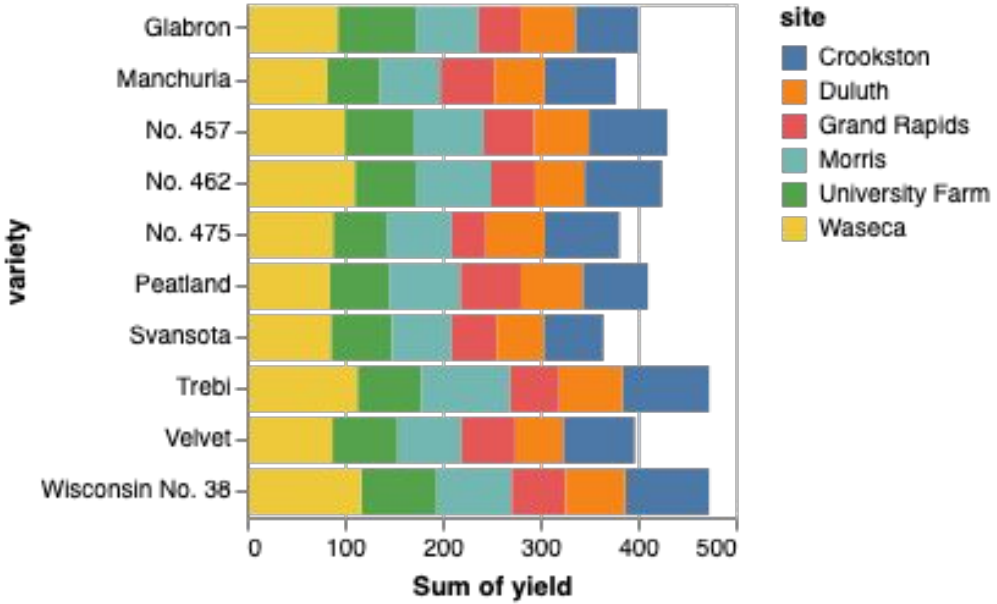


*"I picked religions with the greatest **orange** percentage."*


variety
Glabron
Manchuria
No. 457
No. 462
No. 475
Peatland
Svansota
Trebi
Velvet
Wisconsin No. 38
0
100
200
300
400
500
Sum of yield
site
Crookston
Duluth
Grand Rapids
Morris
University Farm
Waseca



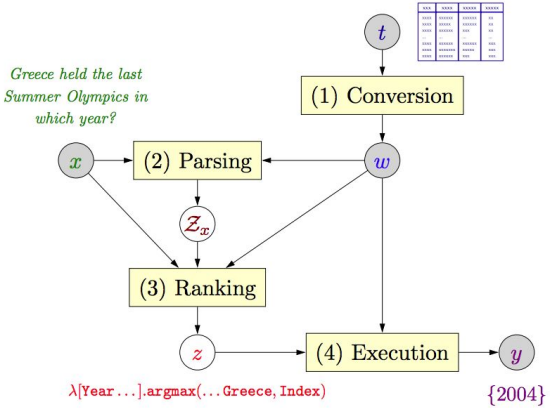
Glabron at University Farm



Glabron at University Farm

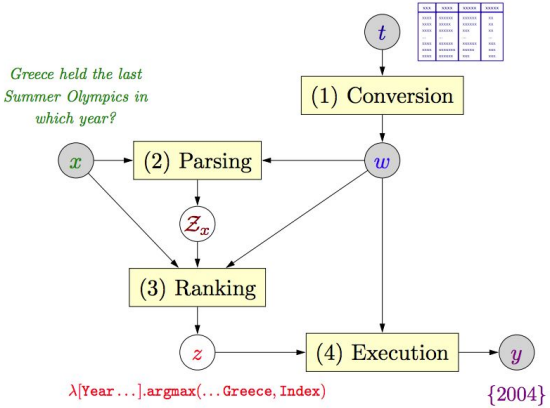
Green component in the top bar

Chart QA Pipeline and Generating Explanations



Compositional Semantic Parsing on Semi-Structured Tables

Pasupat and Liang (2015)



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Sempre

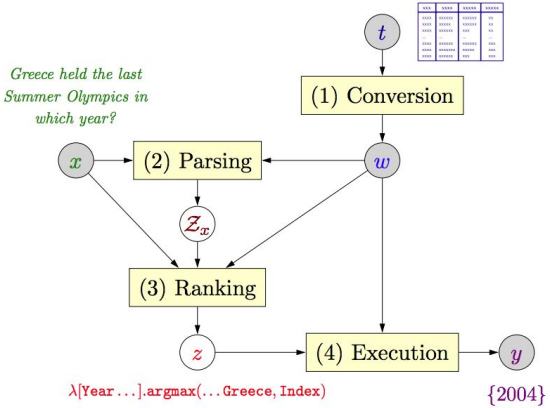

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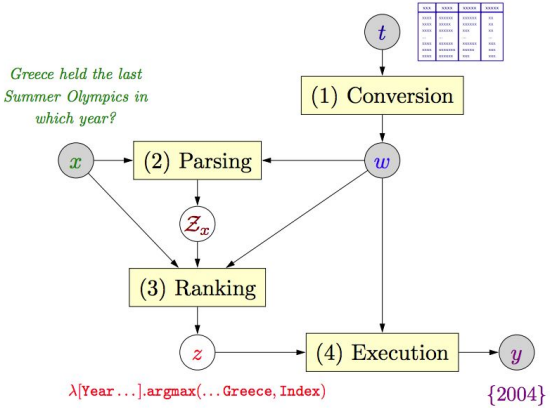
Table

Year	City	Country	Nations
1896	Athens	Greece	14
1900	Paris	France	24
1904	St. Louis	USA	12
. . .	. . .	. . .	. . .
2004	Athens	Greece	201
2008	Beijing	China	204
2012	London	UK	204

Sempre



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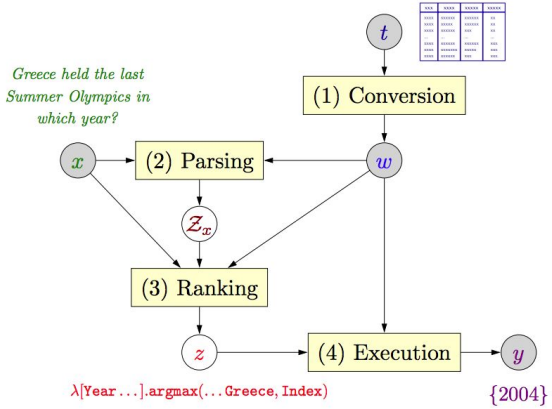
Question

Greece held its last Summer Olympics in which year?

→ **Sempre**



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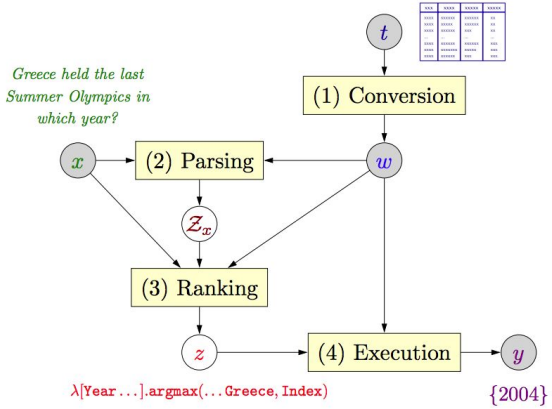

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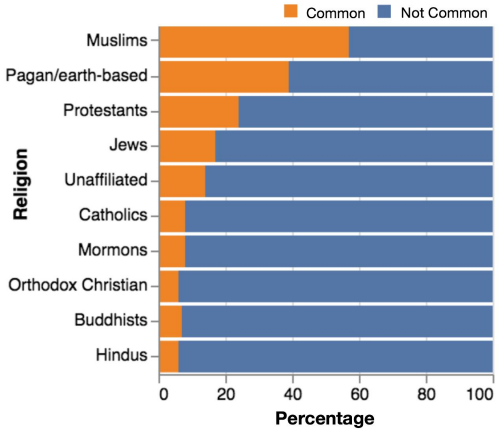
2004

Lambda Expression

R[λx[Year.Date.x]] .argmax(Country.Greece, Index)

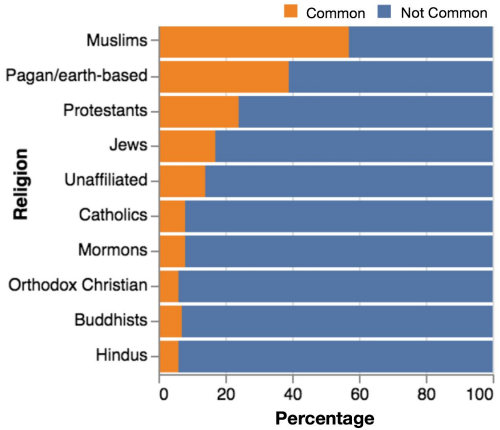
Chart



Question about Chart

Which religion has the shortest orange component?

Chart



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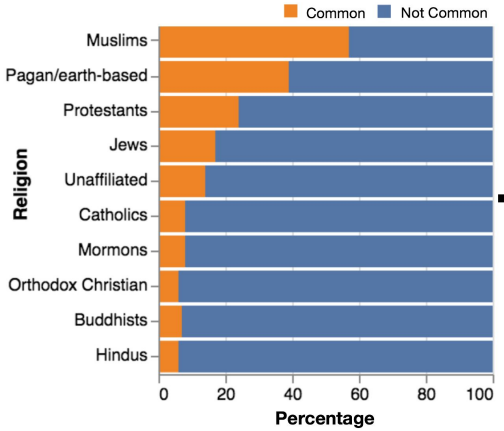

Data Table

Religion	Common	Not common
Muslims	57	43
Pagan/earth-based	39	61
Protestants	24	76
Jews	17	83
⋮	⋮	⋮
Buddhists	7	93
Hindus	6	94

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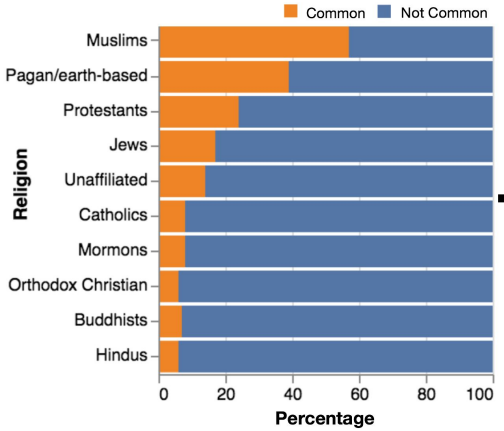

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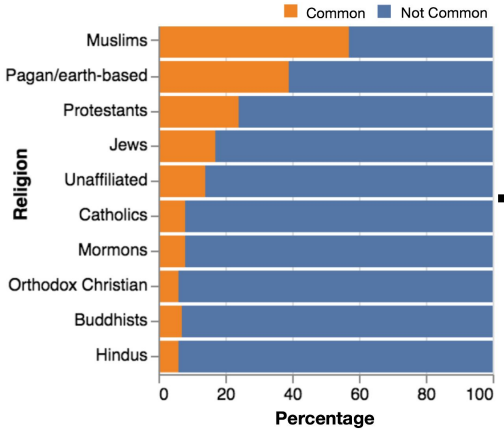
Chart



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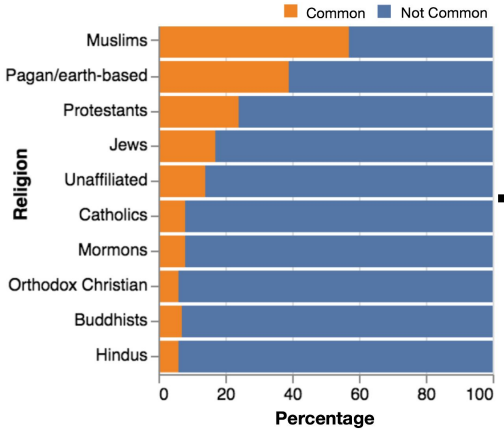

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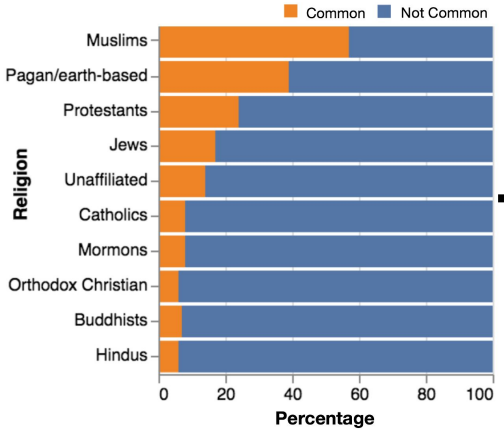

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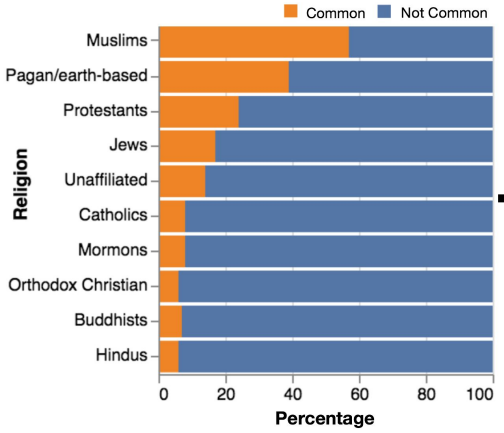
Lambda Expression

argmin[R[Religion].Row, R[λx(R[Number].R[Common].Religion.x)]]

Chart



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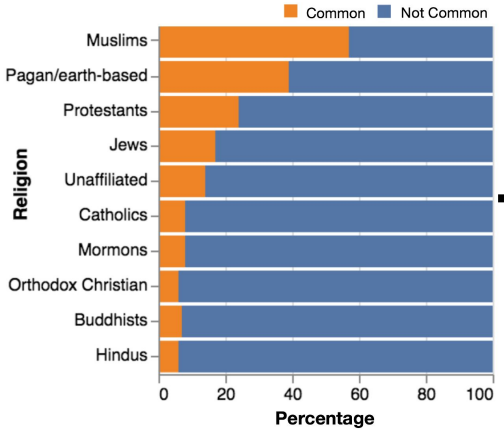
Non-Visual Explanation

I looked up 'Religion' with the least 'Percentage' of 'Common'.

