

VACCINE CONFIDENCE: NAVIGATING AI'S PROSPECTS AND CHALLENGES

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LONDON
SCHOOL of
HYGIENE
& TROPICAL
MEDICINE



Vaccine
Confidence
Project™



D²4H

Laboratory of Data
Discovery for Health

醫衛大數據深析實驗室®

Who we are



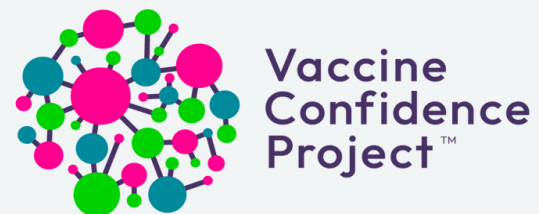
Prof. Pierre Van Damme,
Co-Director



Prof. Heidi J. Larson,
Founding Director



Dr. Leesa K. Lin,
Co-Director





Where we are

Antwerp

Our European Regional Office has been located at the **Centre for the Evaluation of Vaccinations (CEV), University of Antwerp** since 2019. We collaborate with our European partners to develop and evaluate interventions to address vaccine hesitancy and implement the Vaccine Confidence Index™.

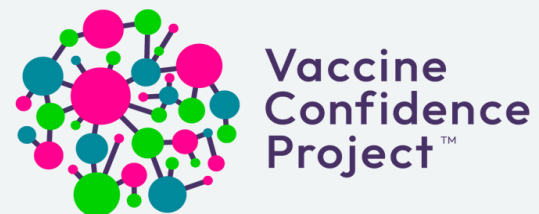
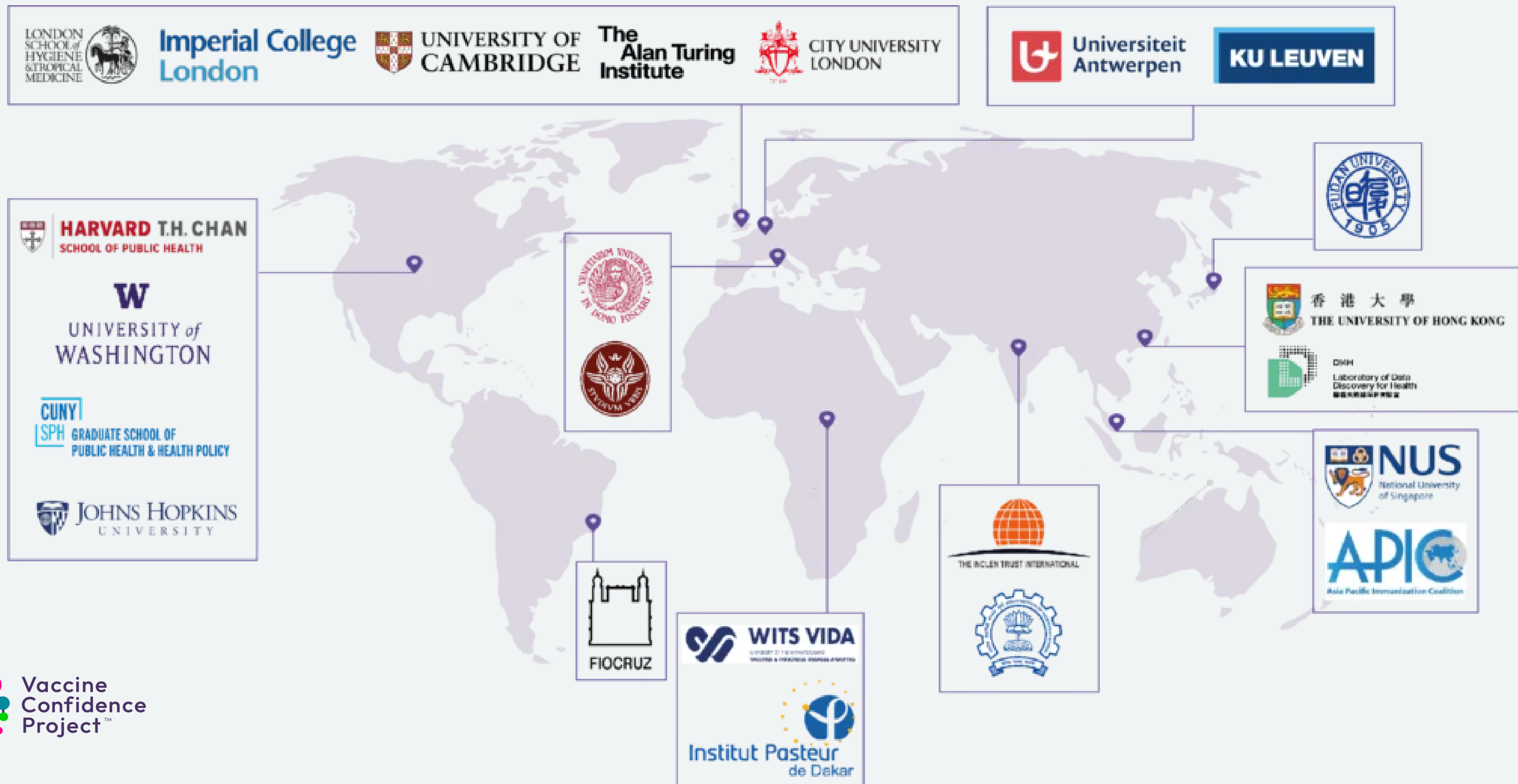
London

The Vaccine Confidence Project was launched in 2010 and continues to operate from the **London School of Hygiene & Tropical Medicine**, a world leader in public and global health research, postgraduate studies, and continuing education.

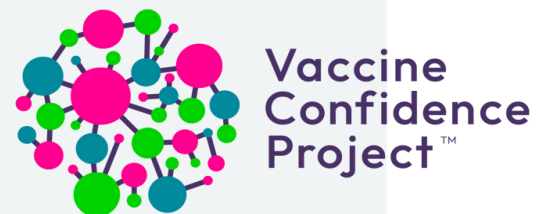
Hong Kong

Our Asia Pacific Regional Office is situated within **Hong Kong University's Laboratory of Data Discovery for Health (D24H)**, where a team of world-leading modellers, statisticians, and behavioral scientists specializes in curating extensive data for dynamic modeling and deep learning, all aimed at driving behavioral change through policy or AI innovations to improve global public health.

Our research partners



Our collaborators



Content

1. Vaccine Hesitancy

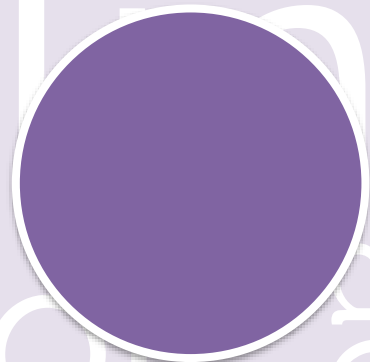
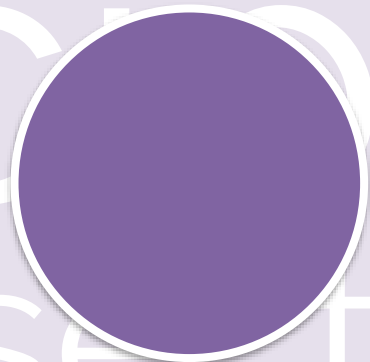
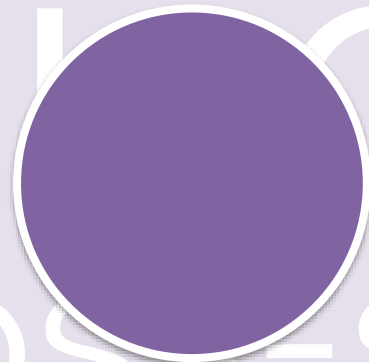
2. Artificial Intelligence

