

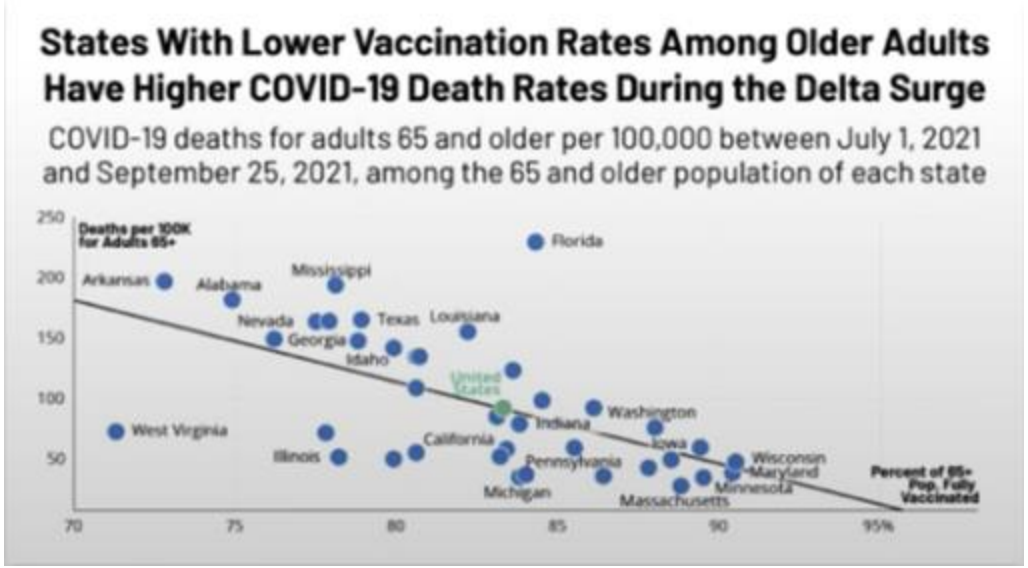
Belief Decay or Persistence? A Mixed-method Study on Belief Movement Over Time

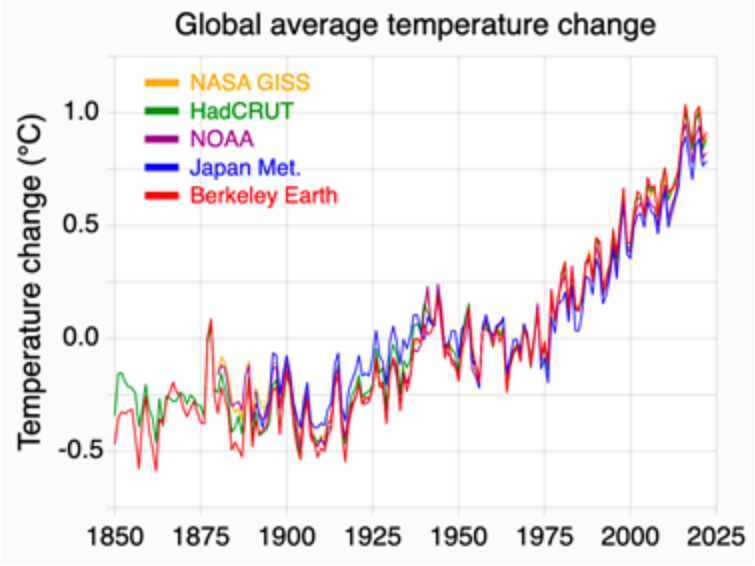
Shrey Gupta [1]
Alireza Karduni [2]
Emily Wall [1]

[1] Emory University, Atlanta, US
[2] IDEO, Chicago, US

EMORY UNIVERSITY

CAV LAB


States With Lower Vaccination Rates Among Older Adults Have Higher COVID-19 Death Rates During the Delta Surge
COVID-19 deaths for adults 65 and older per 100,000 between July 1, 2021 and September 25, 2021, among the 65 and older population of each state
Deaths per 100K for Adults 65+
Percent of 65+ Pop. Fully Vaccinated
250
200
150
100
50
70
75
80
85
90
95%
Florida
Arkansas
Alabama
Mississippi
Nevada
Texas
Louisiana
Georgia
Idaho
United States
Indiana
Washington
West Virginia
California
Iowa
Illinois
Pennsylvania
Wisconsin
Maryland
Michigan
Minnesota
Massachusetts


Global average temperature change
NASA GISS
HadCRUT
NOAA
Japan Met.
Berkeley Earth
Temperature change (°C)
1.0
0.5
0.0
-0.5
1850
1875
1900
1925
1950
1975
2000
2025

Why Study

Belief Change

We are surrounded with information that affects our understanding and beliefs about the world around us.

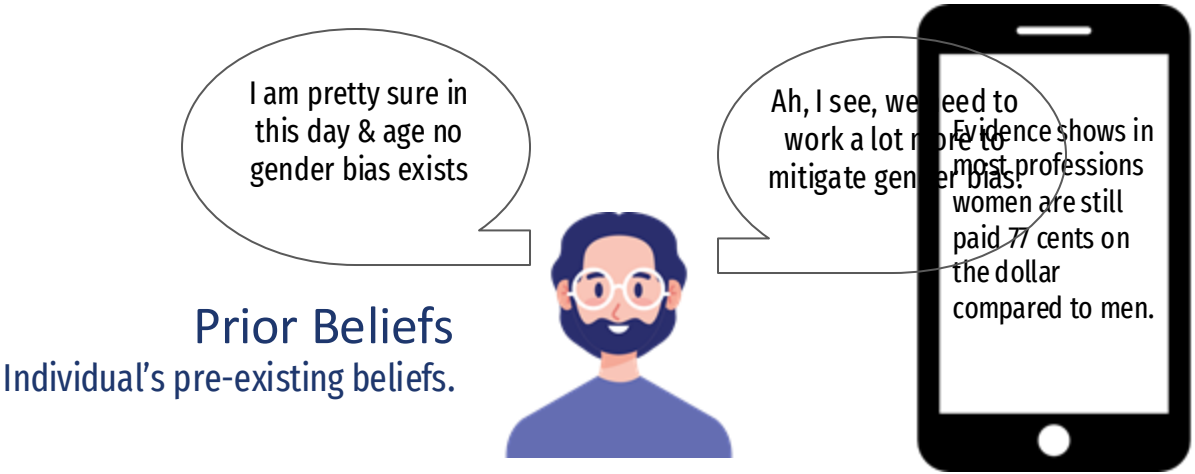
What makes information persistent and persuasive?

Belief Update | Capturing the belief change

Change in beliefs when new evidence is presented.

Posterior Beliefs

Individual's new beliefs after evidence shown.

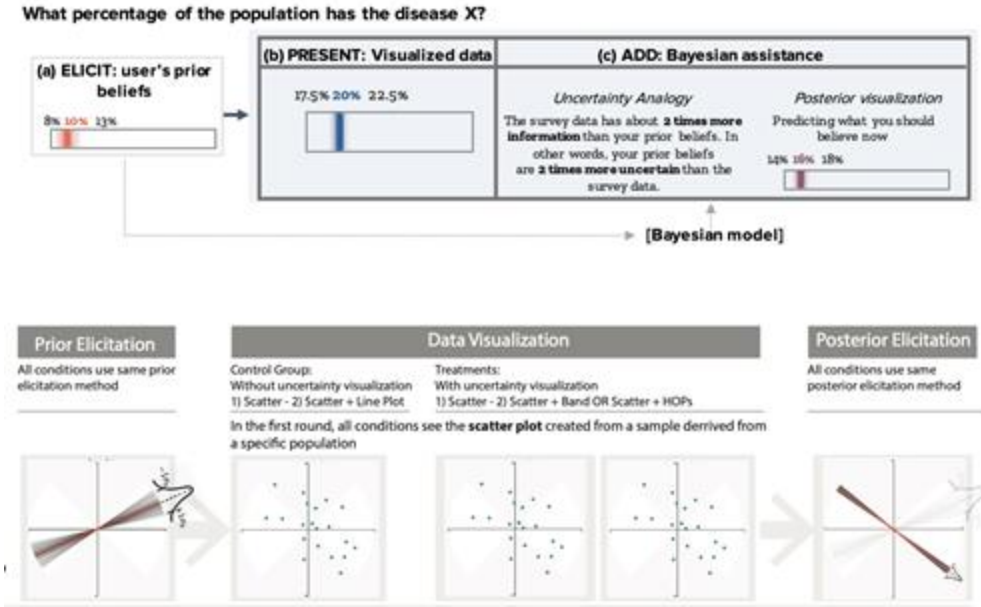


Prior Beliefs

Individual's pre-existing beliefs.