Chart



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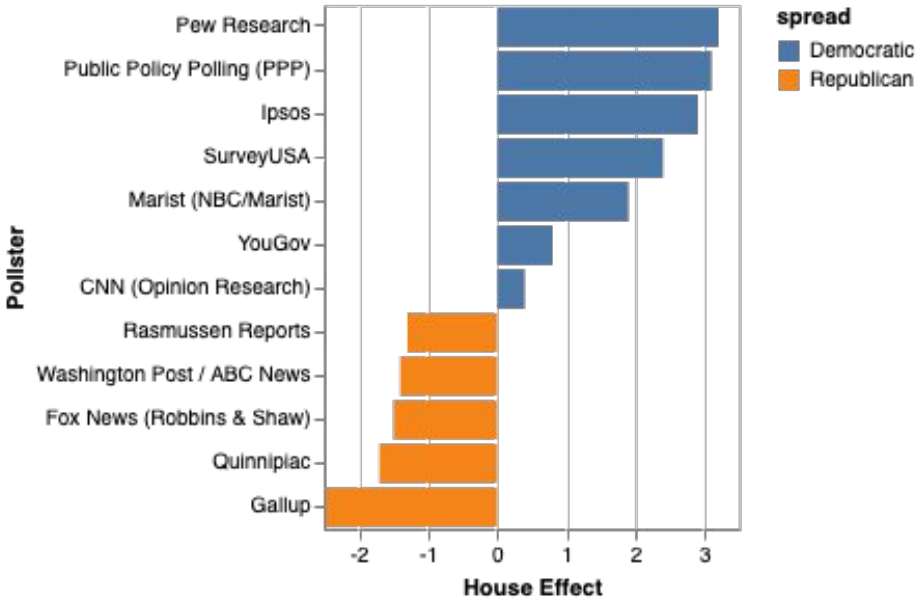
Visual Explanation

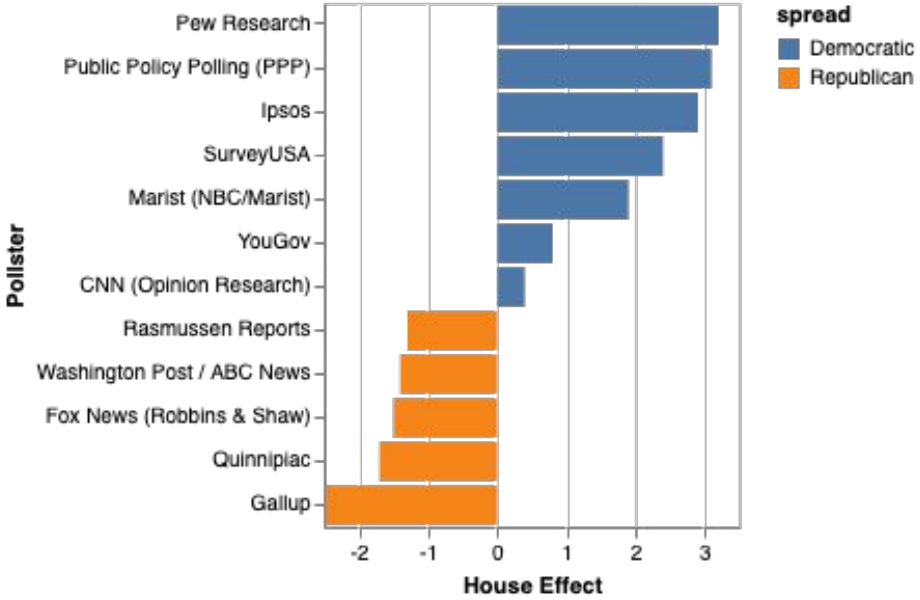
I looked up 'Religion' for the shortest orange bar.

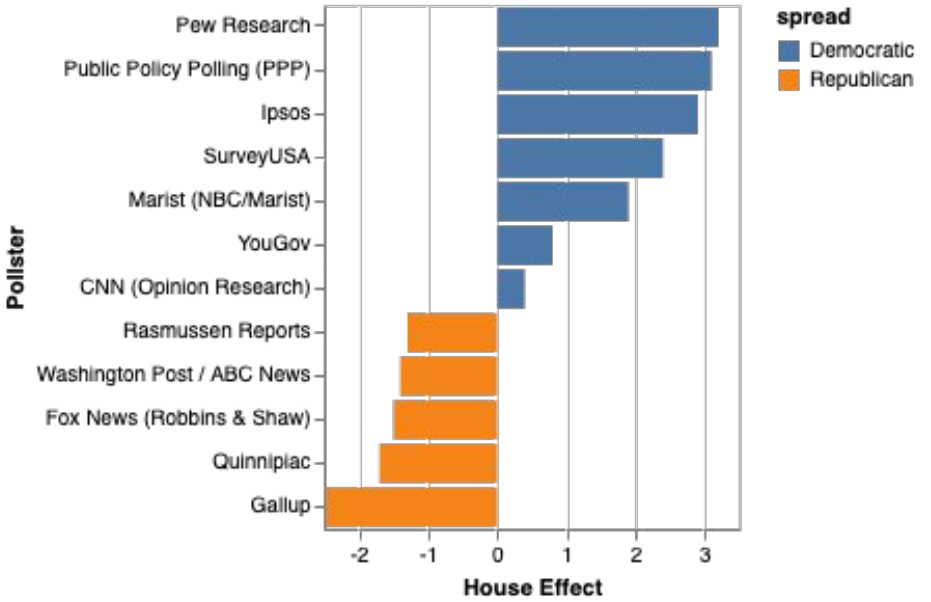
Example Explanations


Pew Research
Public Policy Polling (PPP)
Ipsos
SurveyUSA
Marist (NBC/Marist)
YouGov
CNN (Opinion Research)
Rasmussen Reports
Washington Post / ABC News
Fox News (Robbins & Shaw)
Quinnipiac
Gallup
Pollster
-2
-1
0
1
2
3
House Effect
spread
Democratic
Republican

Question

What is the difference between the value of Gallup and Quinnipiac?



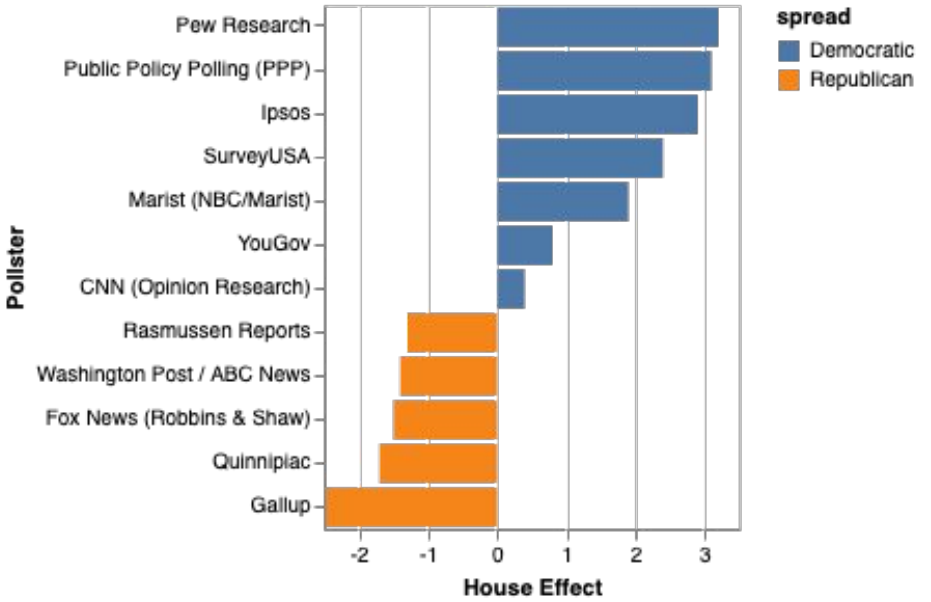


Question

What is the difference between the value of Gallup and Quinnipiac?

Answer

0.8



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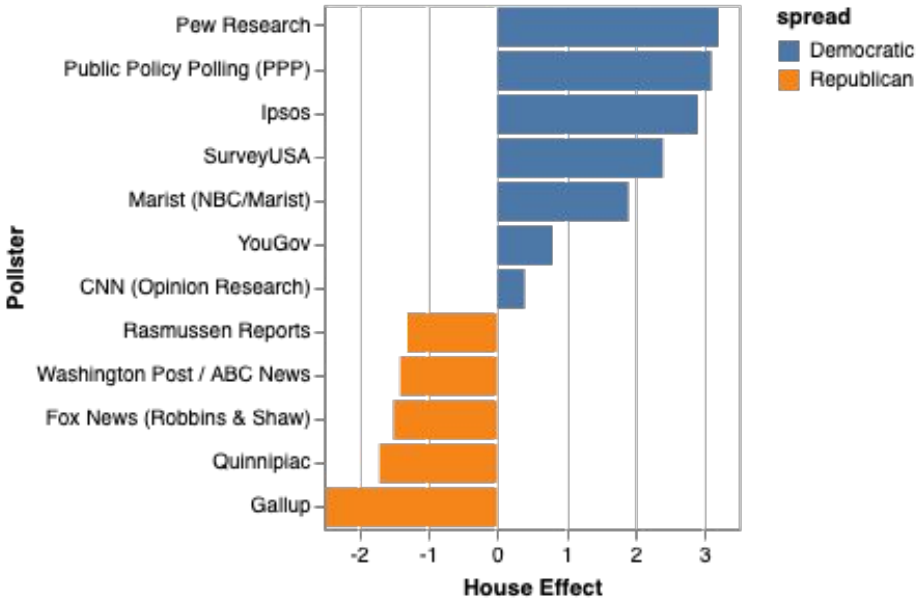

Question

What is the difference between the value of Gallup and Quinnipiac?

Answer

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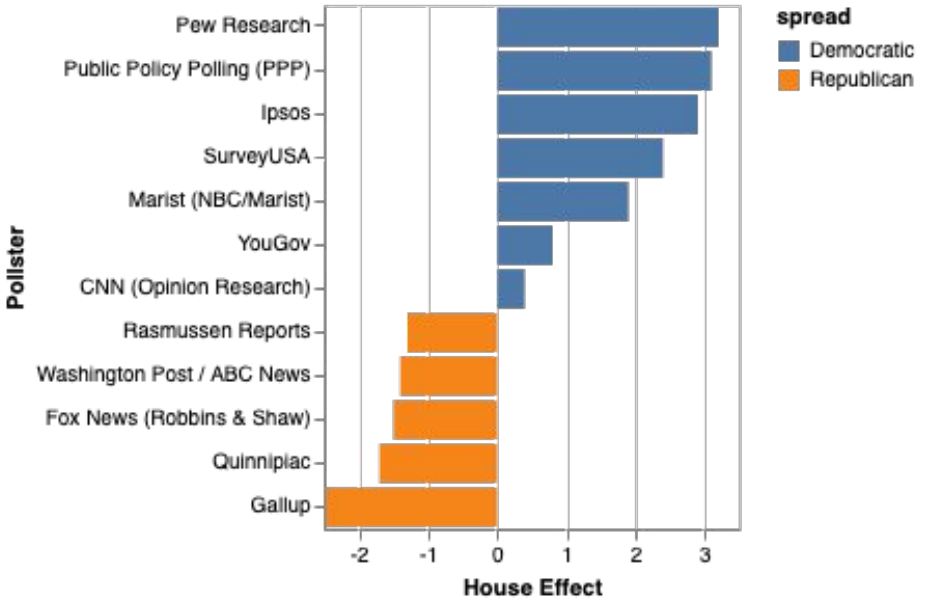
Explanation

I computed the difference between the length of the bar for 'Gallup' and 'Quinnipiac'.