6. Future Research

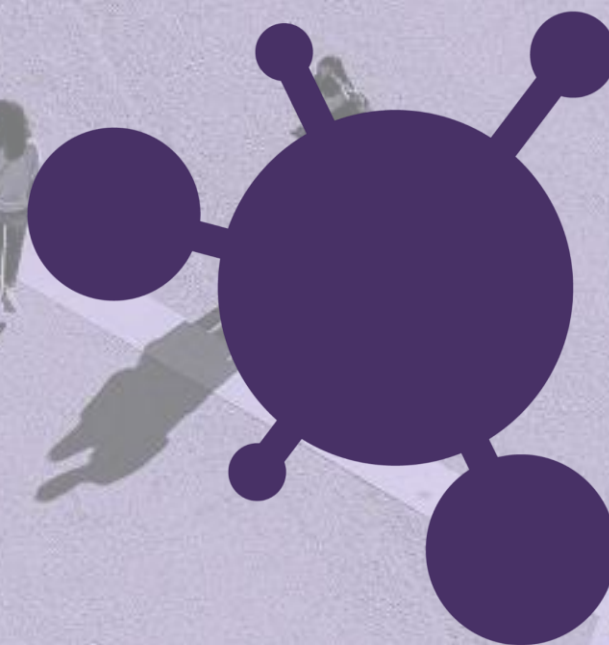
3. General Perceptions

4. Innovations

5. Misinformation



1. Vaccine Hesitancy

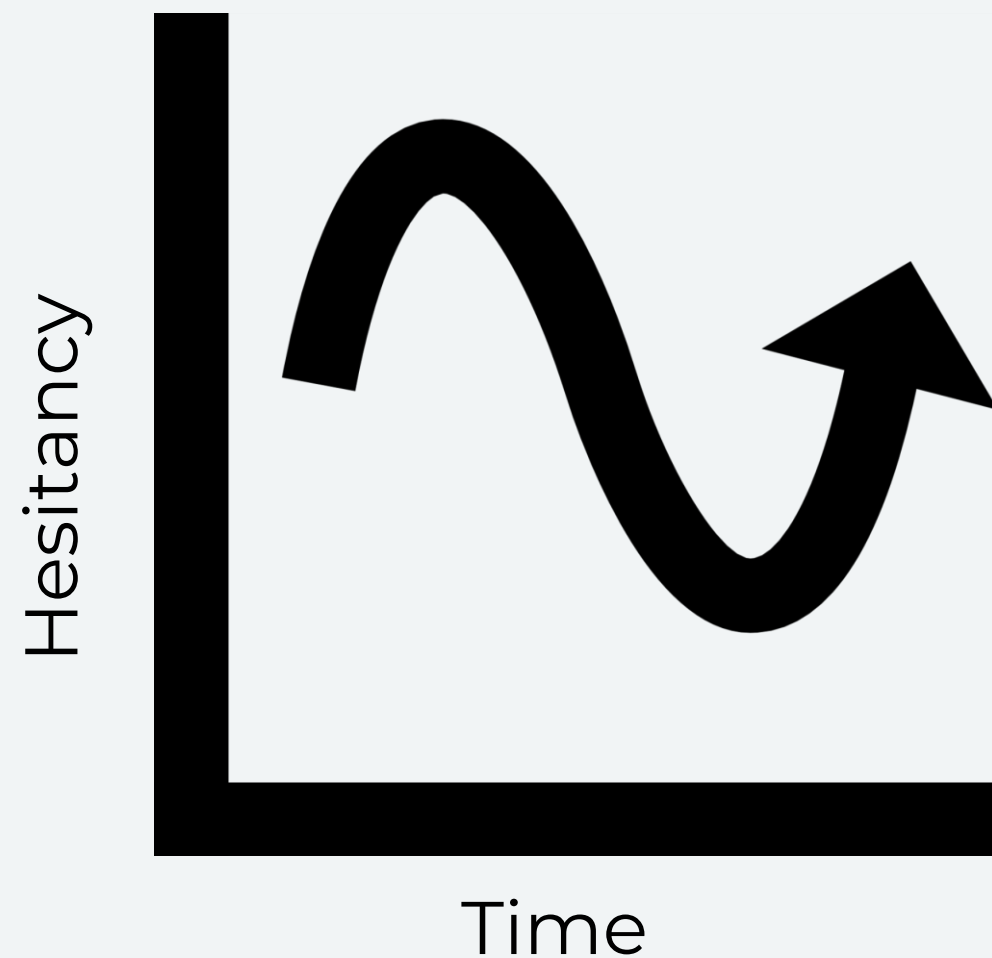


Vaccine Hesitancy

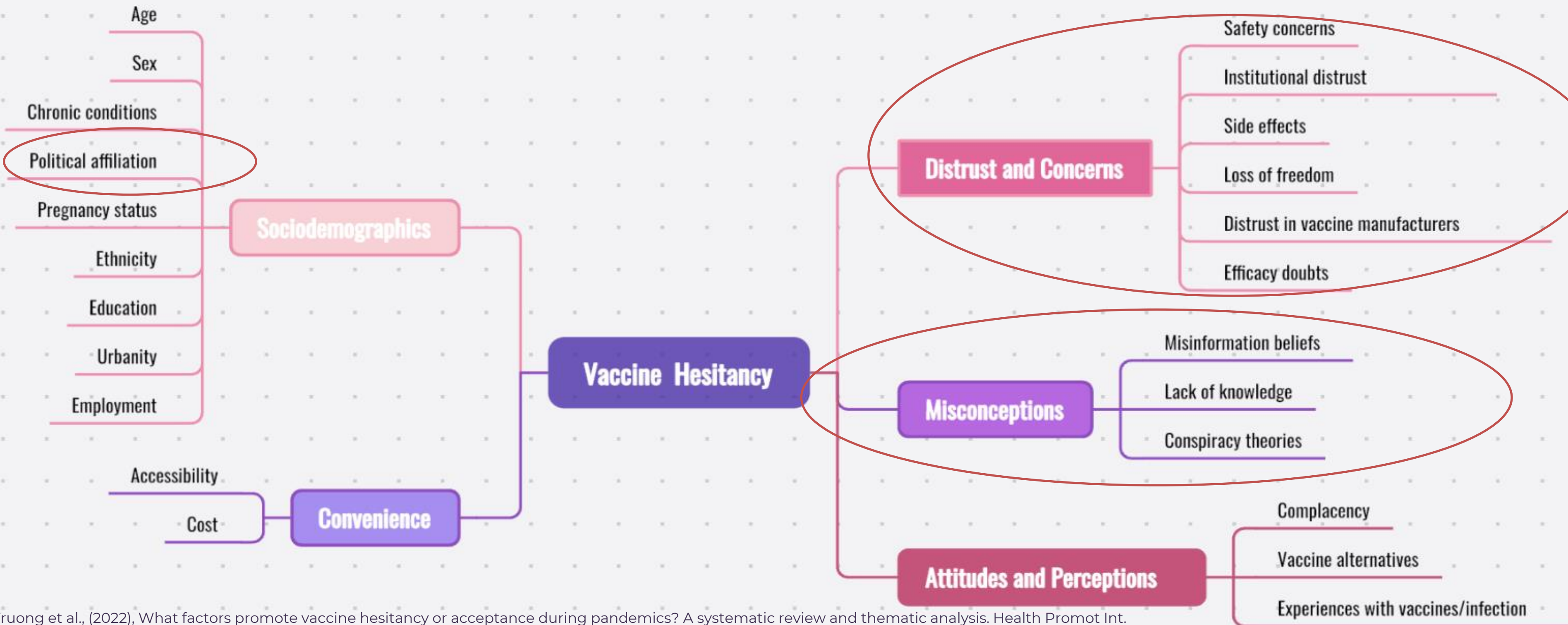
“delays in acceptance or refusal of safe vaccines despite availability of vaccine services.

Vaccine hesitancy is complex and context specific, varying across time, place and vaccines.”

MacDonald NE; SAGE Working Group on Vaccine Hesitancy (2015), Vaccine hesitancy: Definition, scope and determinants. Vaccine.



Contributing Factors



Truong et al., (2022), What factors promote vaccine hesitancy or acceptance during pandemics? A systematic review and thematic analysis. Health Promot Int.

Wang et al., (2022), Mapping global acceptance and uptake of COVID-19 vaccination: A systematic review and meta-analysis. Commun Med.

Zang et al., (2023), Applications of social media and digital technologies in COVID-19 vaccination: Scoping review. J Med Internet Res.

Growing State of Mis/Dis-information

Failure of soft and hard bans of misinformation: **engagement still increases**

Infodemics

Misinformation engaged with **more than real news**
2,000+ COVID-19 rumors shared in 2020
Echo chambers

Will AI contribute to the infodemic or be used to detect, remove, and debunk misinfo?

Acemoglu et al., (2021), Misinformation: Strategic sharing, homophily, and endogenous echo chambers. National Bureau of Economic Research
Broniatowski et al., (2023), The efficacy of Facebook's vaccine misinformation policies and architecture during the COVID-19 pandemic. Sci Adv.
Edelson et al., (2021), Understanding U.S. engagement with (mis)information news sources on Facebook. Association of Computing Machinery
Islam et al., (2020), COVID-19-related infodemic and its impact on public health: a global social media analysis. Am J Trop Med Hyg.