The Belief Update Framework

Previous studies measure “updated” beliefs *immediately after new data is shown.*



Kim, Yea-Seul, et al. "Bayesian-assisted inference from visualized data." *IEEE Transactions on Visualization and Computer Graphics* 27.2 (2020): 989-999.

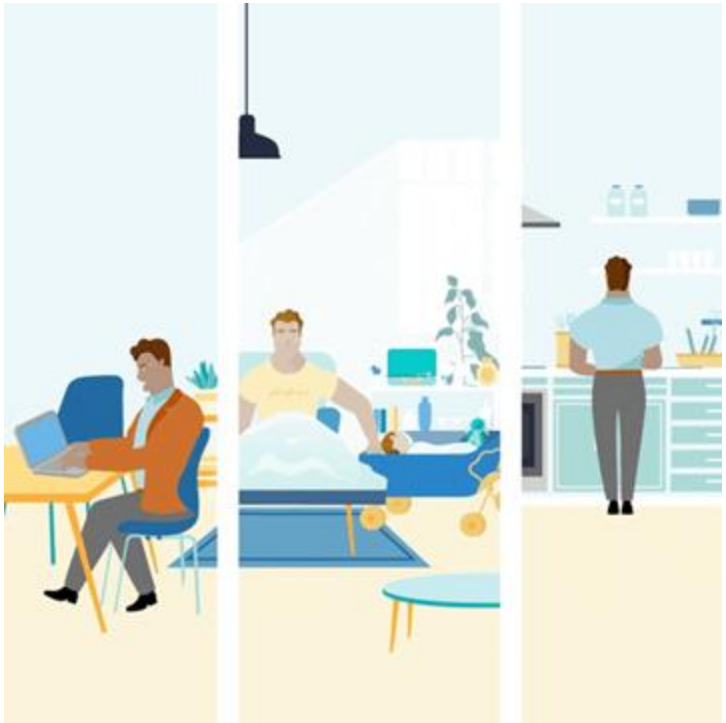
Karduni, Alireza, et al. "A bayesian cognition approach for belief updating of correlation judgement through uncertainty visualizations." *IEEE Transactions on Visualization and Computer Graphics* 27.2 (2020): 978-988.

Belief Update | Effect of Time

When we update our beliefs, do we really retain that information?

What happens after some time passes?

Are our updated beliefs persistent over time?





Belief Decay or Persistence? A Mixed-method Study on Belief Movement Over Time

Shrey Gupta [1]
Alireza Karduni [2]
Emily Wall [1]

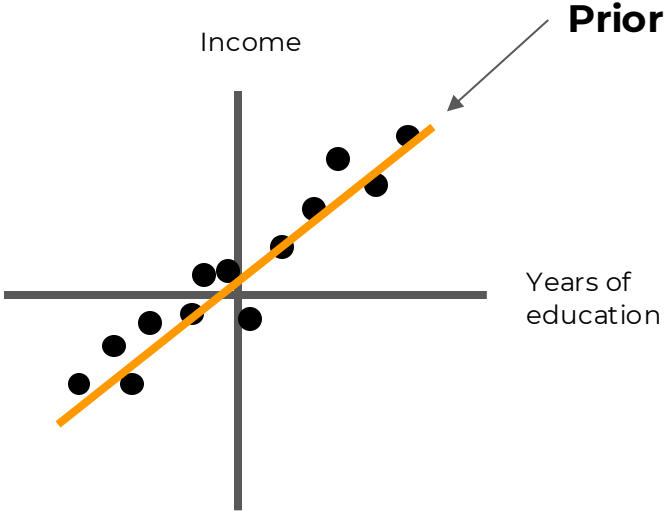
[1] Emory University, Atlanta, US
[2] IDEO, Chicago, US