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0.8

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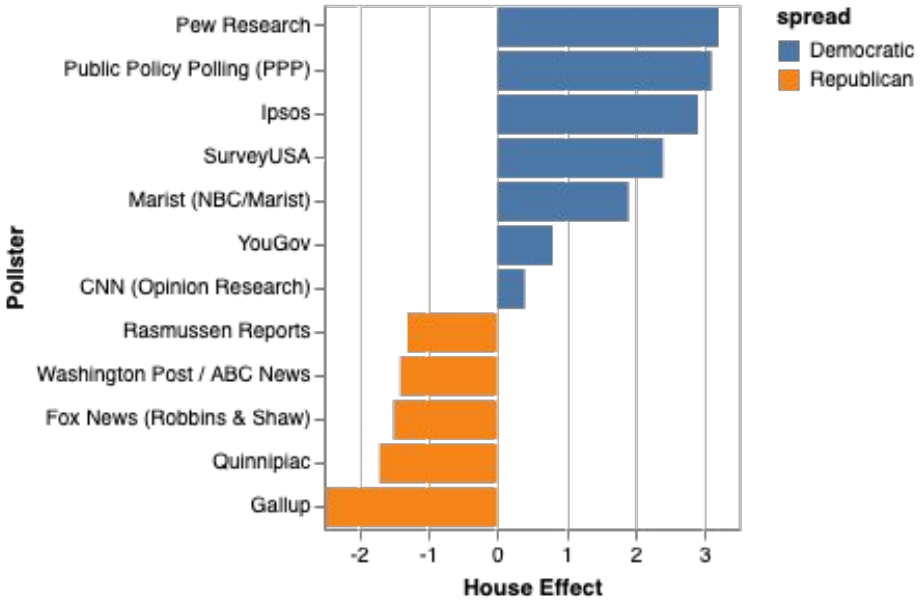
Question

What position is Ipsos in?



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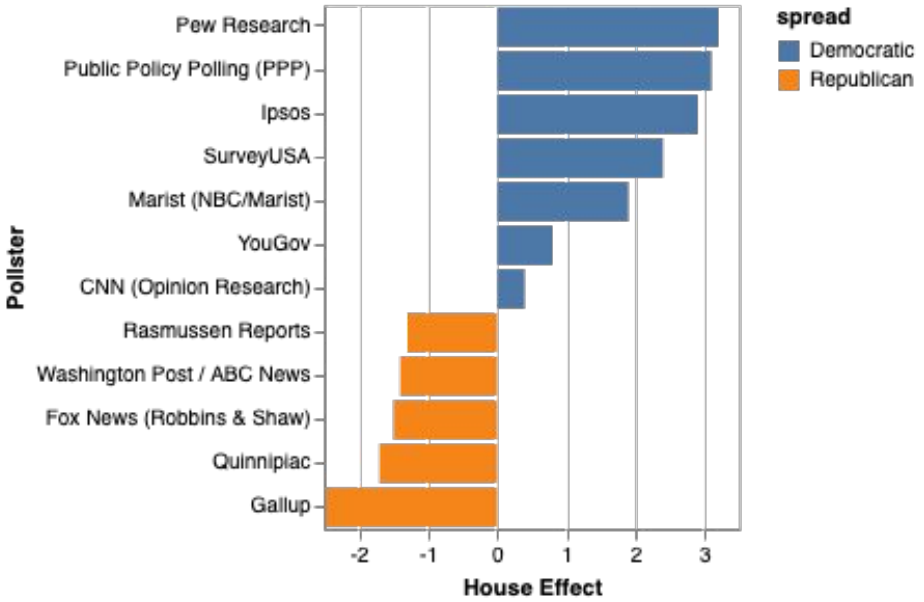
Question

What position is Ipsos in?

Answer

2.9



Question

What is the difference between the value of Gallup and Quinnipiac?

Answer

0.8 ✓

Explanation

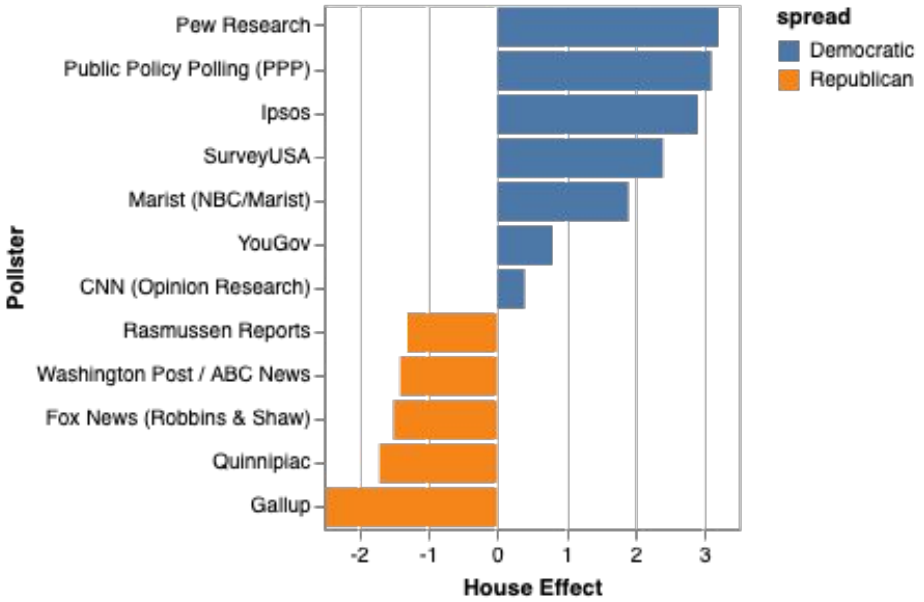
I computed the difference between the length of the bar for 'Gallup' and 'Quinnipiac'.

Question

What position is Ipsos in?

Answer

2.9 ✗



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Question

What position is Ipsos in?

Answer

2.9 ✗

Explanation

I looked up the length of the bar for 'Ipsos'.

User Study

Hypothesis: Visual explanations increase transparency and trust

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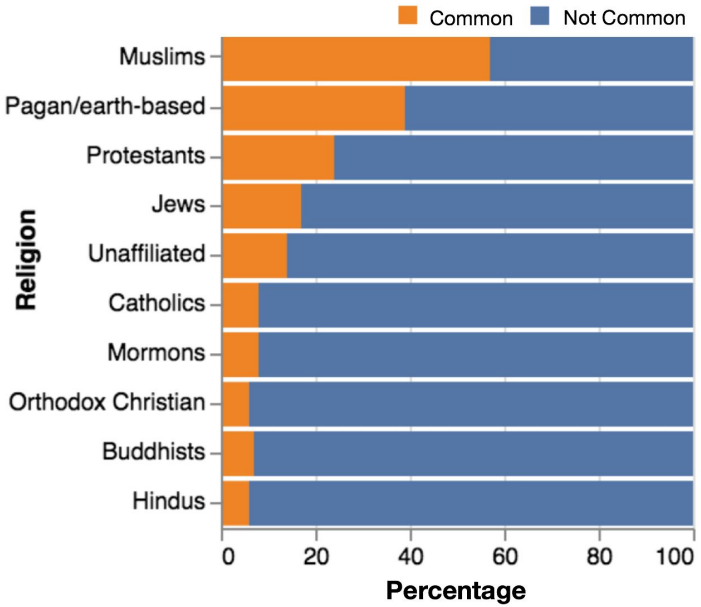
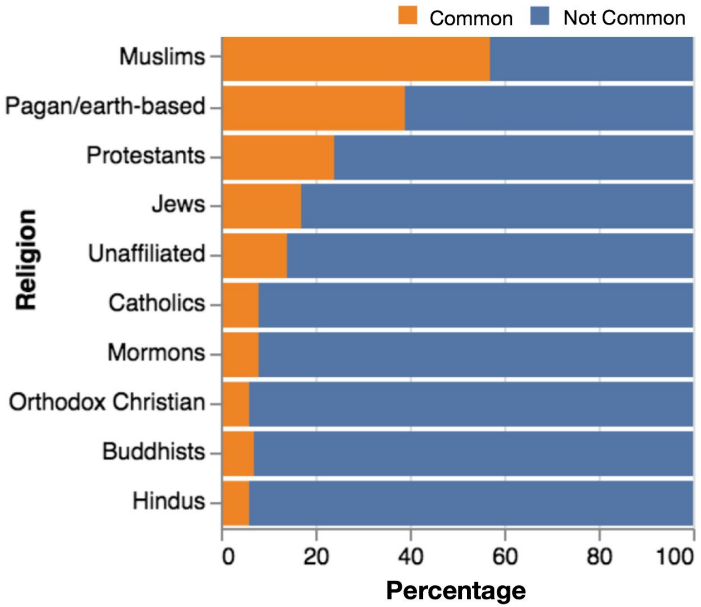


Q: *For which religion did the fewest chaplains think that religious extremism is common?*

Hypothesis: Visual explanations increase transparency and trust



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A1 (vis): *Orthodox Christians, Hindus. I looked up 'Religion' for the shortest orange bar.*

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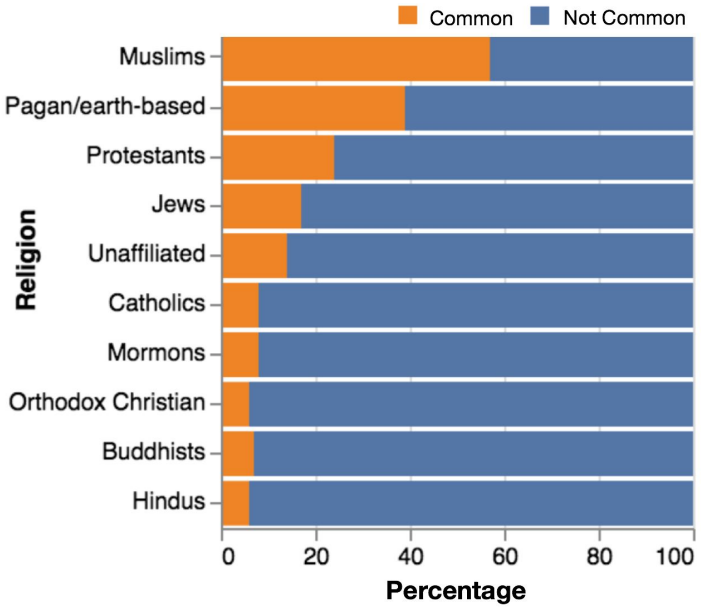

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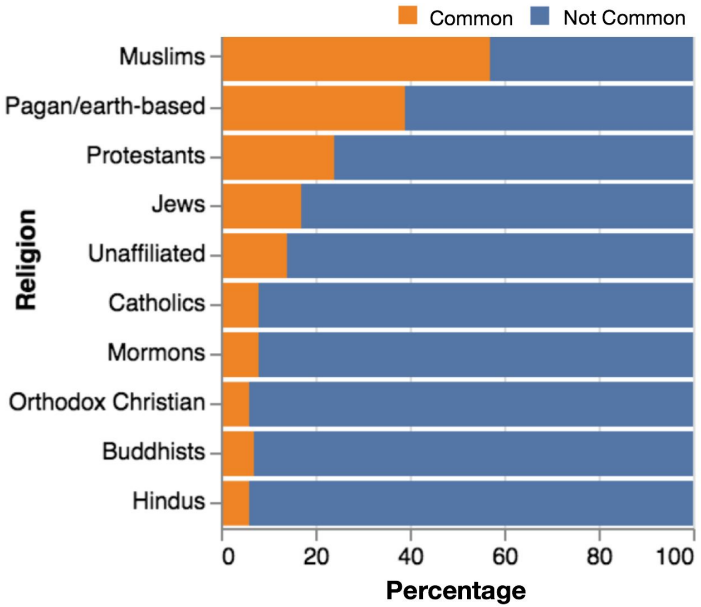

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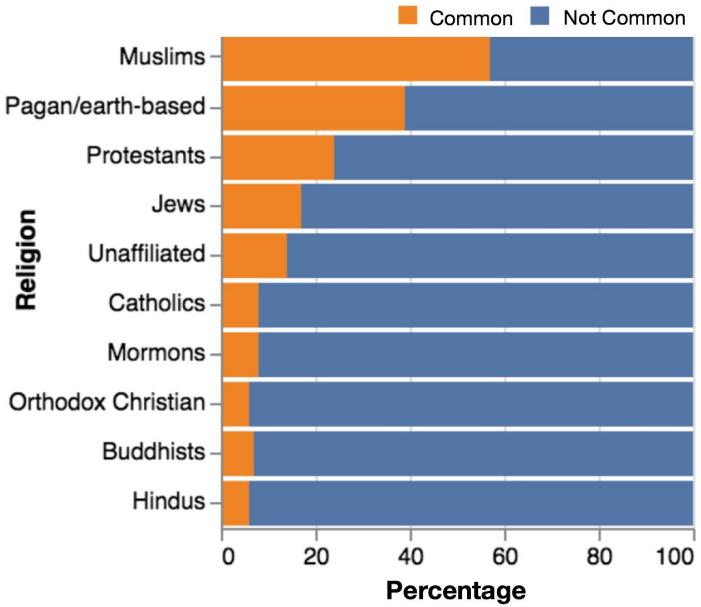

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A4 (human): *Orthodox Christians, Hindus. They have lowest values for 'Common'.*

- 16 participants

- 16 participants
- 20 Chart-Question-Answer-Explanation tuples (5 per explanation type)