Susceptibility to Mis/Dis-information

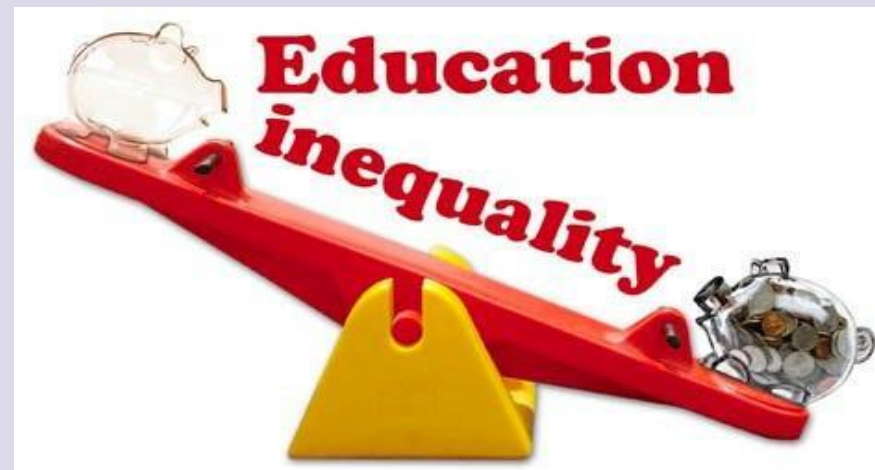
**Corrective
information**



Likely conservative ideology



Younger age



Lower SES



Mental Health Conditions

Reduced compliance



Ecker et al., (2022), The psychological drivers of misinformation belief and its resistance to correction. Nature Reviews Psychology.

Regazzi et al., (2023), Conspiracy beliefs, COVID-19 vaccine uptake and adherence to public health interventions during the pandemic in Europe. Eur J Public Health.

Zhao et al., (2023), The prevalence, features, influencing factors, and solutions for COVID-19 vaccine misinformation: Systematic review. JMIR Public Health Surveill.

Continued influence effect

Belief in misinformation can adversely affect judgements and decision-making.

Even after corrections are made, this misinformation continues to influence people's reasoning



Covid-19 Vaccinations Administered

COVID-19 vaccine doses administered by manufacturer.

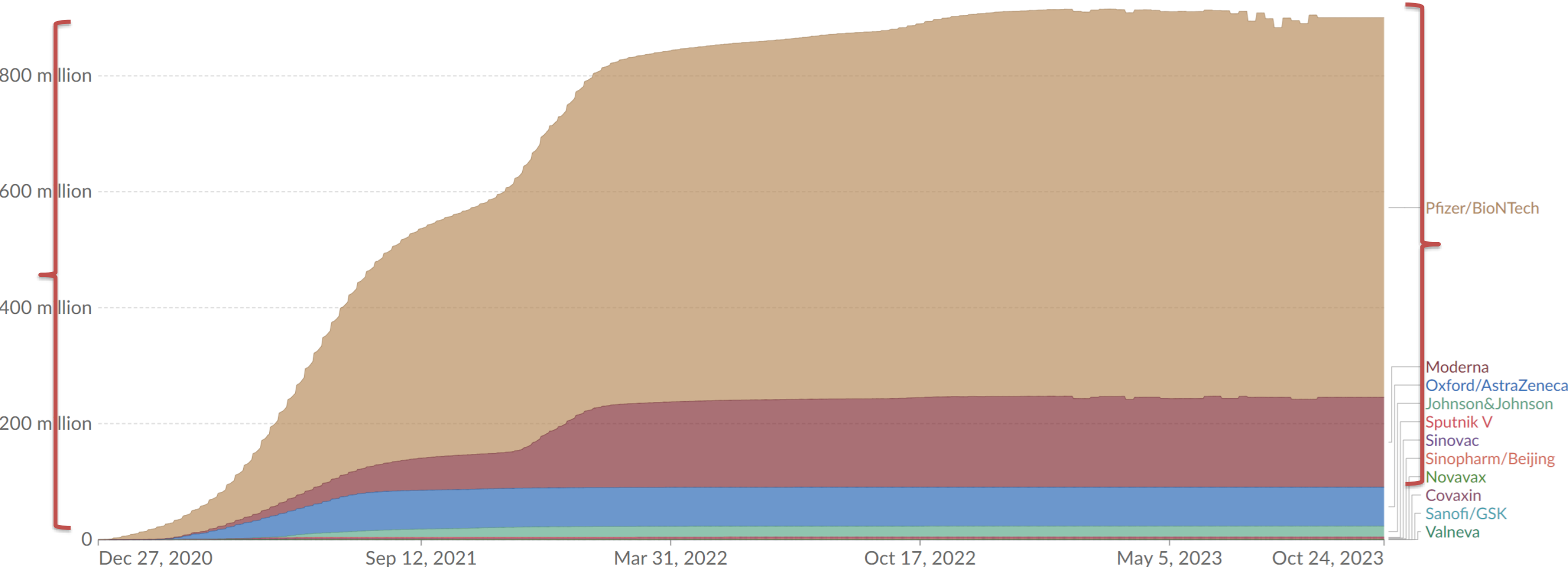
All doses, including boosters, are counted individually.

Our World in Data

Table Chart

Edit countries and regions

Settings



Play time-lapse

Dec 27, 2020

Oct 24, 2023

Data source: Official data collated by Our World in Data - [Learn more about this data](#)

OurWorldInData.org/covid-vaccinations | CC BY

mRNA Covid-19 Vaccines Around the World

Pfizer-BioNTech
165 COUNTRIES



Moderna
114 COUNTRIES





1.1. Global Social Listening I: mRNA Treatment & Technology

Methodology

Data Collection:

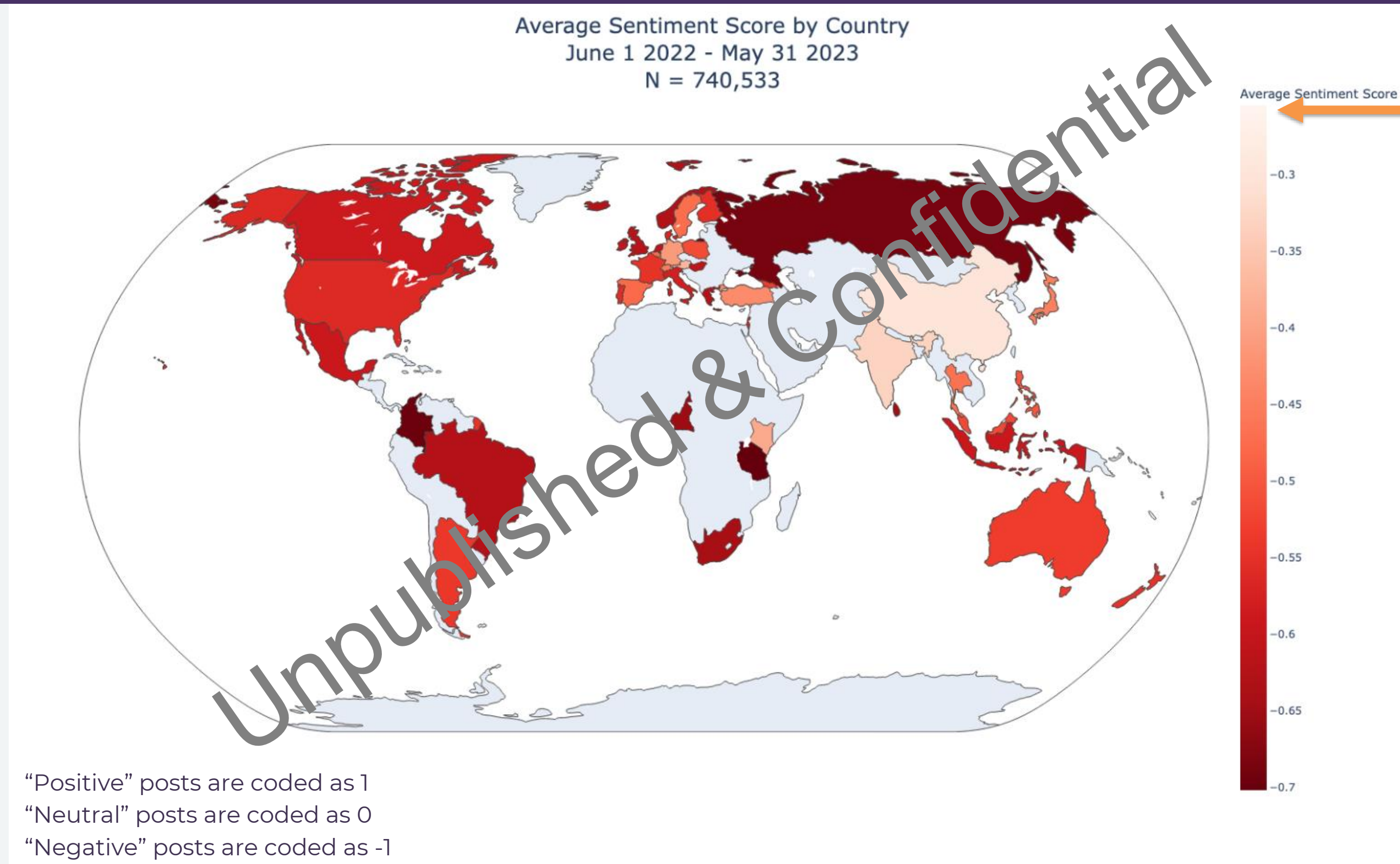
- Sourced mRNA related Twitter data (N = 740,533) from June 1, 2022, to May 31, 2023

Analysis Framework:

- Based on WHO's 3C (Confidence, Complacency, Convenience) Model of Vaccine Hesitancy and Vaccine Confidence Index™ (VCI):
 - Measures include “safety”, “effectiveness”, “importance”, and “trust in authority/manufacturer/healthcare professionals”
 - General sentiment analysis

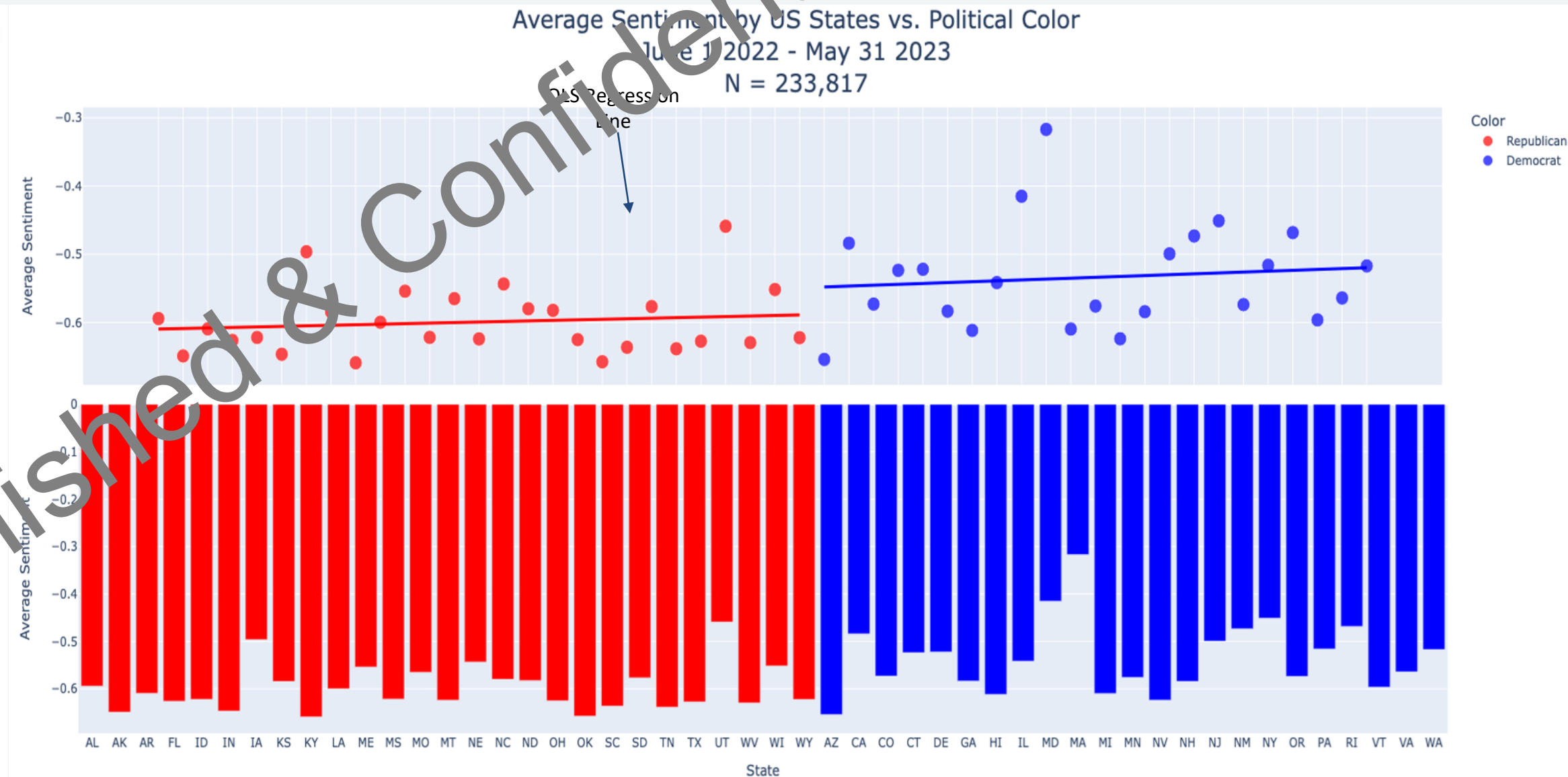
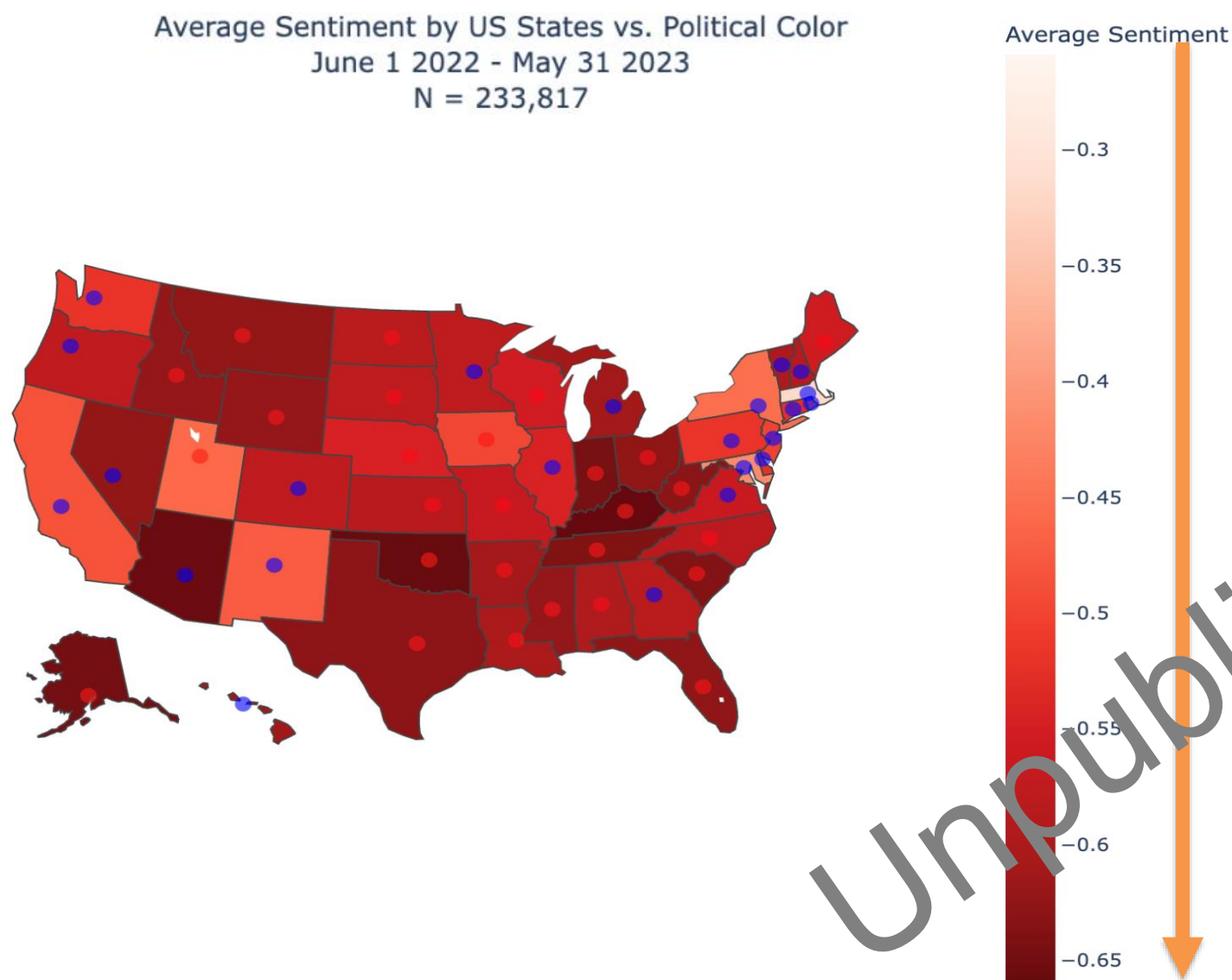