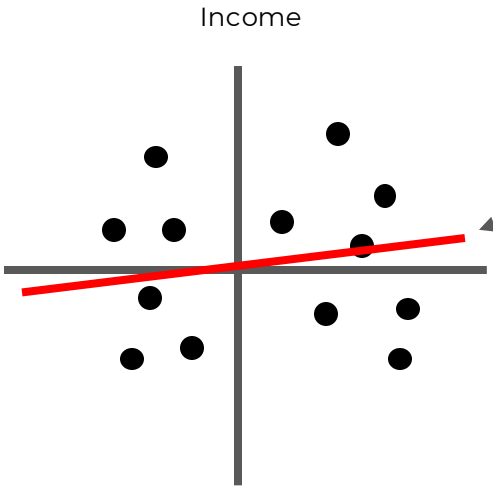
EMORY UNIVERSITY

CAV LAB

“What is the correlation between years of education and income“

I believe **higher education ALWAYS** leads to **higher income.**

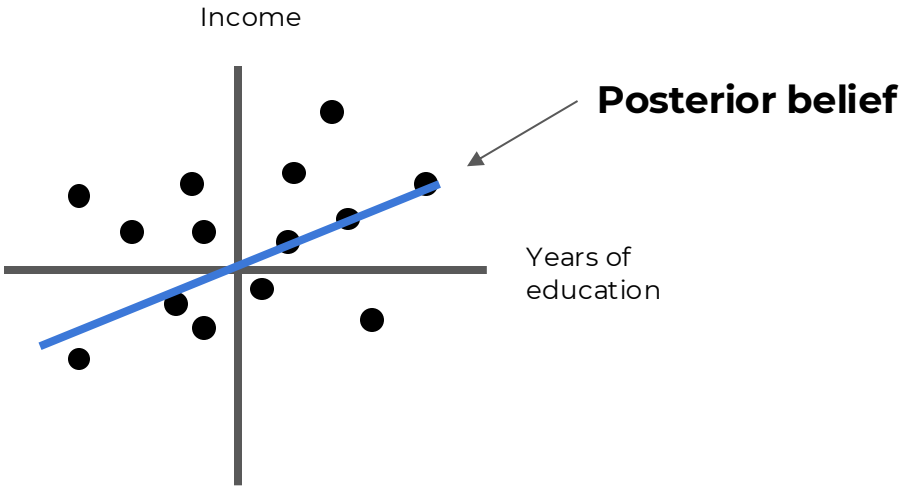




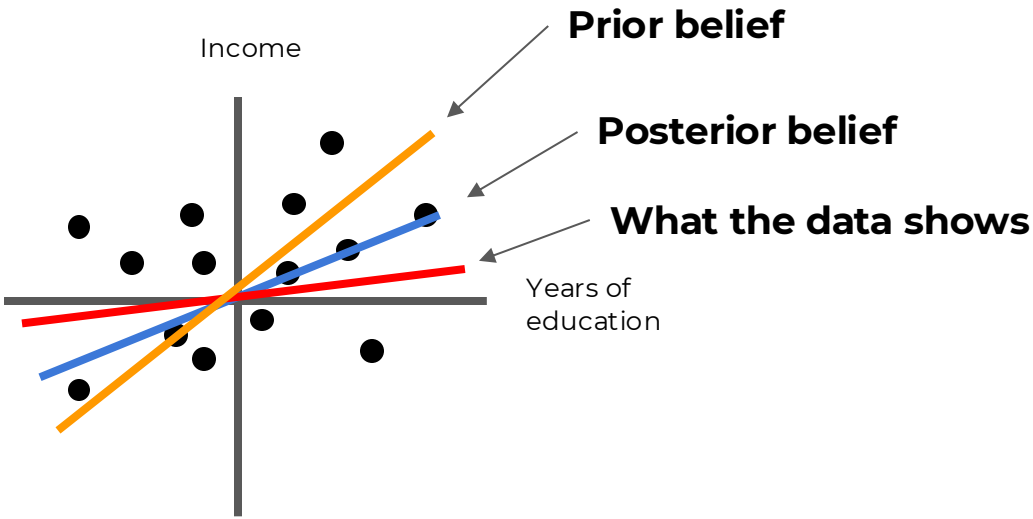
What the data shows

Asked again
“What is the correlation between years of education and income“

I believe **higher education sometimes** leads to **higher income.**



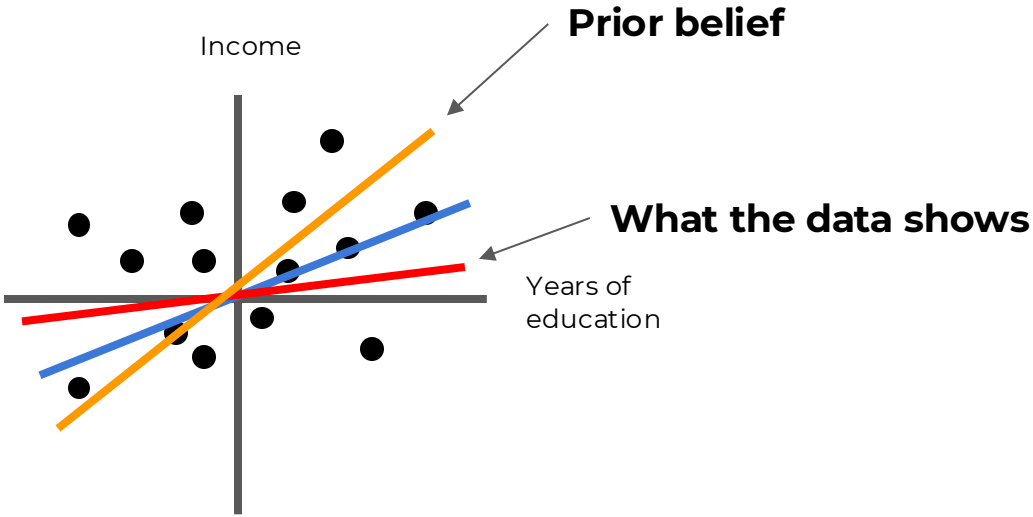
I believe **higher education sometimes** leads to **higher income.**



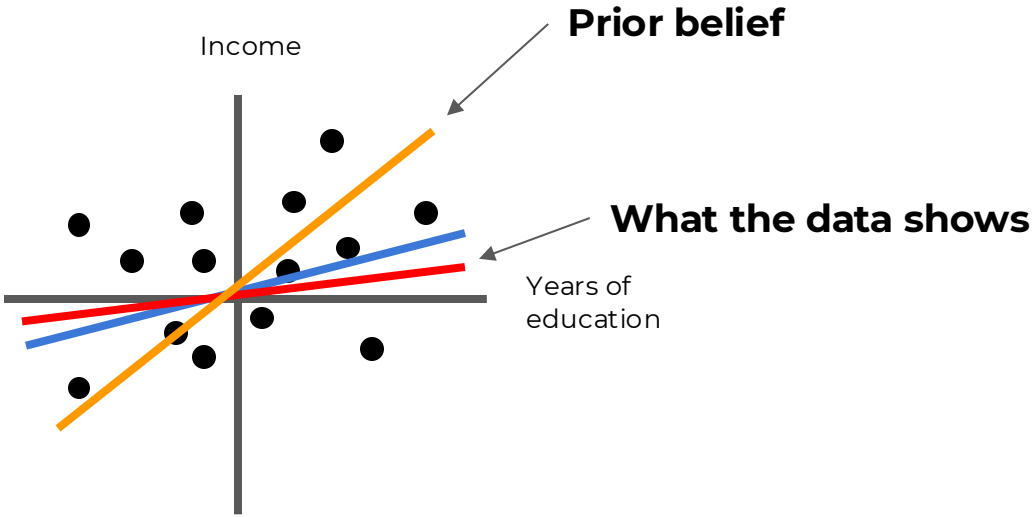
Asked again

“What is the correlation between years of education and income“

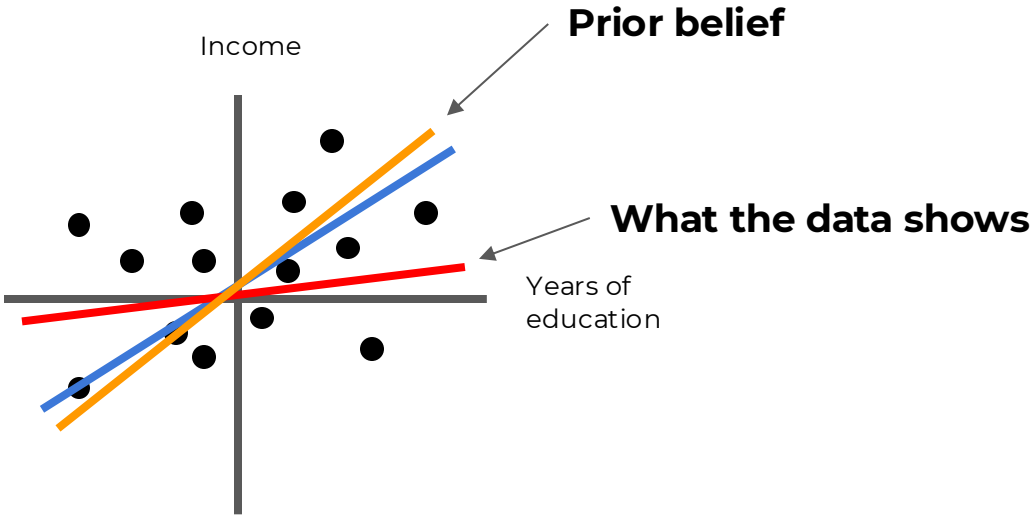
I **Still** believe **higher education sometimes** leads to **higher income.**



I changed my mind, I believe **higher education and income are sometimes** not associated with each other



I think I was originally right, I believe **higher education always** leads to **higher income.**



What happens to the posterior (updated) beliefs over a period of time?

Do the updated beliefs stay the same over a period of time?

Do they change with time?

If they change then what kind of movement is observed?