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Determine Answer Correctness

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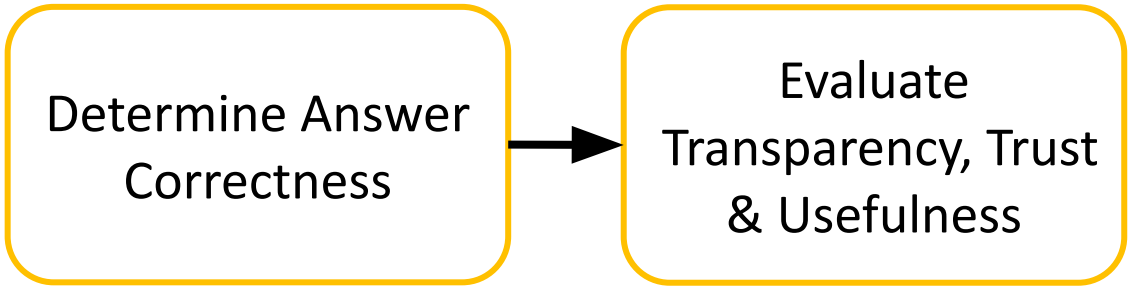

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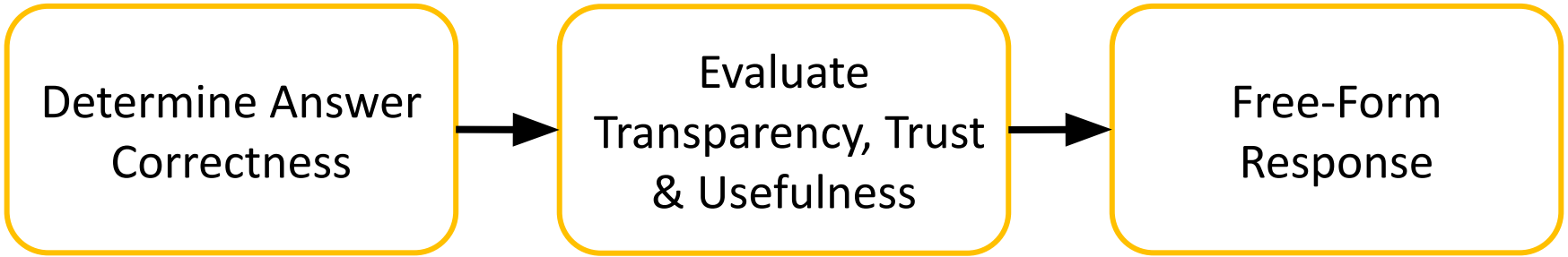
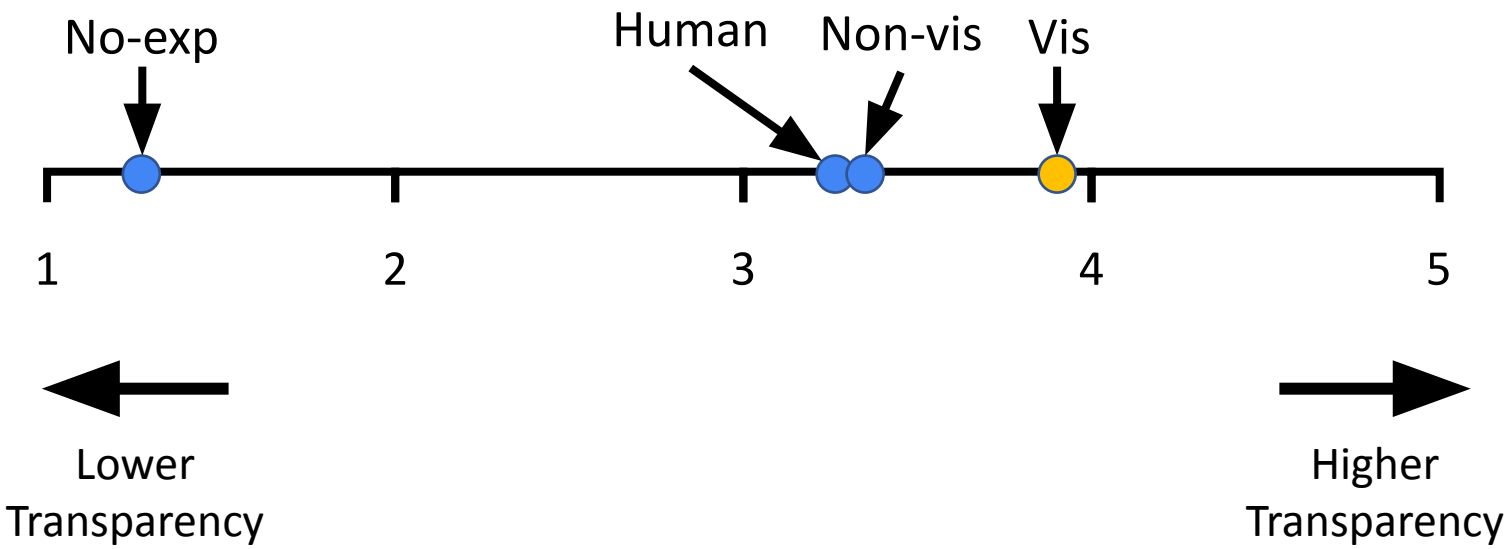


Study Results

Transparency

- Presence of explanations



Transparency

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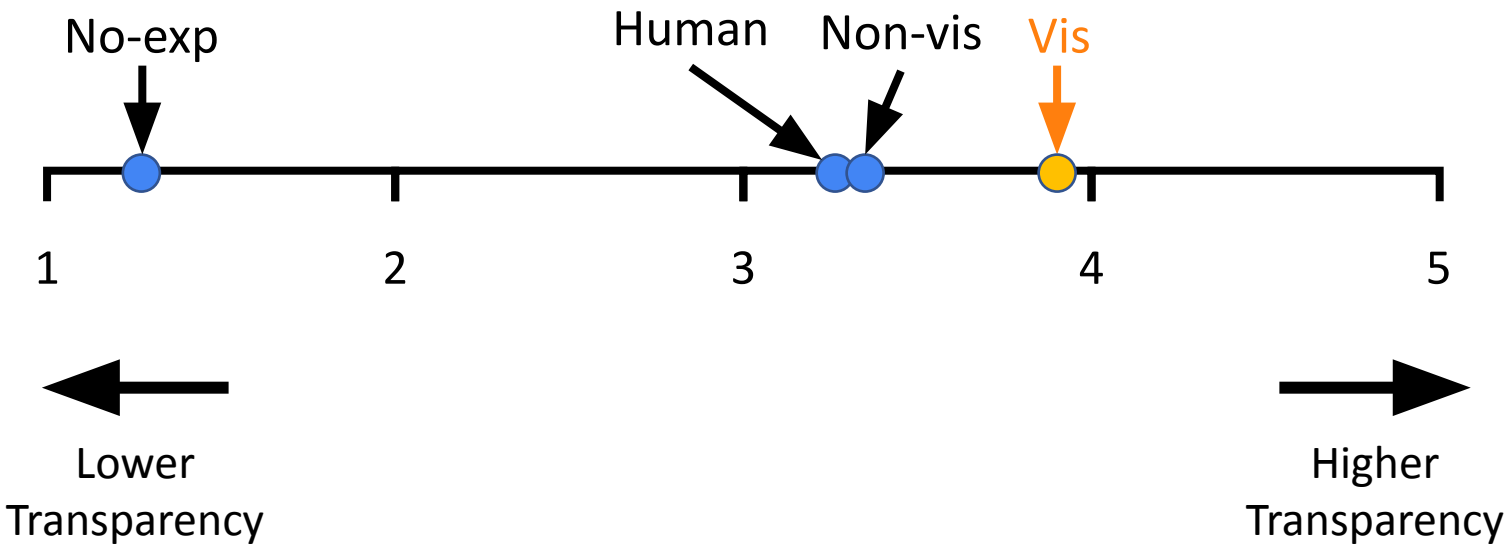

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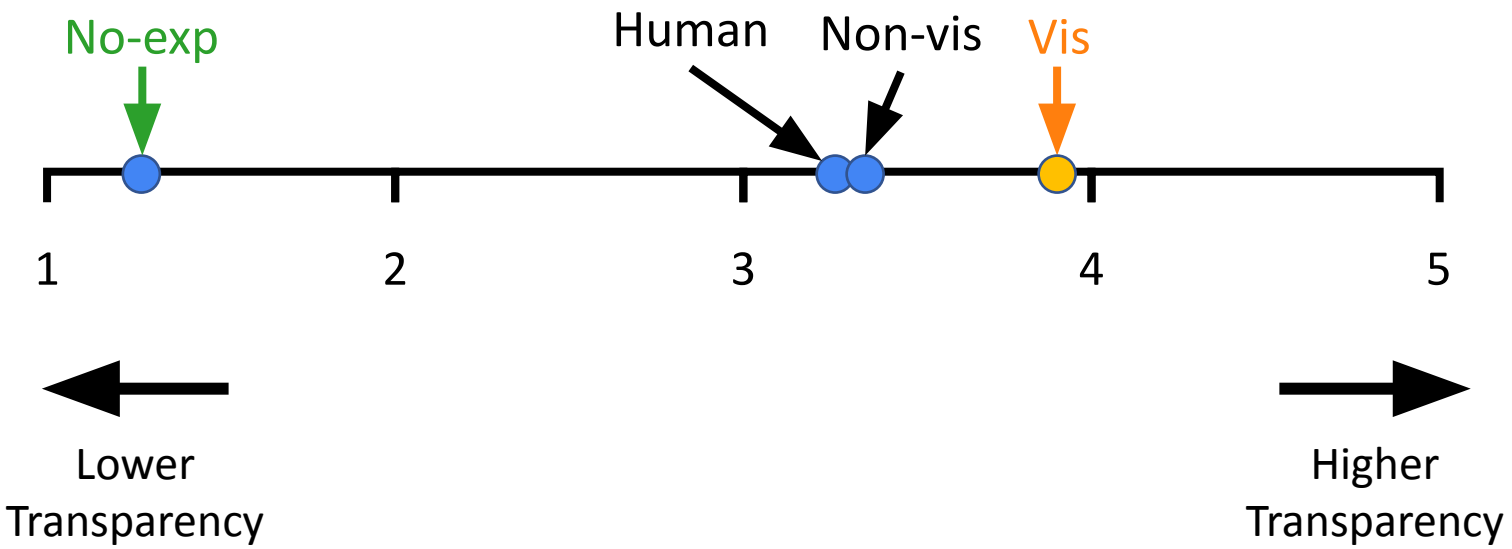

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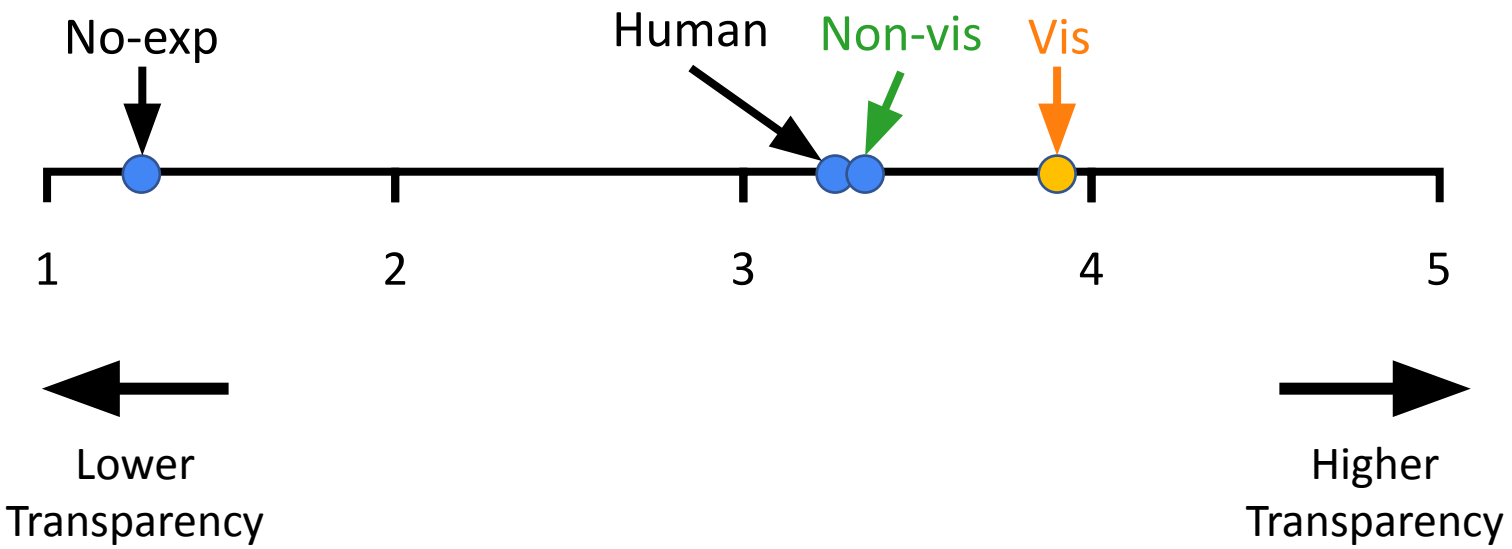