Global Sentiment around mRNA



US Sentiment around mRNA

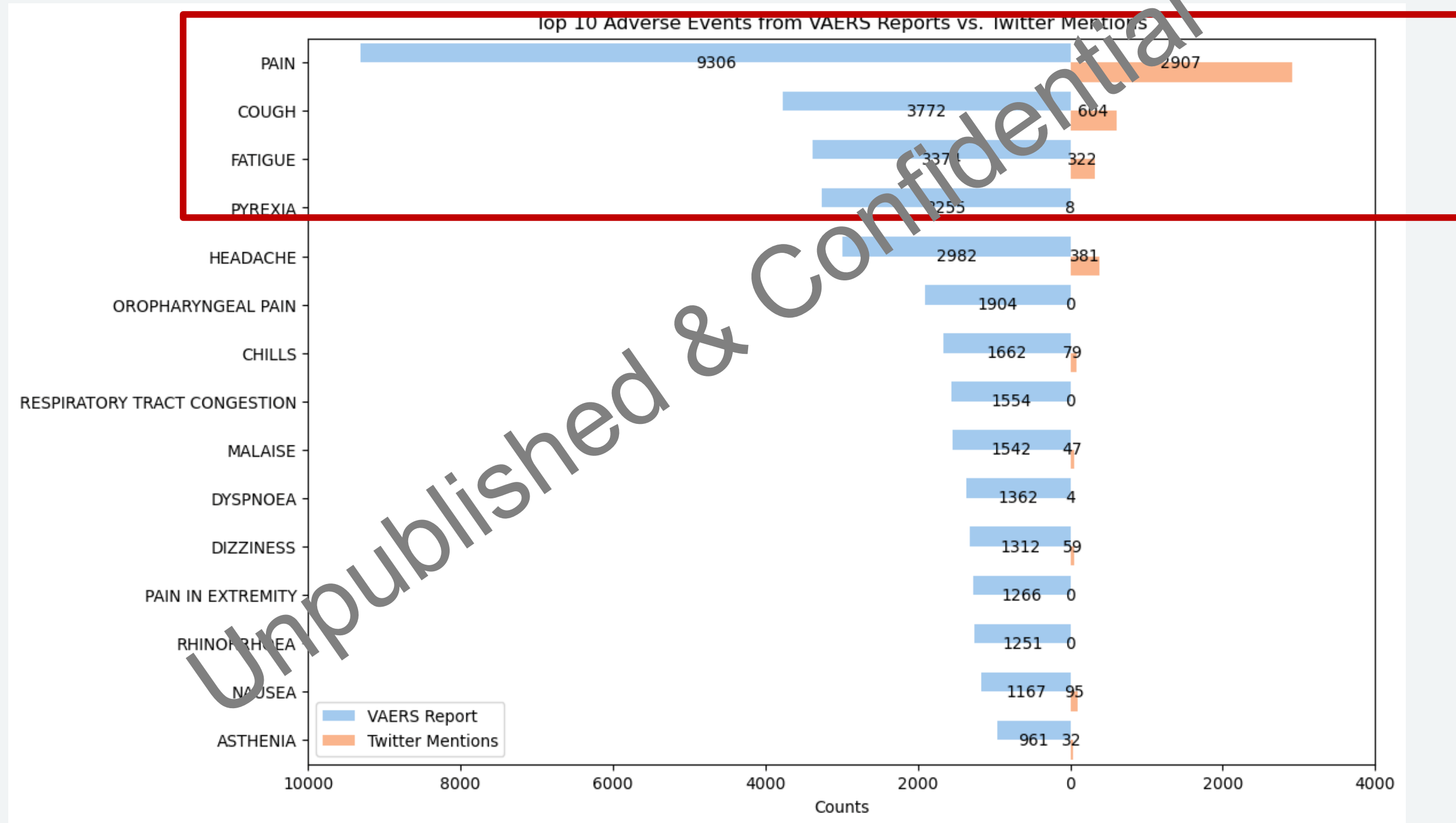
Negative sentiment toward mRNA technology is more prevalent in **Republican-majority states** than in **Democratic-majority states**.



Point-Biserial Correlation: -0.4783, P-Value: 0.0006

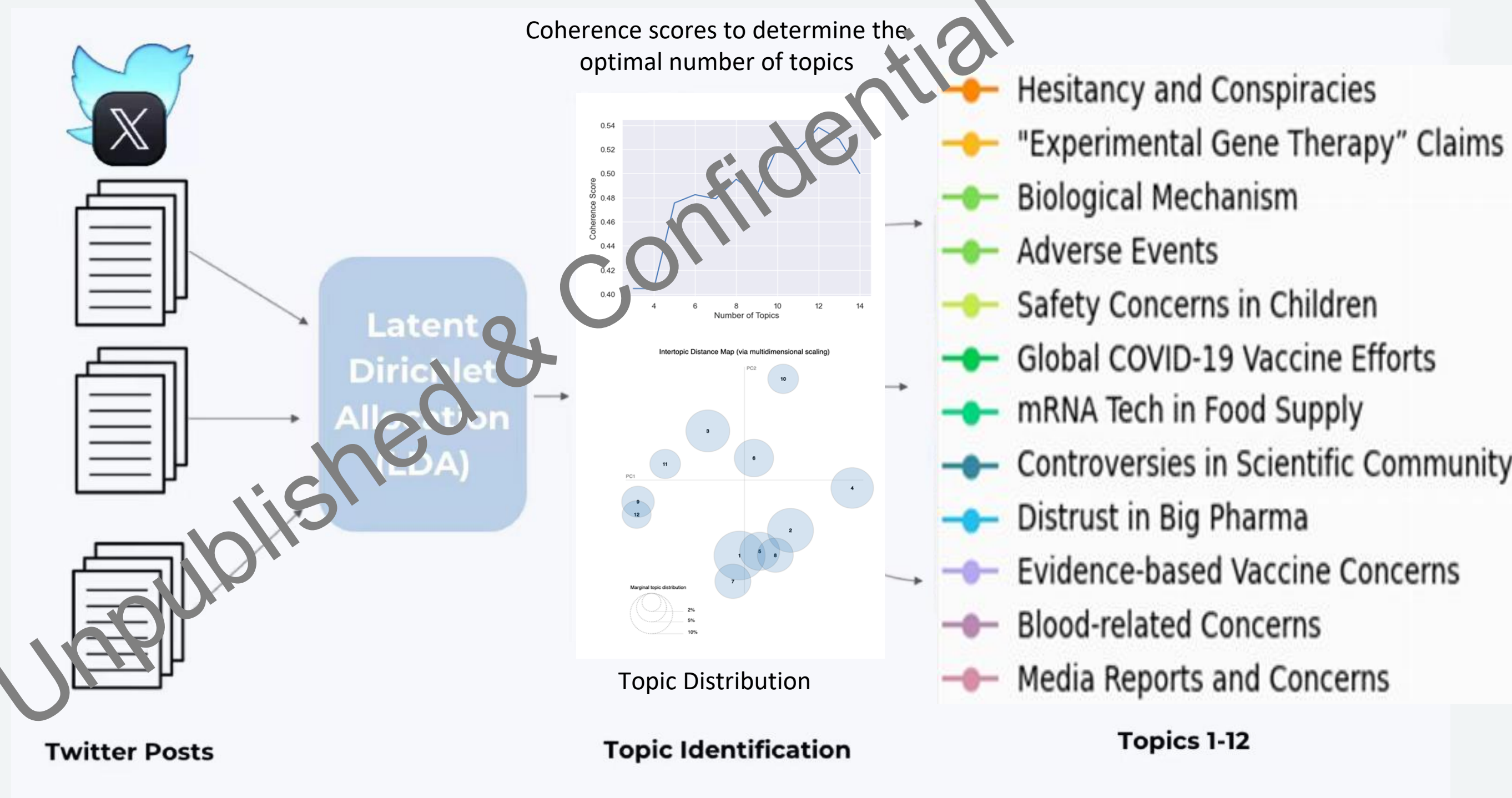
The sentiment score of the Blue states is significantly higher than that of the Red states