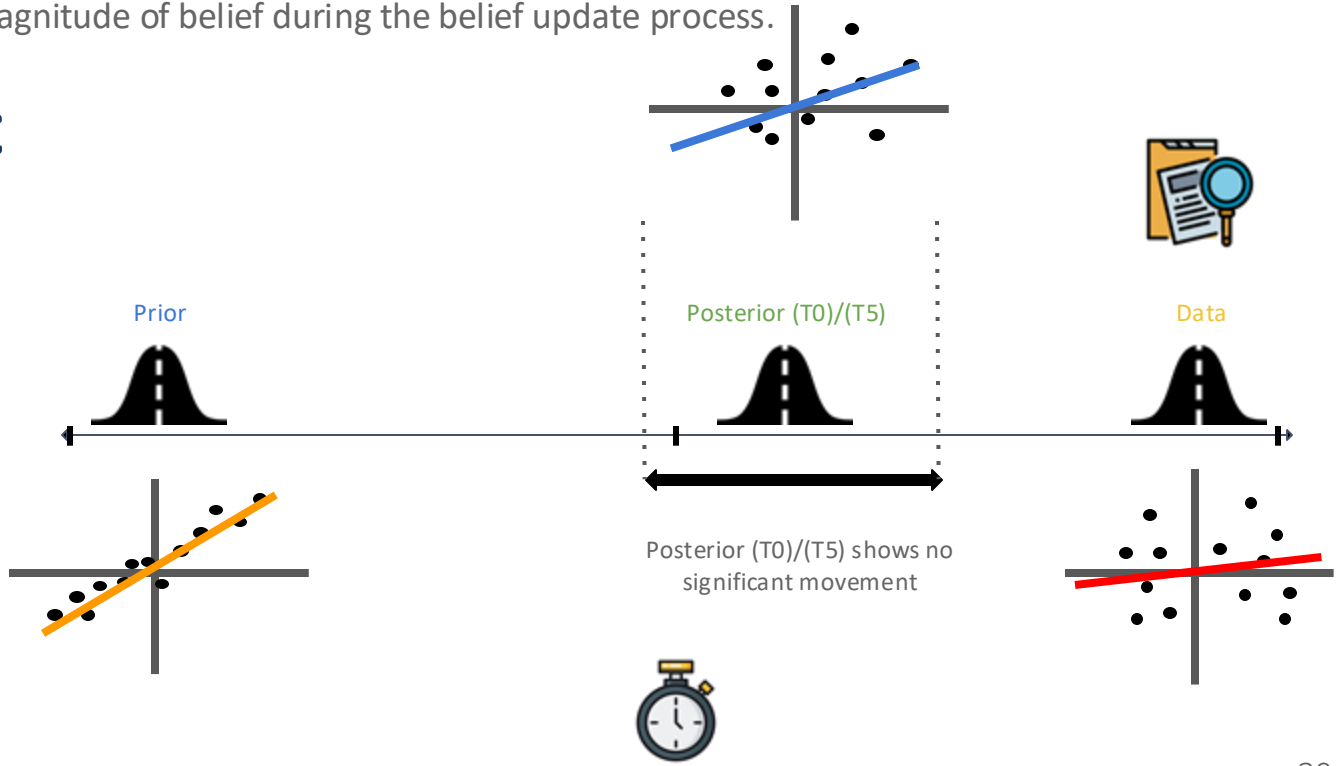
Belief Movement

Change in the direction and magnitude of belief during the belief update process.

Maintenanc

e

No movement observed in posterior beliefs

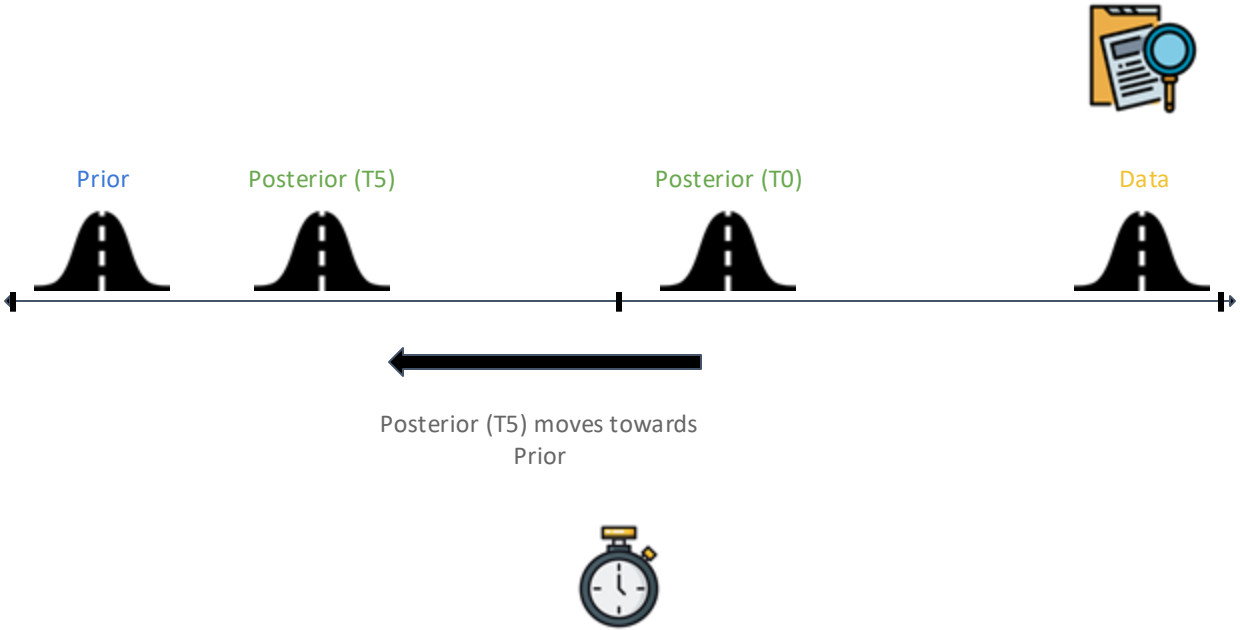


Belief Movement

Change in the direction and magnitude of belief during the belief update process.

Decay

Posterior belief moves *towards prior* belief

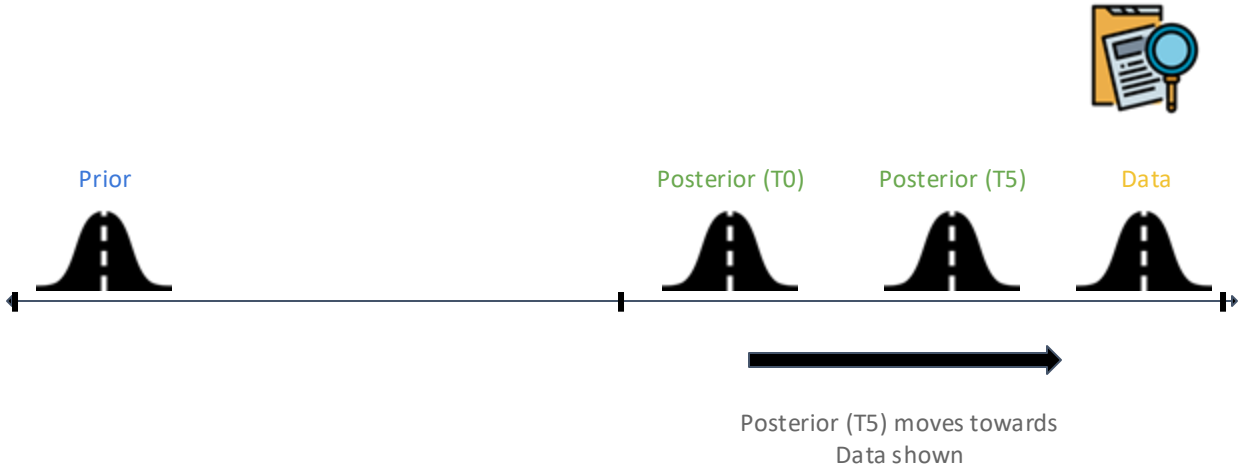


Belief Movement

Change in the direction and magnitude of belief during the belief update process.