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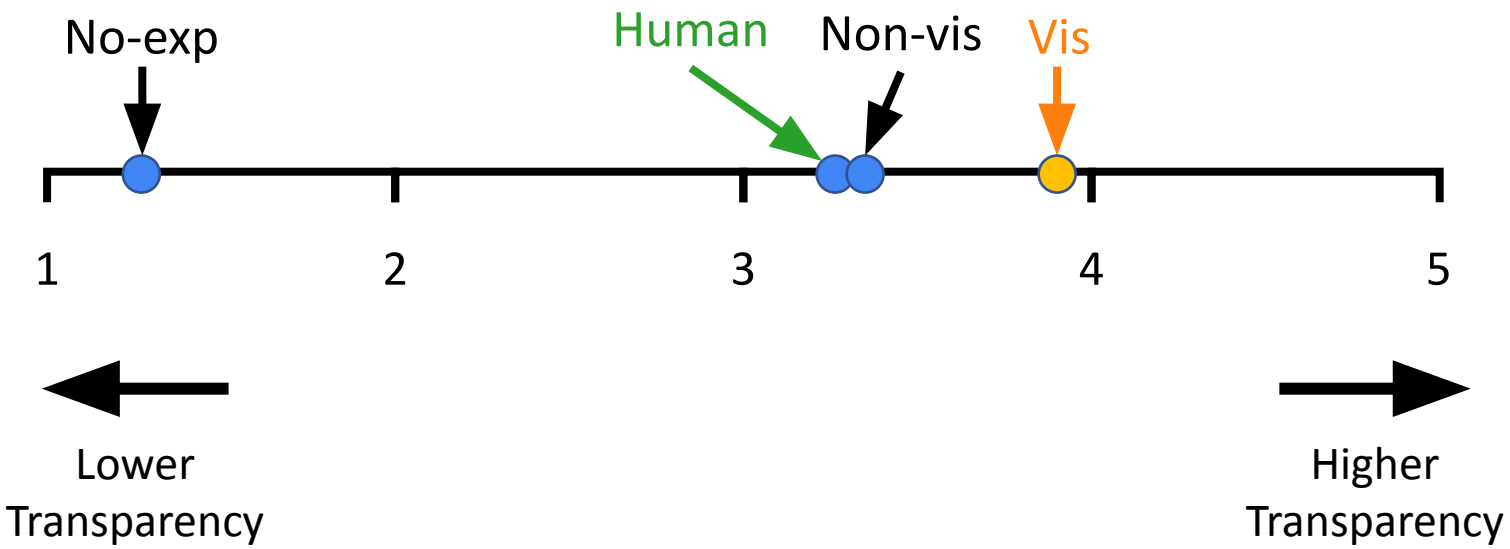
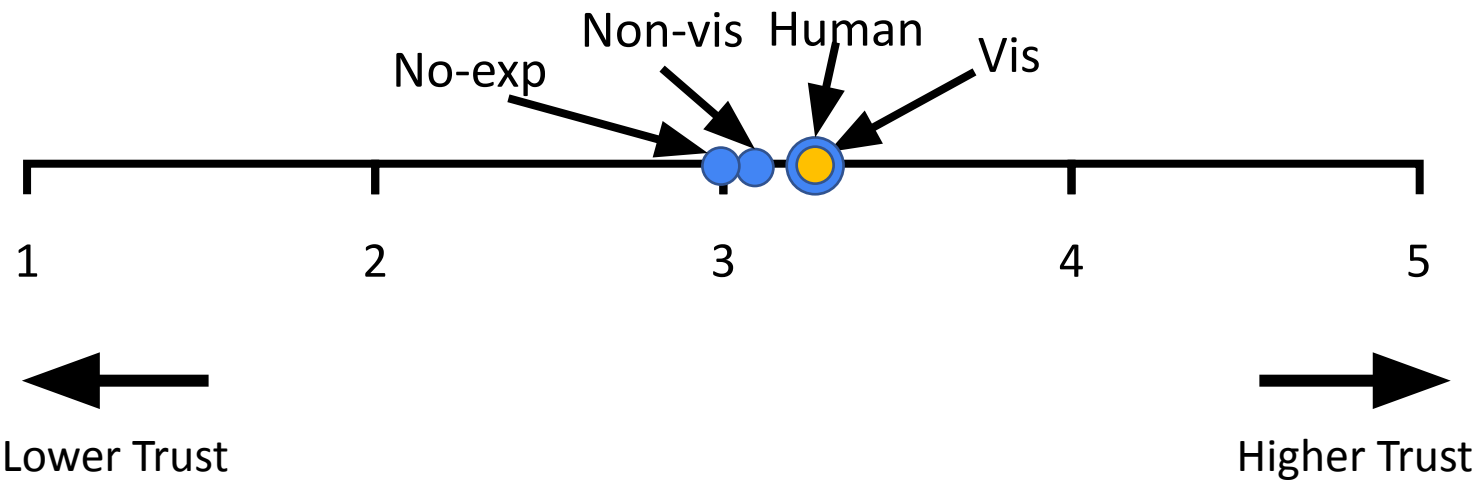


Trust

- Accuracy of answers
- Explanation-answer match



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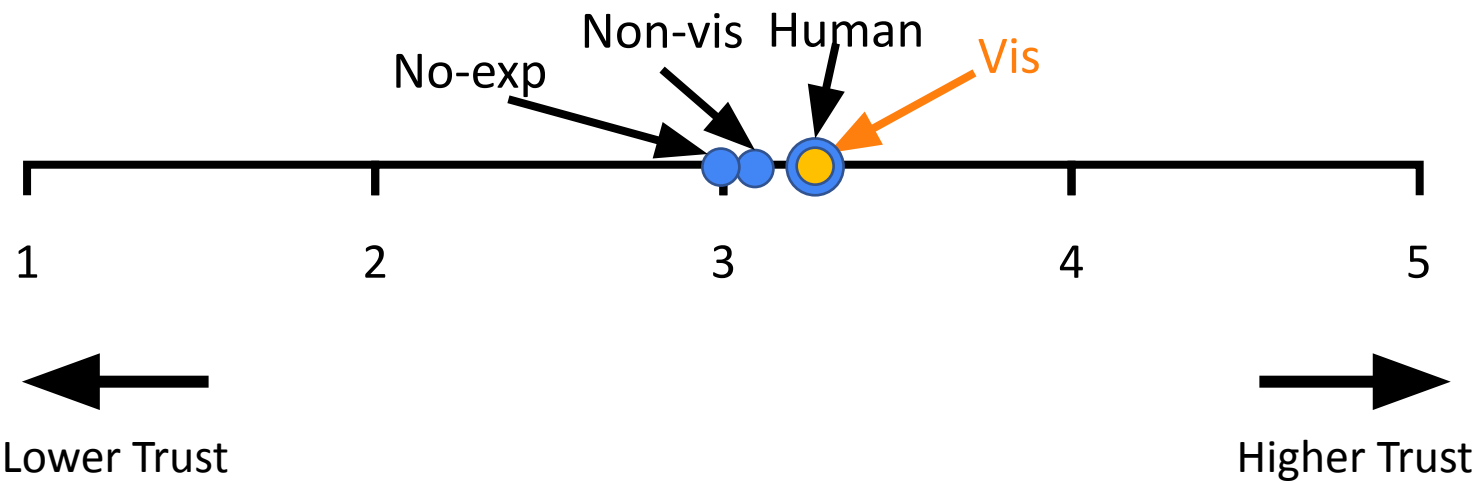

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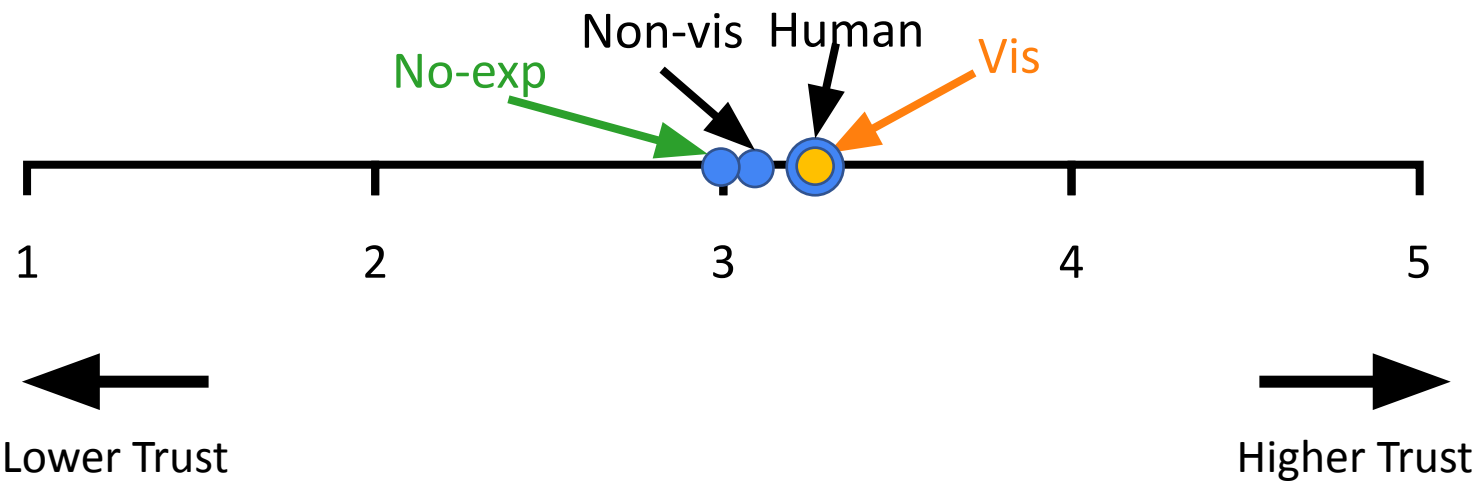

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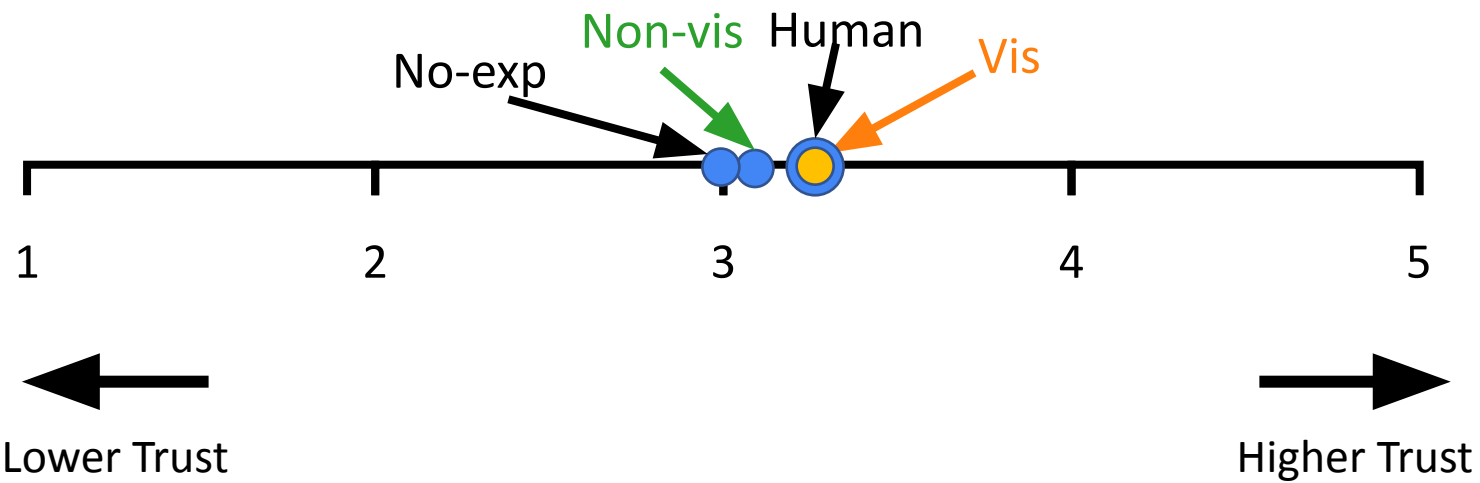