VAERS Reported Adverse Events vs. Twitter Mentions

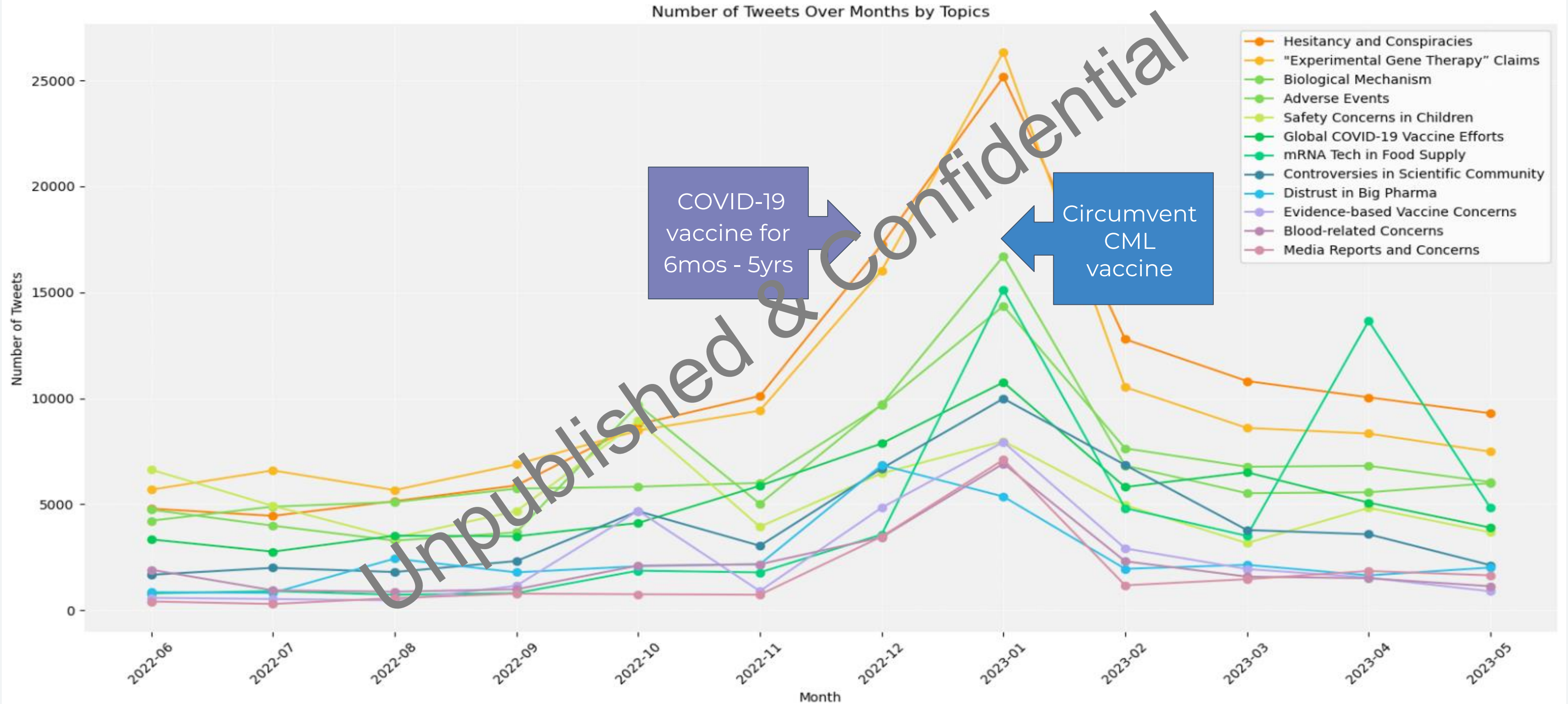


Topic Modelling

- An unsupervised machine learning technique to detect **underlying topics** in a collection of documents (tweets)
- Uncover **hidden thematic structures** in data, providing meaningful insights and **simplifying large volumes of text**



Topic Modelling



Most Salient Words by Topic

Hesitancy and Conspiracies



"Experimental Gene Therapy" Claims



Biological Mechanism



Adverse Events



Safety Concerns in Children



Global COVID-19 Vaccine Efforts



mRNA Tech in Food Supply



Controversies in Scientific Community



Distrust in Big Pharma



Evidence-based Vaccine Concerns



Blood-related Concerns



Media Reports and Concerns



Unpublished & Confidential

Twitter Examples: Conspiracies

@ [REDACTED]: This is horrible. Especially in light of Pfizer's own data that, in their trials, **44 per cent of pregnant women who took the mRNA injections lost their babies.**

(Canada, 18/8/2022 0:32)

@ [REDACTED]: Well well. Canadians still have no idea what Canadians paid to Pfizer in the **secret deals brokered by @JustinTrudeau for stale mRNA....**

(US, 26/9/2022 21:34)



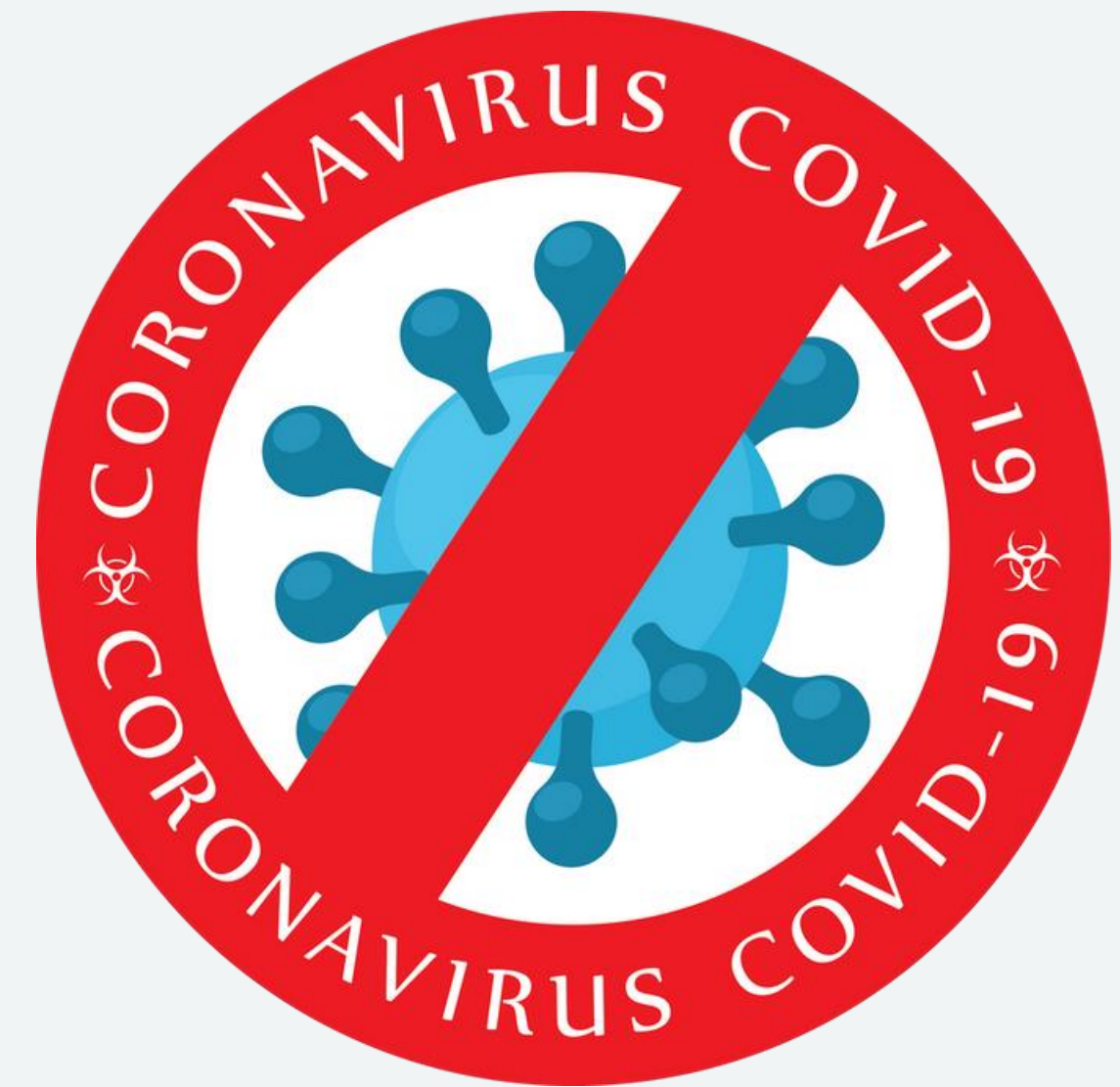
Twitter Examples: Safety

@ [REDACTED]: **mRNA vaxx-induced bacterial pneumonia.** Common symptoms: sore throat; feeling tired; headache; fever; plus, slowly worsening cough that may last for weeks or months. **May be deadly in people with weakened natural immunity**

(US, 14/11/2022 4:51)

@ [REDACTED]: The Moderna mRNA-1273 vaccine was **safe and prompted a robust immune response in children** aged 6 months, 5 years during Omicron circulation.

(Germany, 14/11/2022 2:35)



Twitter Examples: Distrust in Big Pharma

@ [REDACTED]: I distrust & despise pharmaceutical companies, by the way. They profit from sickness & people's fear of death...

(US, 31/12/2022 23:16)

@ [REDACTED]: How many of those that took **Pfizer** and **Moderna** were aware that they actually used a new technology with **no long term safety data** that injects synthetic mRNA code that instructs the body to produce synthetic spike protein?