Strengthening

Posterior belief moves *towards data* shown



HYPOTHESES

We hypothesize that with the passing of time individuals would experience ‘decay’ of their beliefs i.e. forget the data shown (or) resort back to their prior belief

H1: The posterior beliefs would show movement towards prior over time. (Decay)

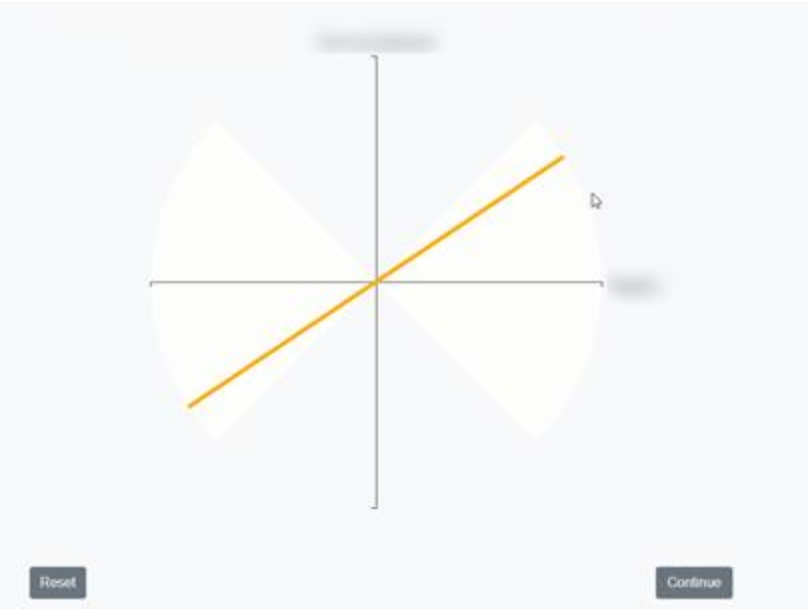
H2: The amount of belief decay over time will be moderated by the
strength of the prior belief.

STUDY DESIGN

Belief Elicitation

Capturing participant beliefs on a specific subject

Line+Cone



DATASET STATISTICS

Immigrant Population x Crime Rate

Social Media Hours x Depression Rate

Years of Education x Income

Evidence

The supporting data was shown using 50 data points in a scatterplot.

No Contextual Information

Only variable names were introduced without contextual information.

Incongruent Evidence

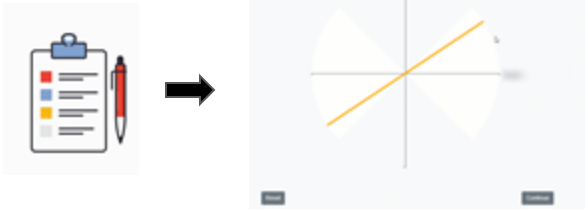
Scatterplot data was generated uniquely to be incongruent to prior beliefs.

Study Design

Participant Background Survey

Study Design

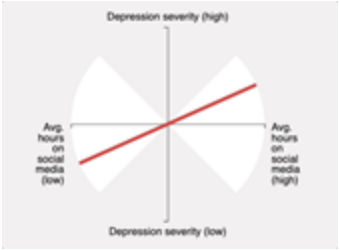
‘Line+Cone’ Training



Study Design

Eliciting Belief

Prior

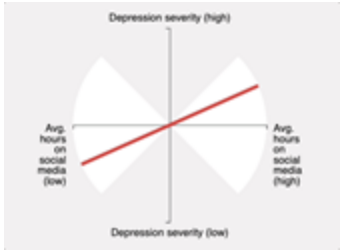


Prior

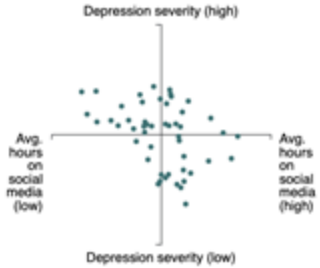
Study Design

Eliciting Belief

Data



Prior

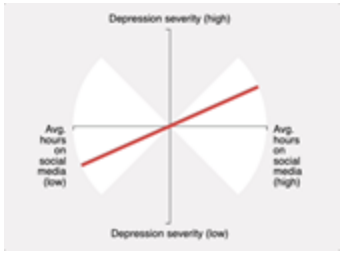


Data
(incongruent)

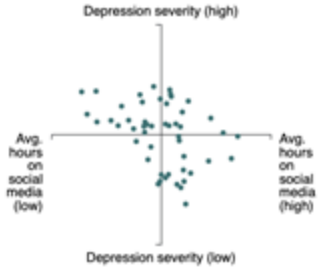
Study Design

Eliciting Belief

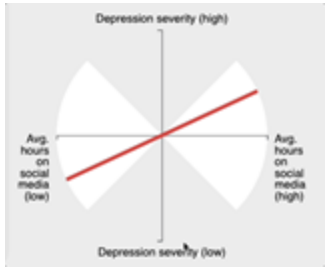
Posterior



Prior



Data
(incongruent)

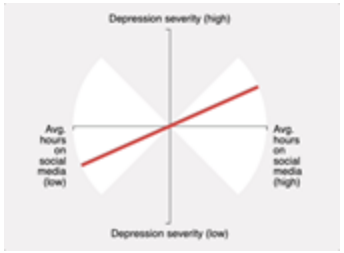


Posterior

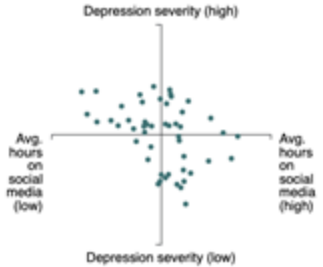
Study Design

Eliciting Belief

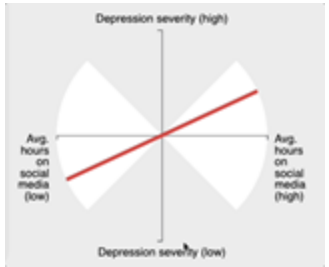
Distraction



Prior



Data
(incongruent)

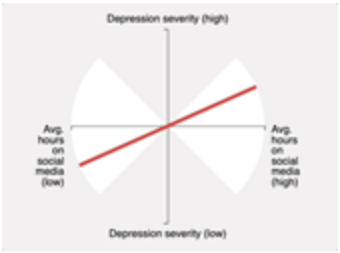


Posterior

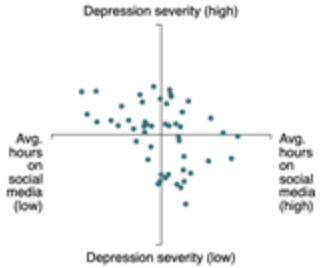
Study Design

Eliciting Belief

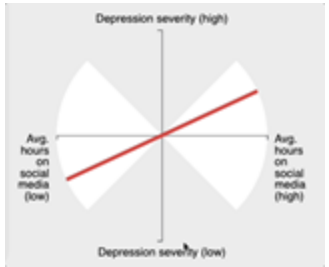
Posterior (T_5)



Prior



Data
(incongruent)



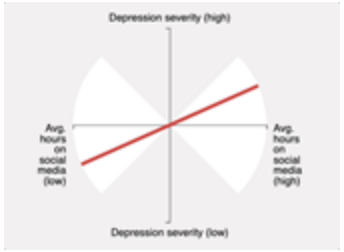
Posterior

Study Design

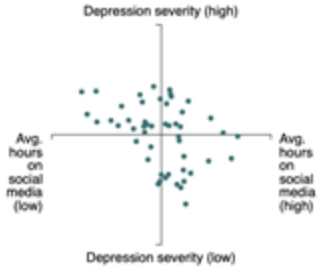
Eliciting Belief

Repeat (per dataset)