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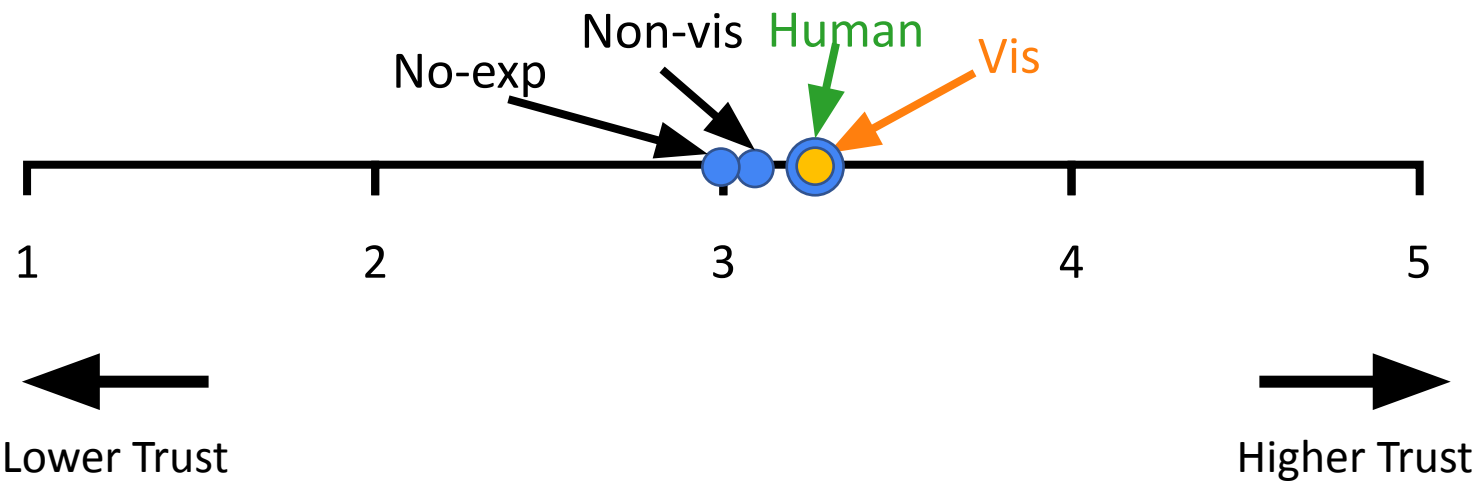


Eviza: A Natural Language Interface for Visual Analysis

[Setlur et al. 2016]

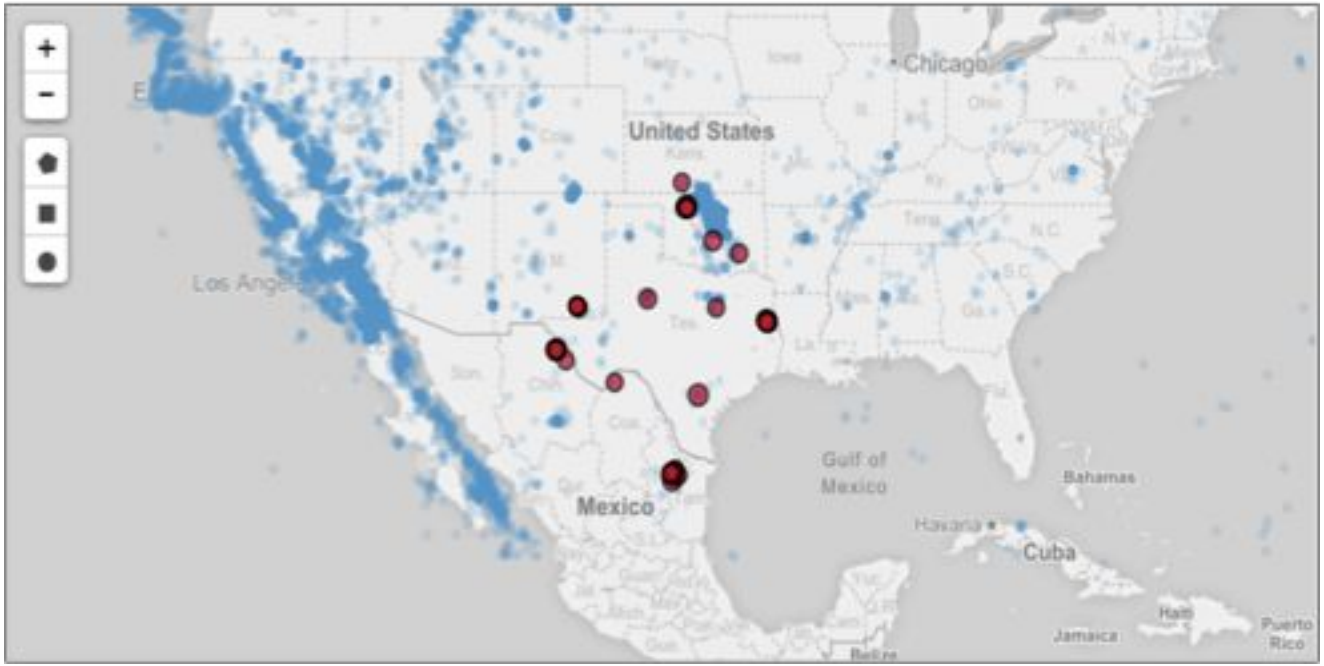
Supporting an analytical conversation

"Find large earthquakes near California"

Eviza

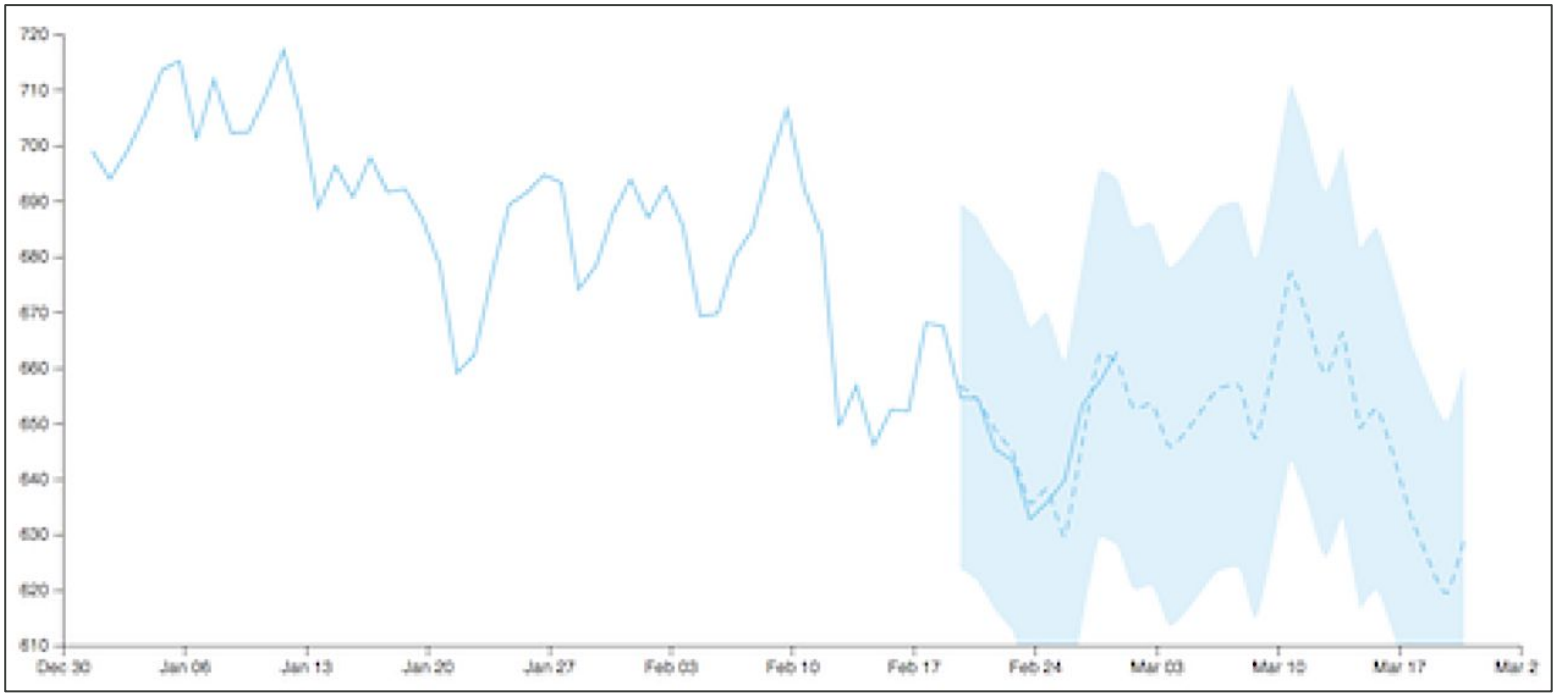
"Find large earthquakes near California"

"How about near Texas"



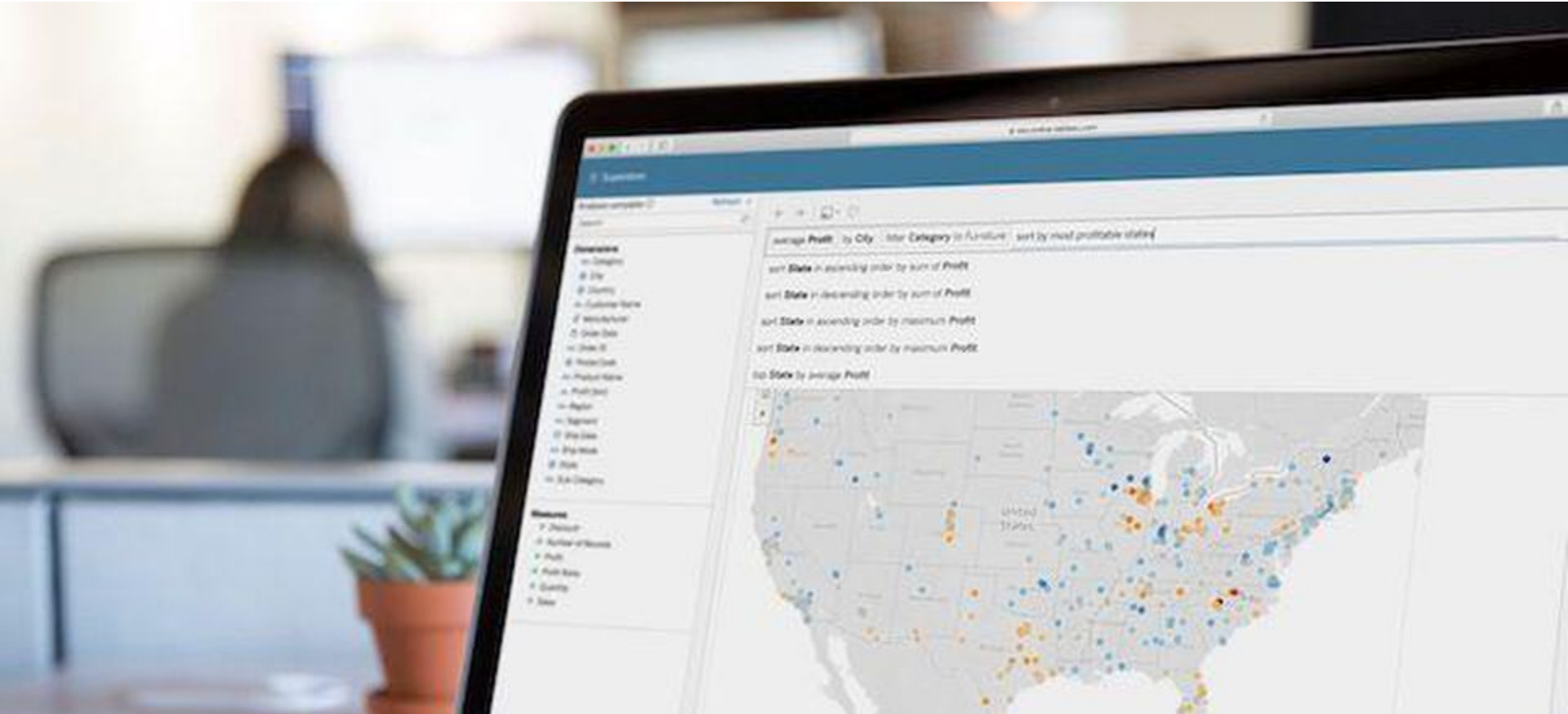
Deeper analytical conversation

"show me the trends for next month"



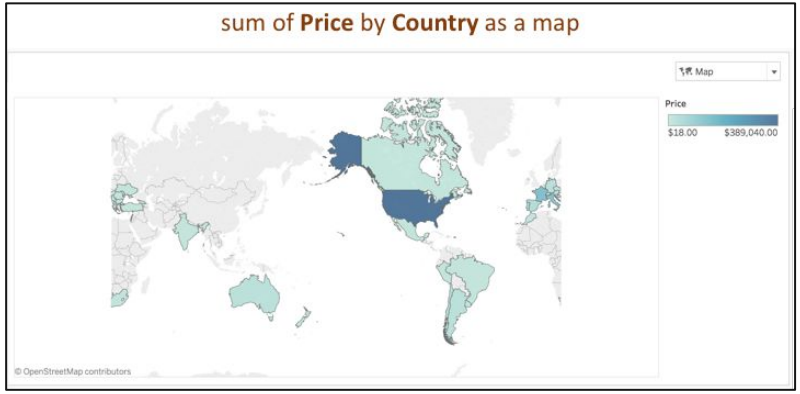
Ask Data

https://www.tableau.com/products/new-features/ask-data

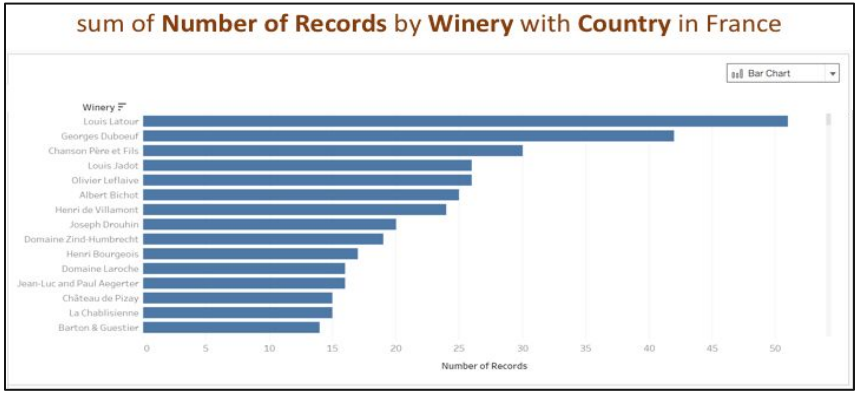


Analytical functions supported

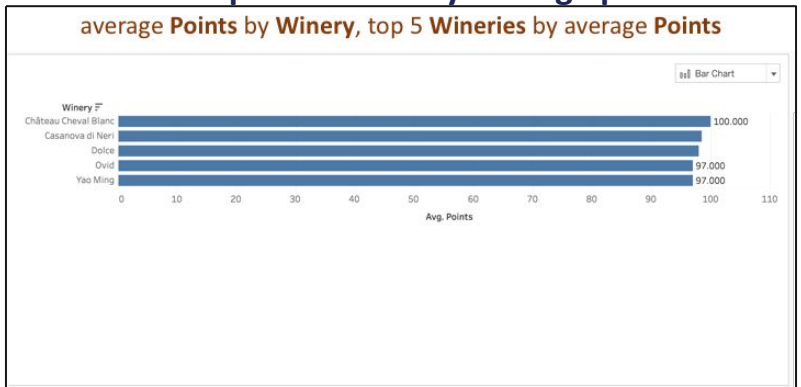
“what’s the sum of price for each country?”