(US, 19/12/2022 2:09)



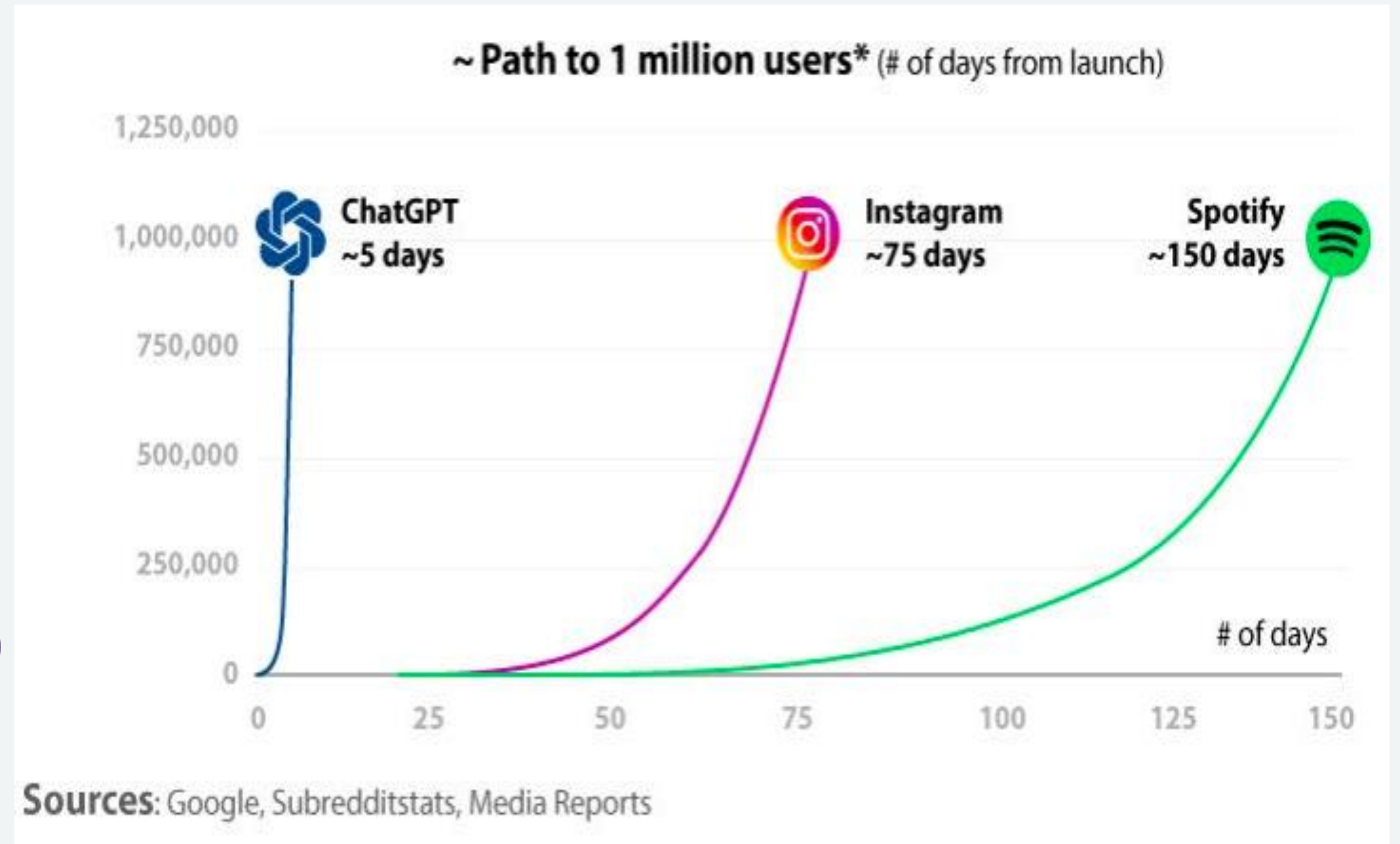


2. AI & Large Language Models



Global Surge of LLMs

- Launch of OpenAI's ChatGPT in **Nov 2022** invigorated public and private interest in LLMs and their applications
- **Generative AI** could increase global GDP by 7% (~\$7 trillion) in next 10 years



AI & Machine Learning

The ability of computers to process high volumes of data to **identify patterns** and **make decisions**

Artificial Intelligence

The theory and development of computer systems to perform tasks normally requiring human intelligence

Machine Learning

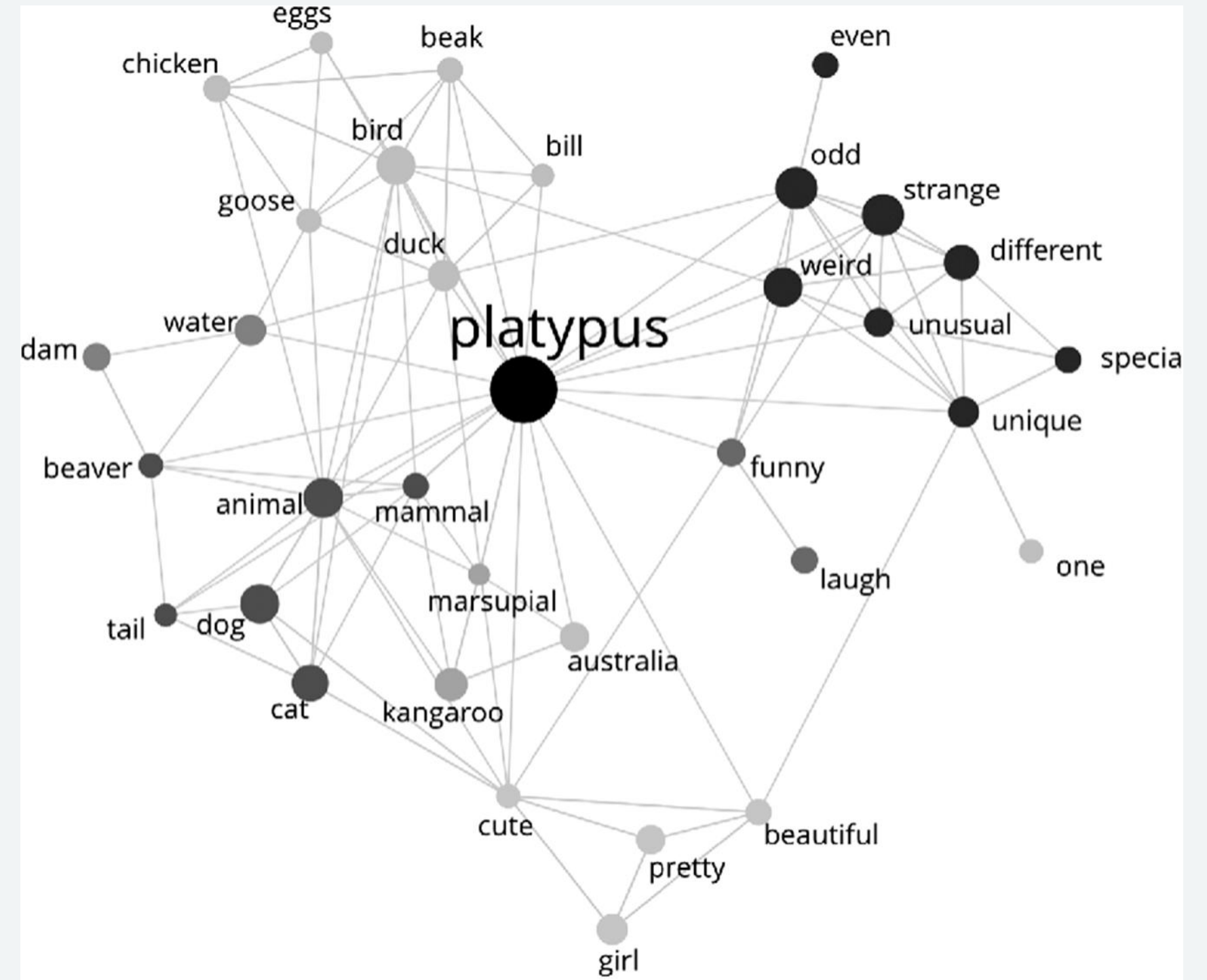
Gives computers “the ability to learn without being explicitly programmed”

Deep Learning

Machine learning algorithms with brain-like logical structures of algorithms called neural networks to **automatically learn from data**