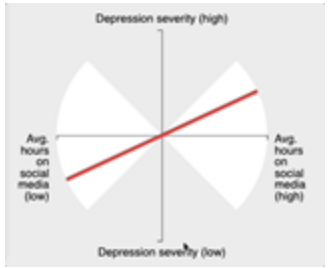
X 3 (for each dataset)



Prior



Data
(incongruent)

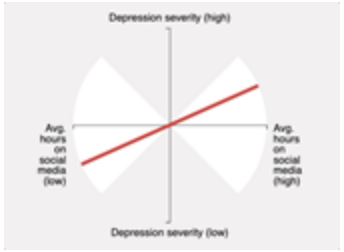


Posterior

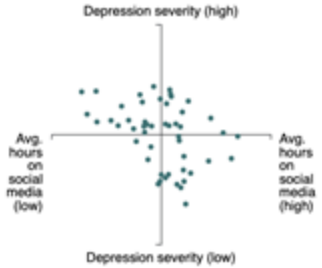
Study Design

Retrospective Analysis

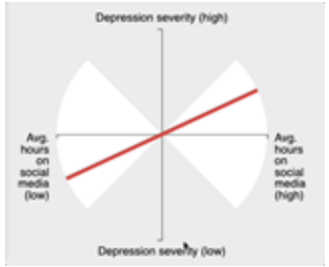
X 3 (for each dataset)



Prior



Data
(incongruent)



Posterior

PARTICIPANT STATISTICS

Participants
101 participants using Prolific platform.

Background
18+ | Fluent english | From United States

Gender
Male: 49 | Female: 51 | Other: 1

Age
Age range from 18 to 79

Education
Education range from high-school to doctorate

ANALYSIS

We analyzed participant data to identify if there were statistically significant signs of belief ‘decay’.

We also qualitatively analyzed participant responses for hidden trends.

ANALYSIS

We analyzed participant data to identify if there were statistically significant signs of belief ‘decay’.

We also qualitatively analyzed participant responses for hidden trends.

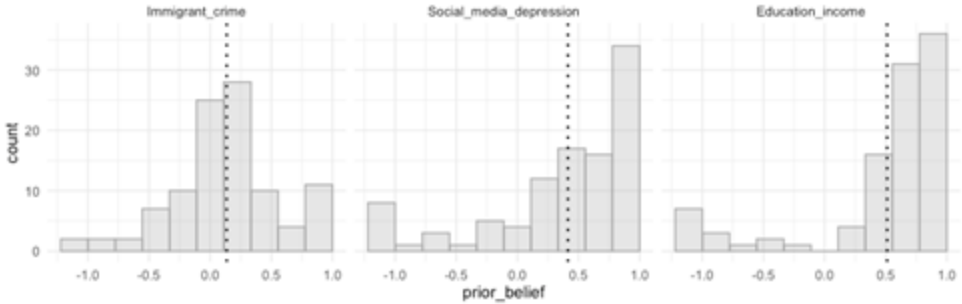
Analysis 1

Quantitative Analysis

Observing Priors

Prior Beliefs

Trends of participants' prior beliefs for the 3 datasets were widely diverging.



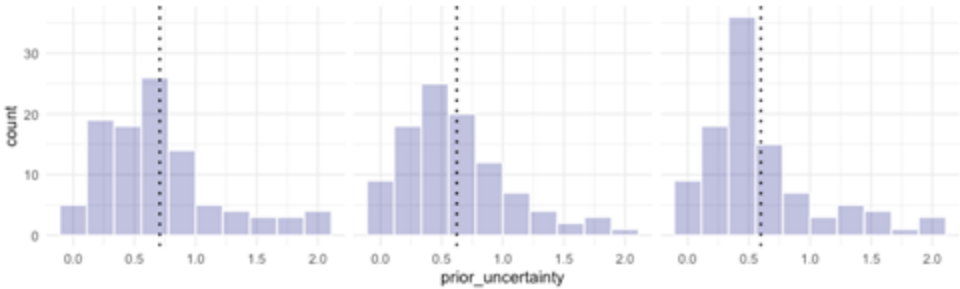
Observing Priors

Prior Beliefs

Trends of participants' prior beliefs for the 3 datasets were widely diverging.

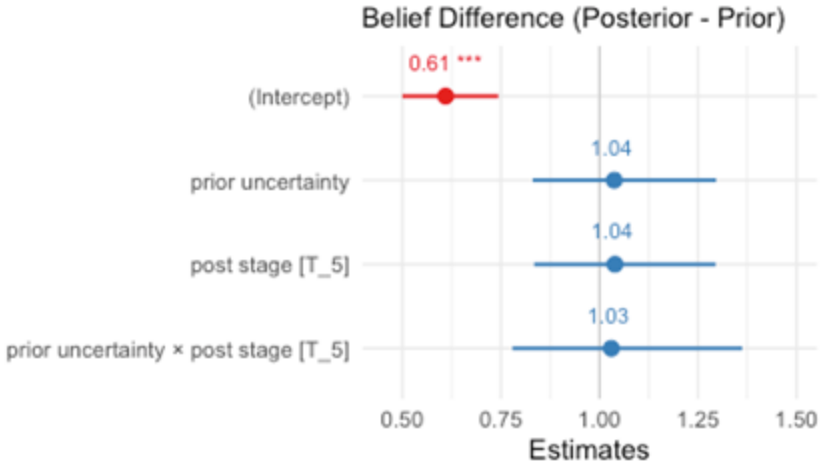
Prior Uncertainty

Trends of participants' posterior beliefs for the 3 datasets were widely diverging.



Statistical Findings

Mixed-effects Regression



Testing Hypothesis 1:
For (Posterior(t) - Prior), *no significant difference observed* between T_5 and T_0 (β = 0.038 [-0.181 0.258], z = 0.344, p=0.731).

Testing Hypothesis 2:
For prior uncertainty (β = 0.029 [-0.249, 0.308], z = 0.208, p=0.835) on the difference between participants' elicited posterior (at T_0 and T_5) and prior beliefs, *no significant effect observed*.

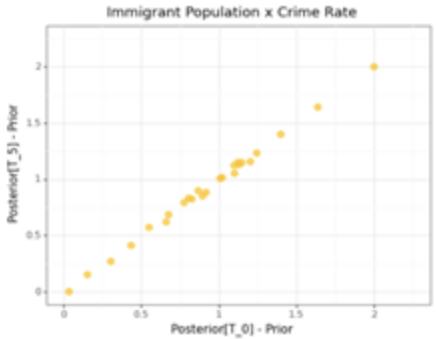
Statistical Findings

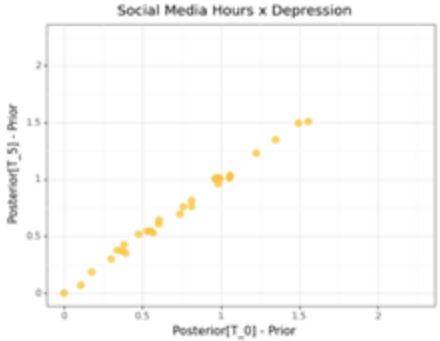
Belief Trend

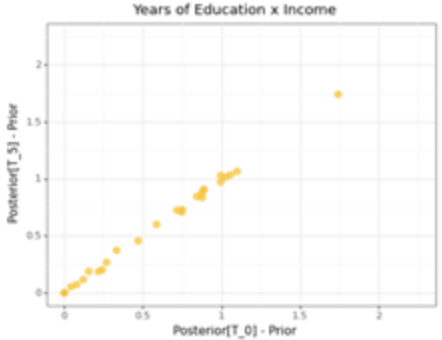
Threshold (ε = 0.05)

Most individuals showed movement towards prior (⅔ datasets)

Belief Movement	Immigrant Population x Crime Rate	Social Media Hours x Depression	Years of Education x Income
Maintenance	25	31	38
Towards Prior	45	37	28
Towards Data	31	33	35