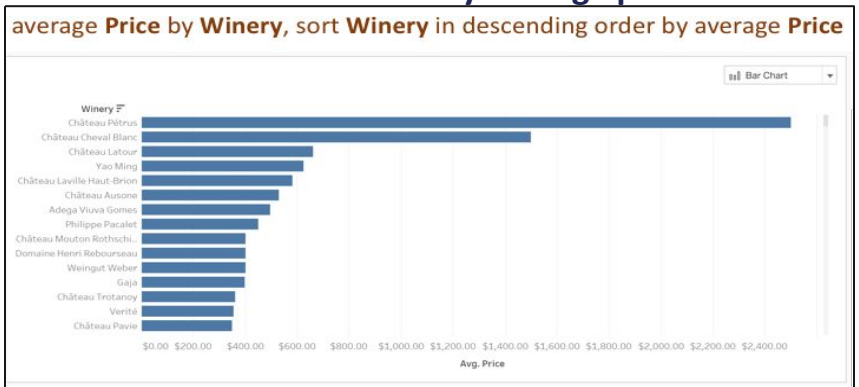
“wineries in france”



“top 5 wineries by average points”



“sort wineries by average price”



AUGMENTING SEMANTICS

Datetime	price	Latitude	Longitude	area	#beds	openhouse_time	Source
1/4/2016	600000	38.8977	77.0365	5320	3	3:00pm	re.us/dfj3.php
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

“Show me house prices”

“Show me house prices” in Ask Data

Prices ≈ price

Datetime	price	Latitude	Longitude	area	#beds	openhouse_time	Source
1/4/2016	600000	38.8977	77.0365	5320	3	3:00pm	re.us/dfj3.php
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

“Show me expensive house prices” in Ask Data

Expensive refers to price

Datetime	price	Latitude	Longitude	area	#beds	openhouse_time	Source
1/4/2016	600000	38.8977	77.0365	5320	3	3:00pm	re.us/dfj3.php
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Expensive: adjective; entailing great expense; very high **priced**; costly

“Show me house cost”

Cost is a synonym of price

Datetime	price	Latitude	Longitude	area	#beds	openhouse_time	Source
1/4/2016	600000	38.8977	77.0365	5320	3	3:00pm	re.us/dfj3.php
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Cost: amount, charge, damage, **price**, expenditure...

“Show me large houses”

Large refers to size, which can be measured as area

Datetime	price	Latitude	Longitude	area	#beds	openhouse_time	Source
1/4/2016	600000	38.8977	77.0365	5320	3	3:00pm	re.us/dfj3.php
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

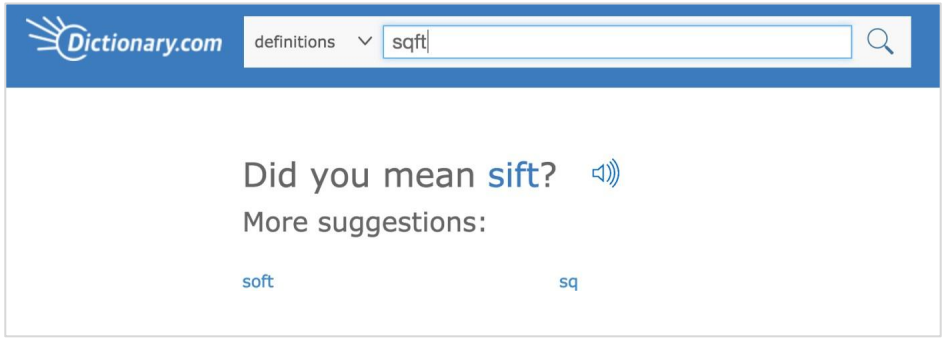
Large: adjective; ample in dimensions, quantity, or number. Having much size or **extent**, capacity, scope, length, breadth etc., or relatively being of more than common **measure** wide, broad, spacious, great, big, or bulky

Area: noun; a **measure** of the **extent** of a surface it is measured in square units

“Show me sqft of houses”

Sqft measures area

Datetime	price	Latitude	Longitude	area	#beds	openhouse_time	Source
1/4/2016	600000	38.8977	77.0365	5320	3	3:00pm	re.us/dfj3.php
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮



Using word similarity

“The house is 5000 sqft.”

“The house has 5 beds.”

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“I have a pet cat.”

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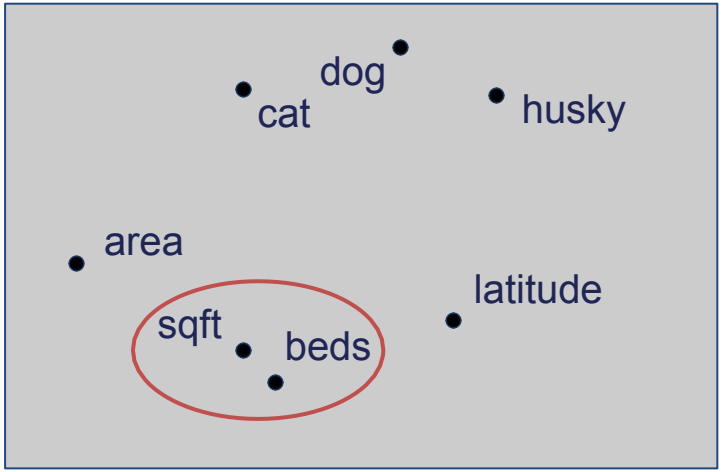
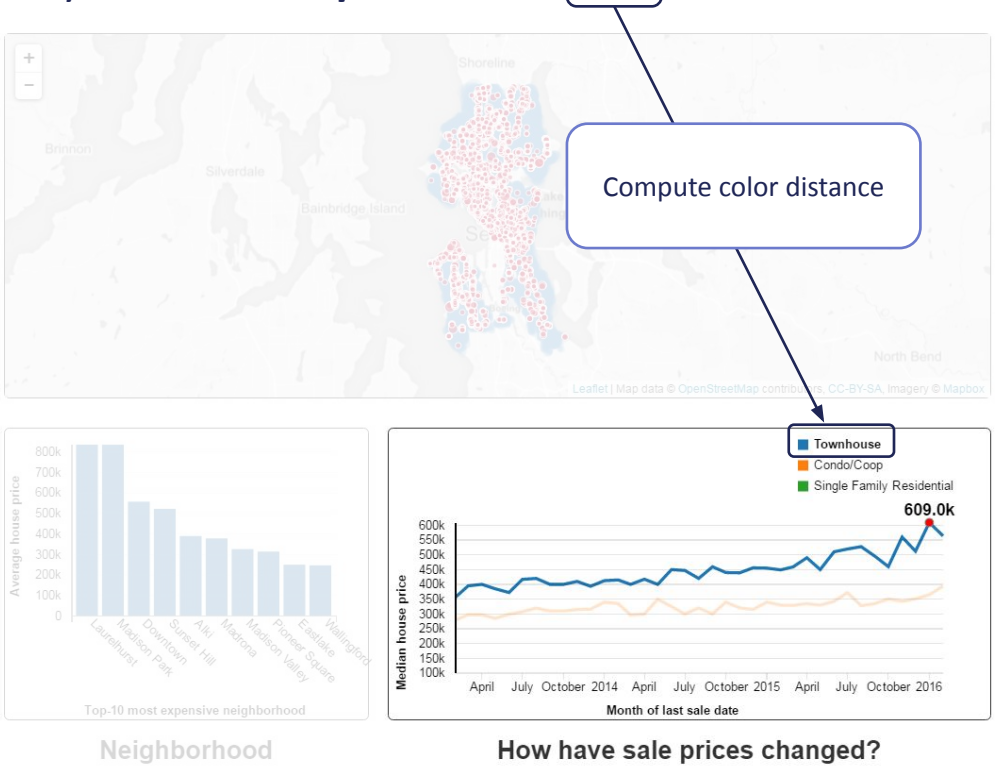
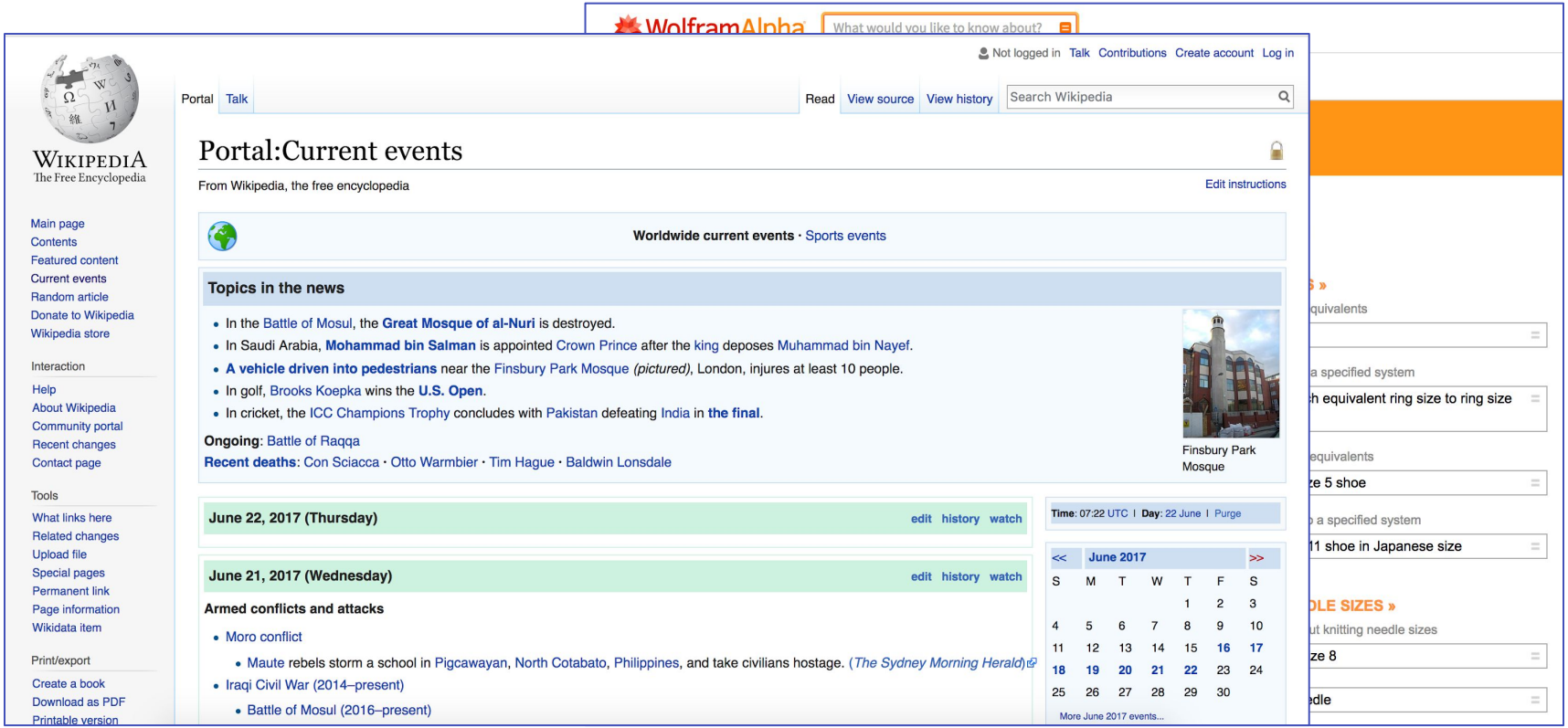