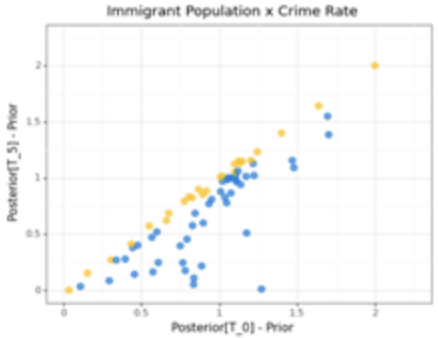
Statistical Findings

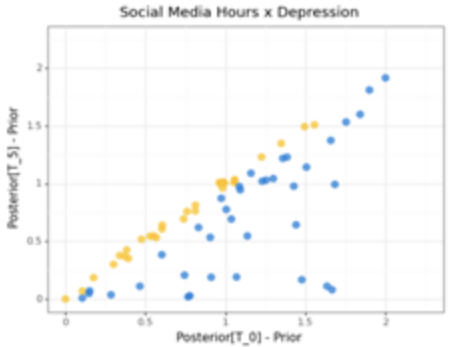
Belief Trend

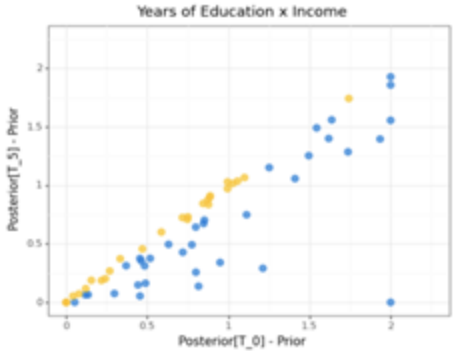
Threshold (ε = 0.05)

Most individuals showed movement towards prior (⅔ datasets)

Belief Movement	Immigrant Population x Crime Rate	Social Media Hours x Depression	Years of Education x Income
Maintenance	25	31	38
Towards Prior	45	37	28
Towards Data	31	33	35







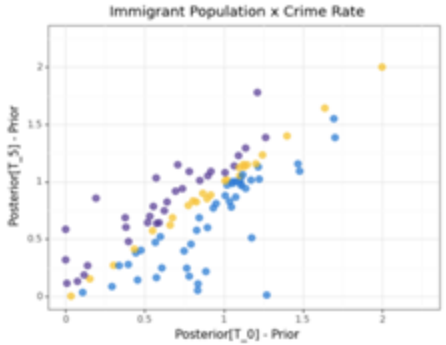
Statistical Findings

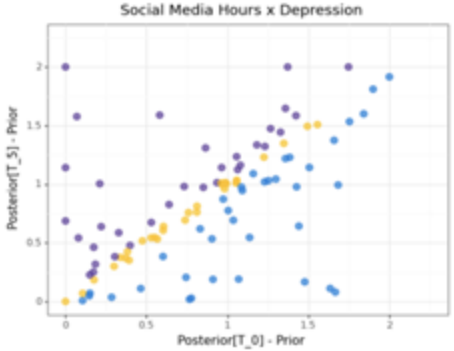
Belief Trend

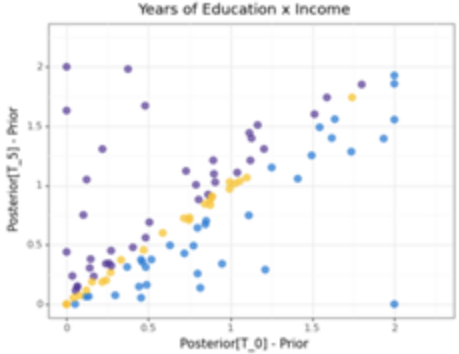
Threshold (ε = 0.05)

Most individuals showed movement towards prior (⅔ datasets)

Belief Movement	Immigrant Population x Crime Rate	Social Media Hours x Depression	Years of Education x Income
Maintenance	25	31	38
Towards Prior	45	37	28
Towards Data	31	33	35







Statistical Findings

Alternative Formulations

Belief Movement	Immigrant Population x Crime Rate	Social Media Hours x Depression	Years of Education x Income
Maintenance	45	45	51
Towards Prior	32	31	26
Towards Data	24	25	24

Threshold (ε = 0.1):
Most individuals maintained their beliefs (50% more than for ε = 0.05)

Belief Movement	Immigrant Population x Crime Rate	Social Media Hours x Depression	Years of Education x Income
Maintenance	73	72	75
Towards Prior	20	15	12
Towards Data	8	14	14

T5 is within Uncertainty of T0
Almost 70% responses show belief maintenance.

ANALYSIS

We analyzed participant data to identify if there were statistically significant signs of belief ‘decay’.

We also qualitatively analyzed participant responses for hidden trends.

Analysis 1

Quantitative Analysis

Findings

We found no evidence to suggest systematic belief decay

ANALYSIS

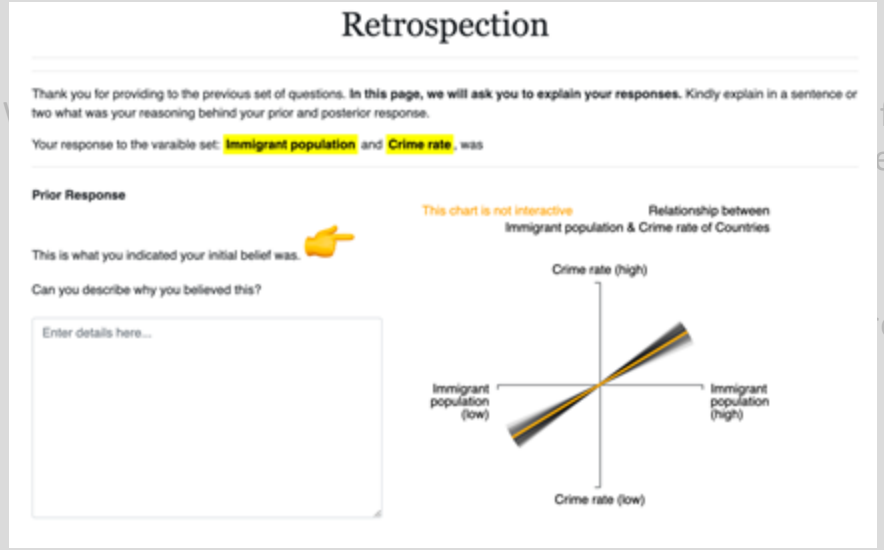
We analyzed participant data to identify if there were statistically significant signs of belief ‘decay’.

We also qualitatively analyzed participant responses for hidden trends.

Analysis 2

Qualitative Analysis

ANALYSIS



Analysis 2

Qualitative Analysis

Methodology

Participants were asked to reflect on their responses.

ANALYSIS

Qualitative Codes (Prior)	Categories
Direction	positive/negative/neutral/relationship but unspecified/NA
Source	research/news/cites studies/personal experience/NA
Confidence	strong/weak/NA
Interface difficulty	true/false

Qualitative Codes (Posterior (t=0))	Categories
Direction	positive/negative/neutral/NA
Factors	prior/data/other/NA
Confidence	strong/weak/NA
Unexpected/Manipulation/Rationalize	checkbox
Interface Difficulty	checkbox

Qualitative Codes Posterior (t=5)	Categories
Direction	positive/negative/neutral/NA
Factors	prior/data/other/NA
Confidence	strong/weak/NA
Time Interval Effect	strengthen/decay/made no impact/NA
Unexpected/Manipulation/Rationalize	checkbox
Interface Difficulty	true/false

Analysis 2

Qualitative Analysis

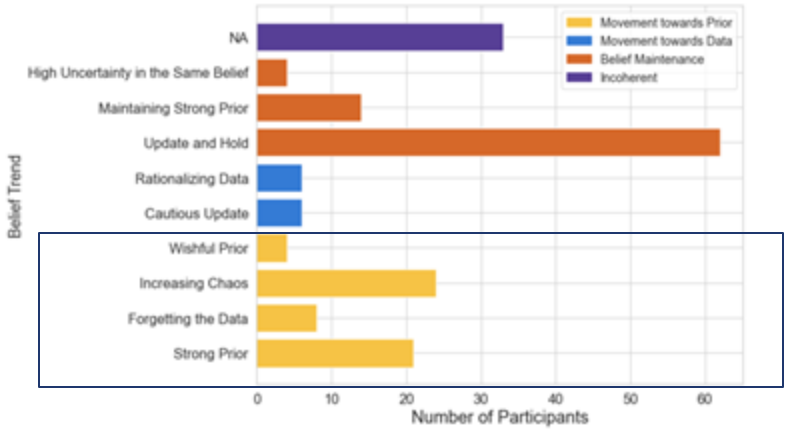
Methodology

Codebook was established to identify participants' rationale

9 Prototypical Themes

Observed using participant's retrospective responses

Towards Prior



Strong Prior

Participants resort back to prior beliefs after the Tetris task.

Quote: "I felt even more confident in my previous answer the more I thought about it, and felt it might even be more positively correlated than before."

Forgetting the Data

Participants forgot the data shown during the Tetris task.

Quote: "I couldn't remember my response after viewing the data on the scatter plot so I defaulted to my original belief it seems."

Increased Chaos

Participants increased their uncertainty over time.

Quote: "That still doesn't make sense to me because why would more people earn less for more education?? so I decided to increase the chaos factor."

Wishful Prior

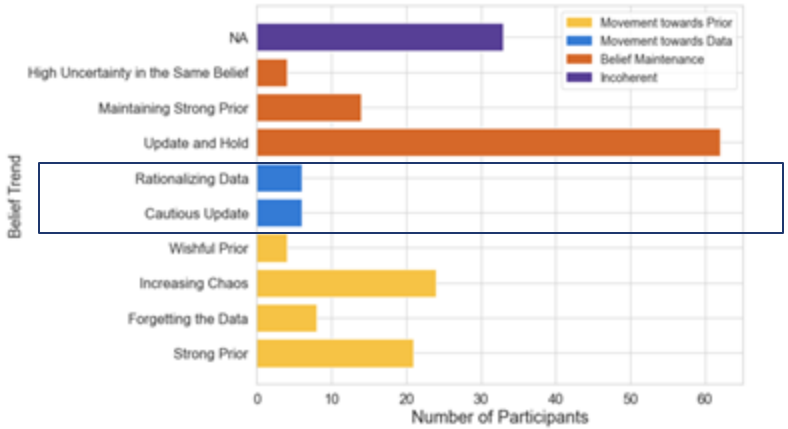
Participants expressed regret to not resort to their prior beliefs.

Quote: "I went along with the data, but I shouldn't have. I think it was a mistake to change from my first graph."

9 Prototypical Themes

Observed using participant's retrospective responses

Towards Data



Cautious Update

Participants updated their beliefs with increased uncertainty.

Quote: "I think I was able to change my mind as I was not quite sure of the relationship between these events."

Rationalizing the Data

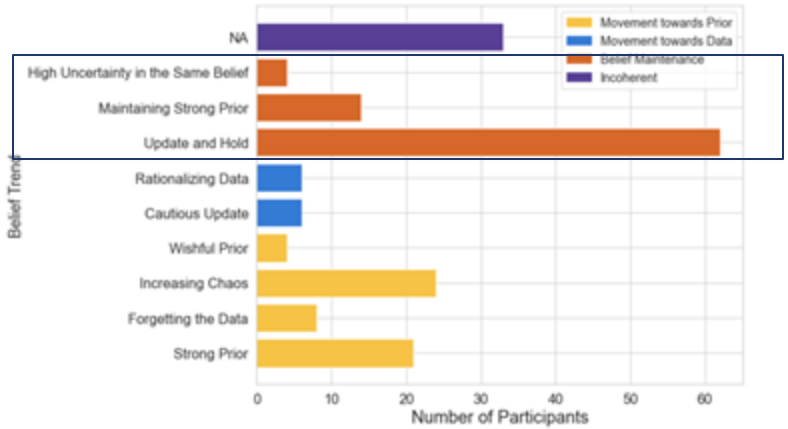
Participants updated their beliefs with increased confidence

Quote: "I believe that the data concluded that the more hours spent on social media, the less likely one is to have depression, and I was sure of it after the game."

9 Prototypical Themes

Observed using participant's retrospective responses

Maintenance



Update and Hold

Participants held their updated beliefs throughout the study

Quote: "I updated my belief based on the scatterplot I was shown."

Maintaining Strong Prior

Participants discarded the data shown and maintained their prior belief throughout the study.

Quote: "I decided to stick with my initial belief because I had a feeling that I was correct, but I wasn't 100% sure."

High Uncertainty in the Same Belief

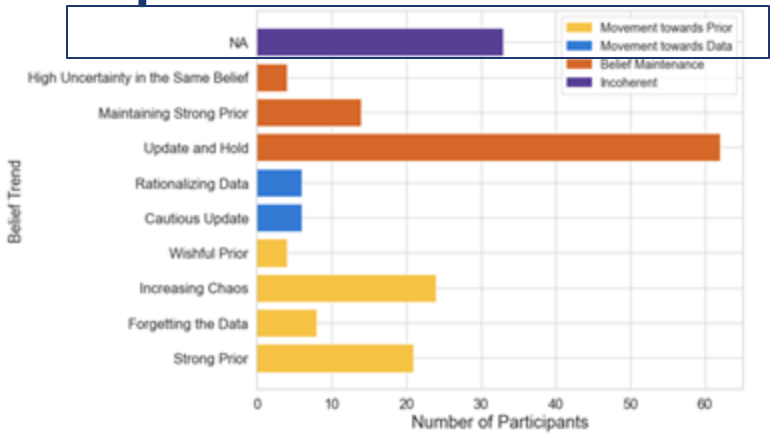
Participants maintained updated beliefs with high uncertainty throughout the study.

Quote: "According to the data there is a strong negative correlation but I do not believe this so I left a wide range of error."

9 Prototypical Themes

Observed using participant's retrospective responses

Incoherent Responses



ANALYSIS

We analyzed participant data to identify if there were statistically significant signs of belief ‘decay’.

We also qualitatively analyzed participant responses for hidden trends.

Analysis 2

Qualitative Analysis

Findings

- No global trends observed for belief decay
- 9 themes observed for belief movement

DISCUSSION

Mimicking Beliefs

Individuals may have simply mimicked the data shown without impacting their true beliefs.

Ambiguous Belief Movement

Noisy qualitative encoding can generate inaccurate belief movement trends.

‘Factual’ Retrospection

Discrepancy b/w actual beliefs v. perceived beliefs by participants in retrospection.

FUTURE WORK

Extended Time Intervals

Larger durations (days/weeks/months) should be tested for belief persistence.

Varying Visualizations

Diverse visualization for both eliciting beliefs and providing evidence should be tested.

‘Real’ Evidence

Real data with contextual information rather than synthetic incongruent data.

CONCLUSION

We hypothesized that individuals would experience belief decay over time.

We analyzed the belief movement over time for individuals in response to new information presented.

The quantitative analysis found no statistically significant evidence to support our hypothesis.

The qualitative analysis revealed 9 belief movement trends.

This work fills a gap in prior work by beginning to scrutinize assumptions made in belief update studies.