Visualization properties

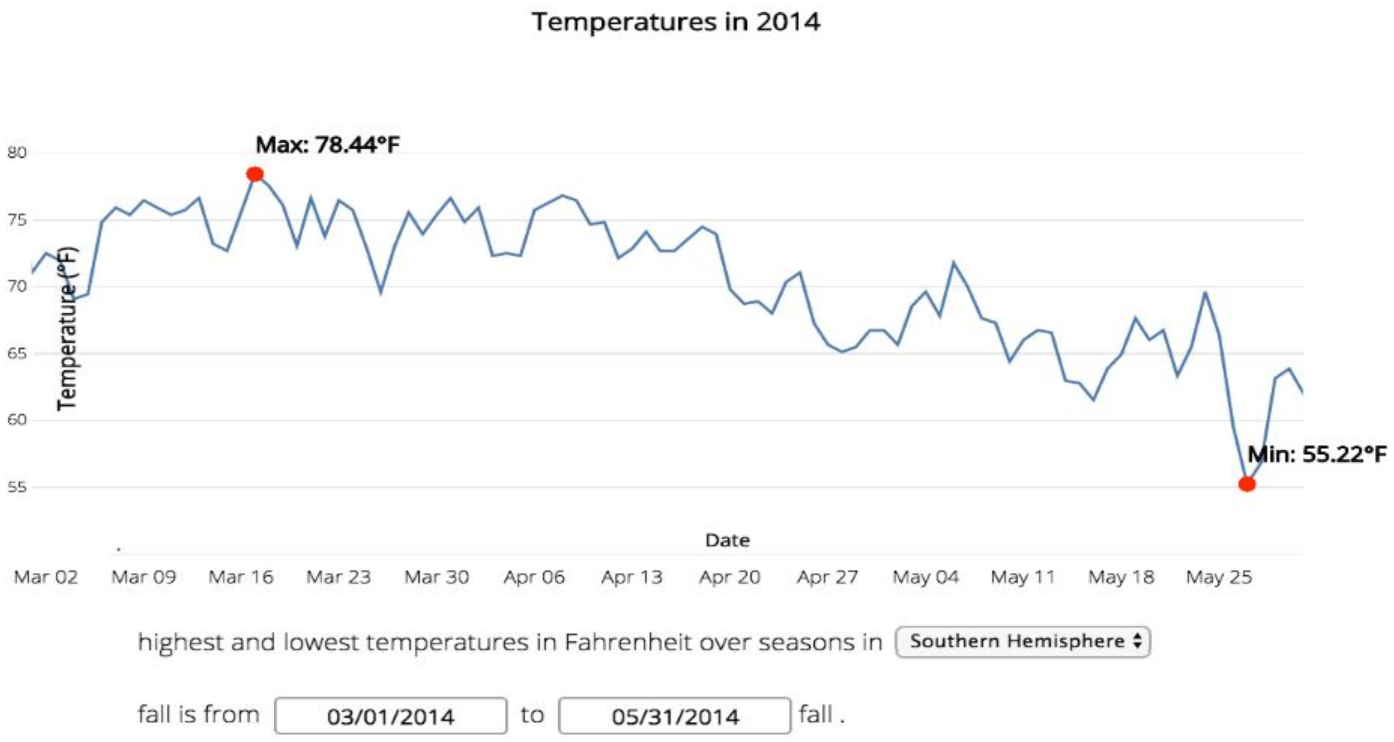
Query: *what's the **spike** in that **blue** **line**?*



External knowledge



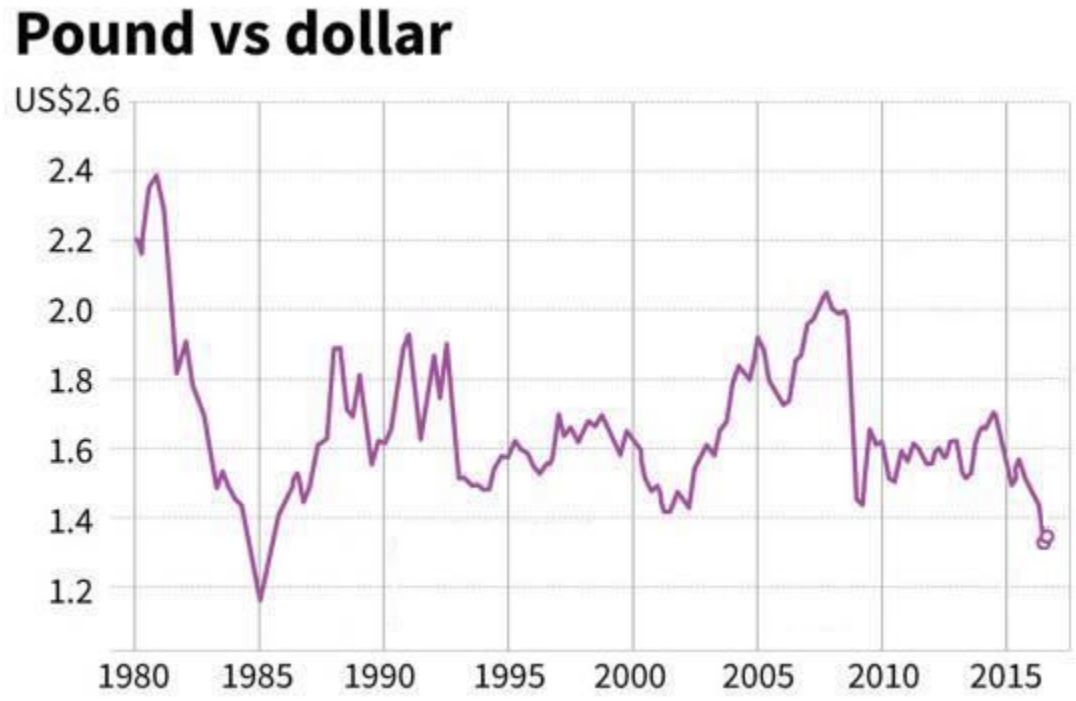
“highest and lowest temperatures in **Fahrenheit** over **fall**”



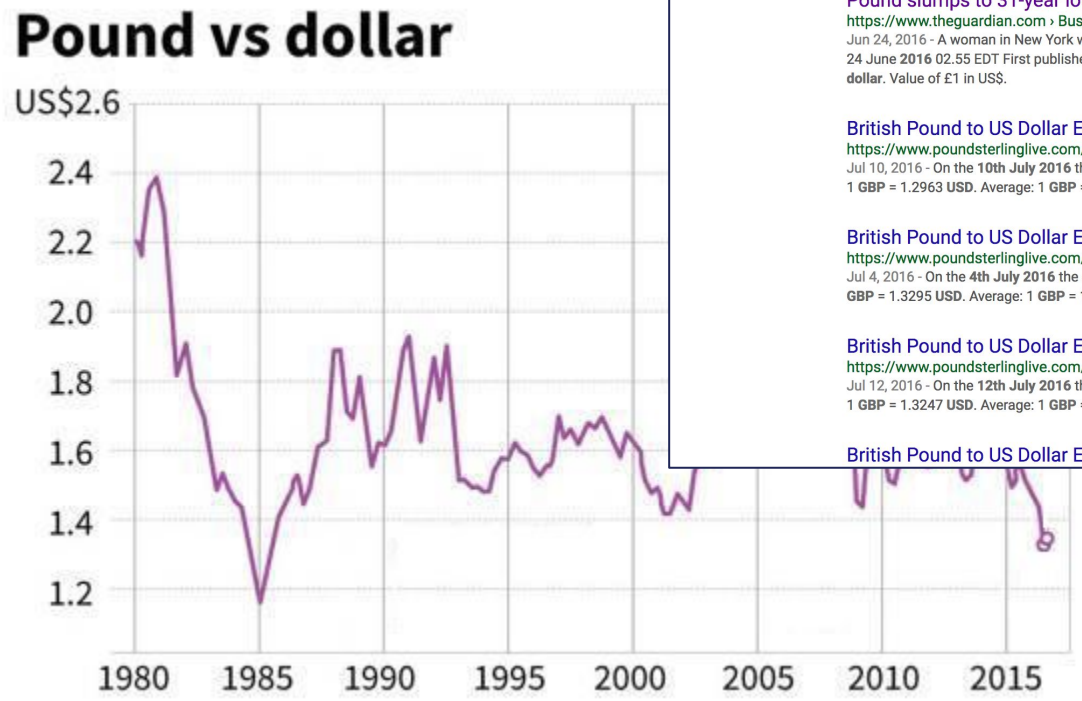
31)

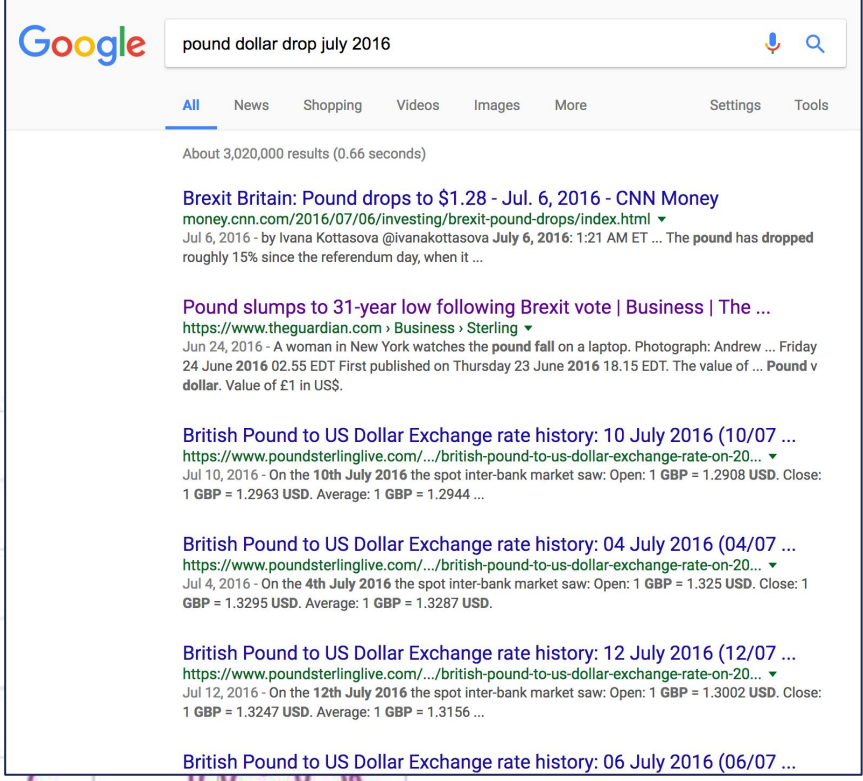
rn

“what is the drop in july 2016?”



“what is the drop in





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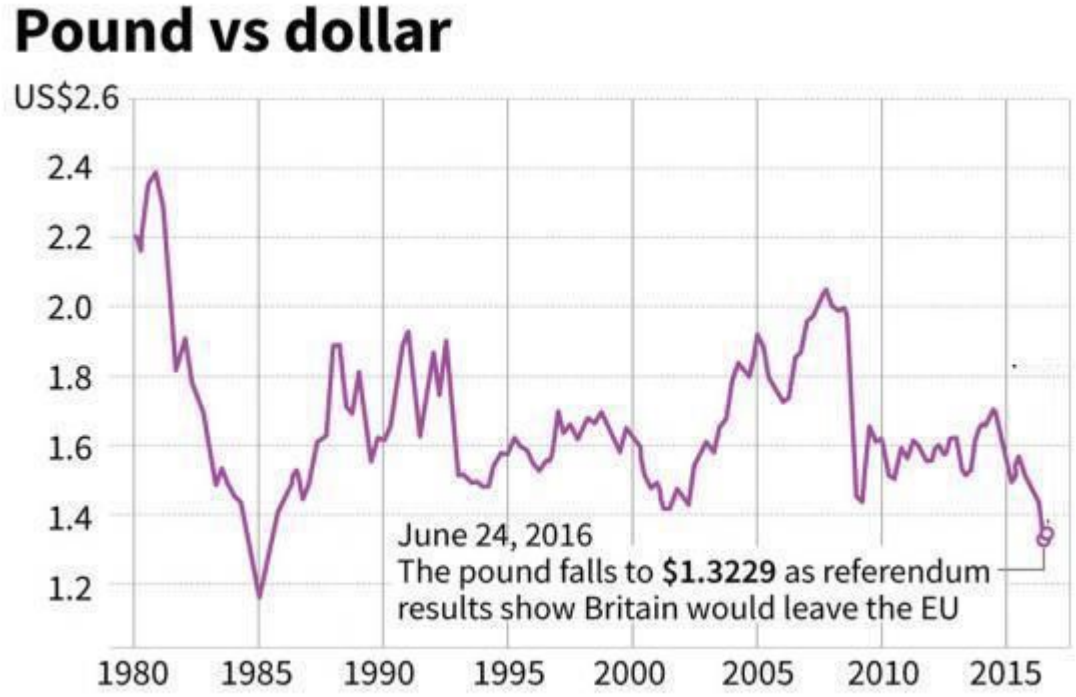

Summary

Text and language play an important role in visual analysis

- Linking text with visualization
- Understanding how readers integrate charts and captions
- Visual question and answering
- Natural language interfaces