Large Language Models

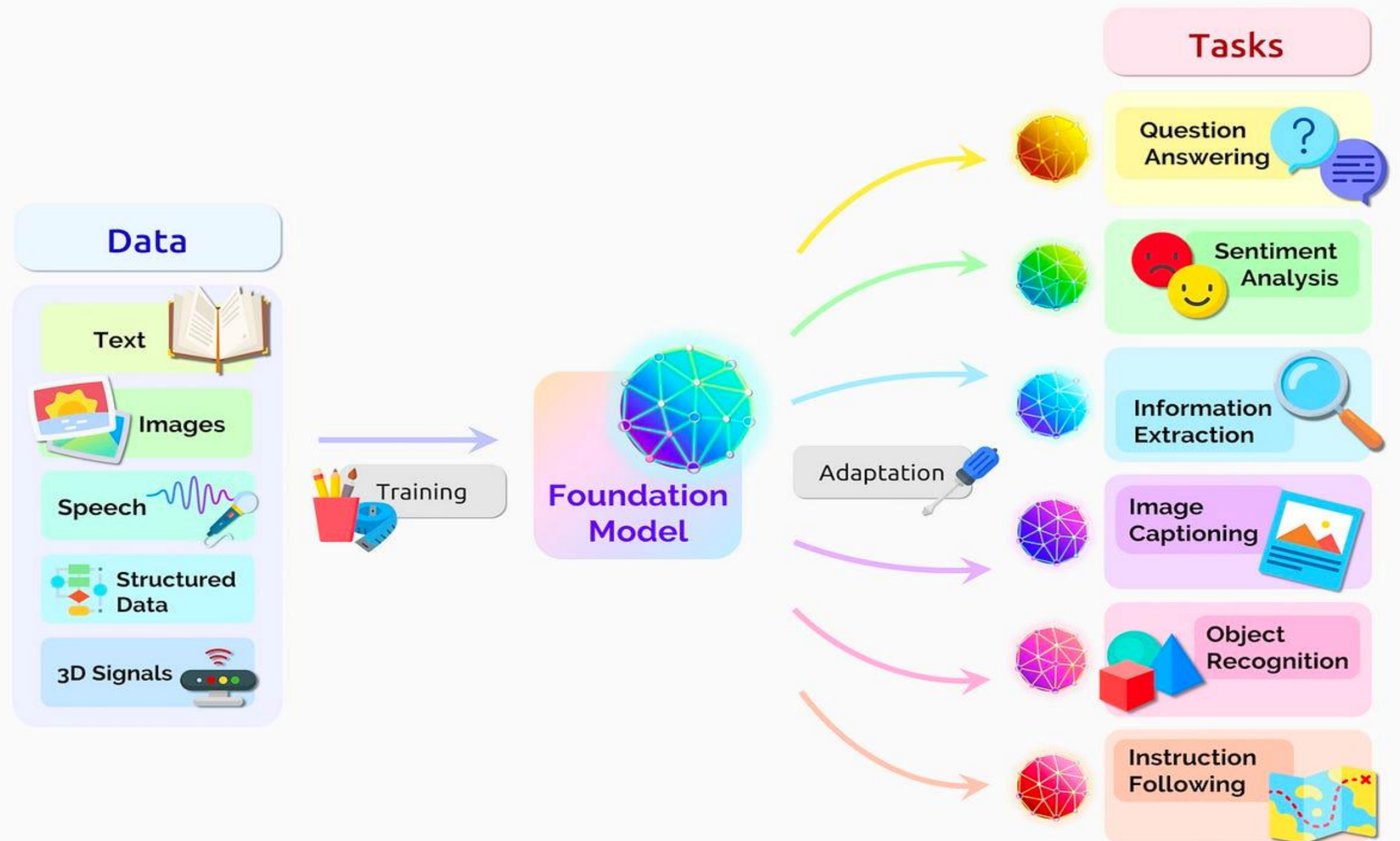
By analysing high volumes of text data, **LLMs form networks** that represent **statistical frequencies** and **relationships of words** and **concepts**



Deyne et al., (2017), Large-scale network representations of semantics in the mental lexicon. Big Data in Cognitive Science.

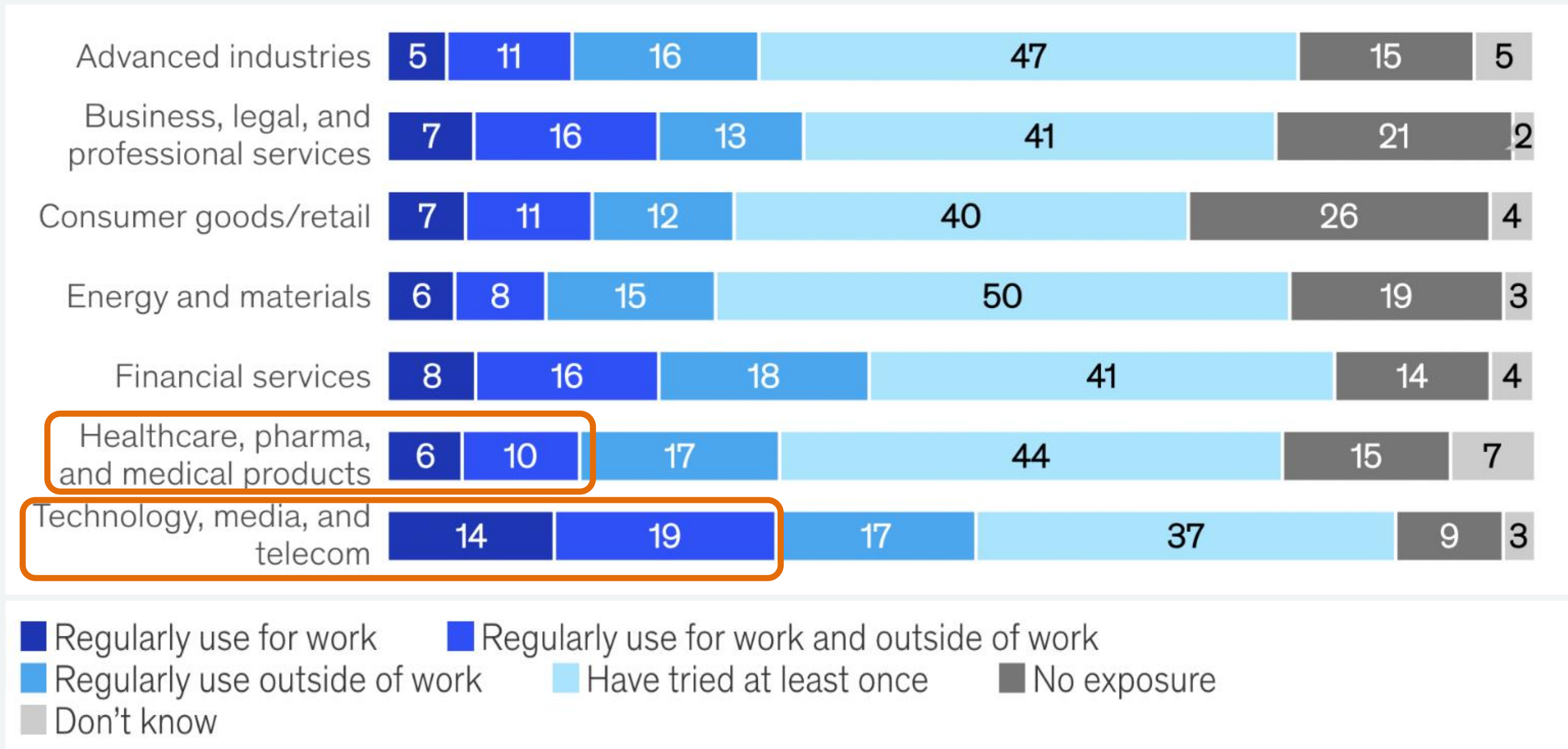
Generative AI

AI that creates **new content** like **text, images, or music**



Generative AI at Work

22% already use generative AI for work



LLMs for Vaccine Acceptance



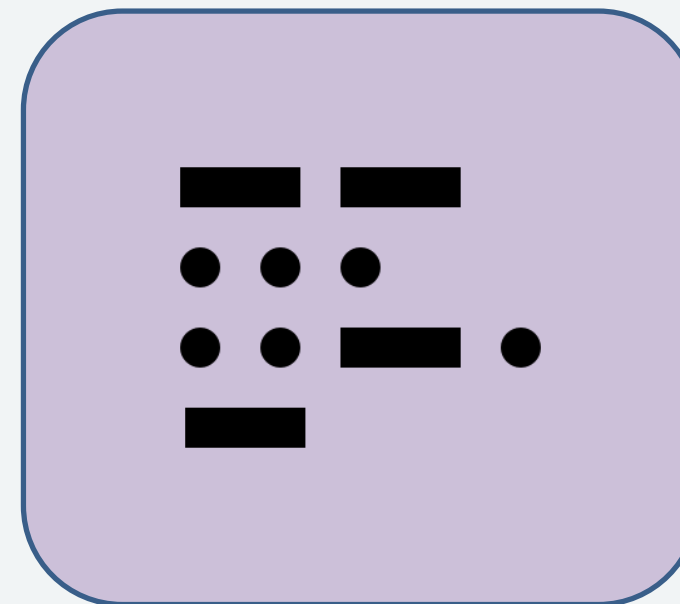
Information Retrieval



Sentiment Analysis



Text, Image, Music
Generation



Code Generation



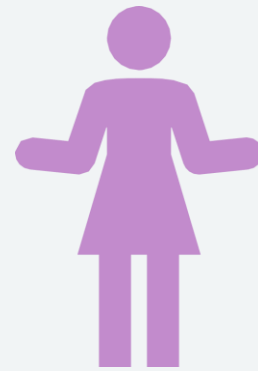
Chatbots



3. General Perceptions of AI



Surveying the Public



Support for AI to assist physicians as high as **94%**; benefits in **access** and **efficiency**

Confidence **varies by application**; general familiarity with AI, but **not clinical AI itself**

Concerns of **privacy, inaccuracies, lack of humanistic features**; only **10-36%** would use AI **without provider oversight**

Strong preference for human provider opinions and oversight

Young et al., (2021), Patient and general public attitudes towards clinical artificial intelligence: a mixed methods systematic review. Lancet Dig Health.

Physicians' Opinions

A partner not a competitor: 68% disagree AI will replace physicians



Over **60%** of physicians are **positive** about AI, but just **10-30% had used in practice**

Lack of empathy, inaccuracies, and unpredictability cited as concerns; LMIC under sampled



3.1. Global Social Listening II: Perceptions on AI



Methodology

Data Collection:

- 235,785 global AI-related Twitter posts from Oct 1st, 2022, to June 30th, 2023

Analysis:

- Sentiment and eight common dimensions of AI confidence were measured
- Model trained using LLMs and manual coding

Unpublished & Confidential

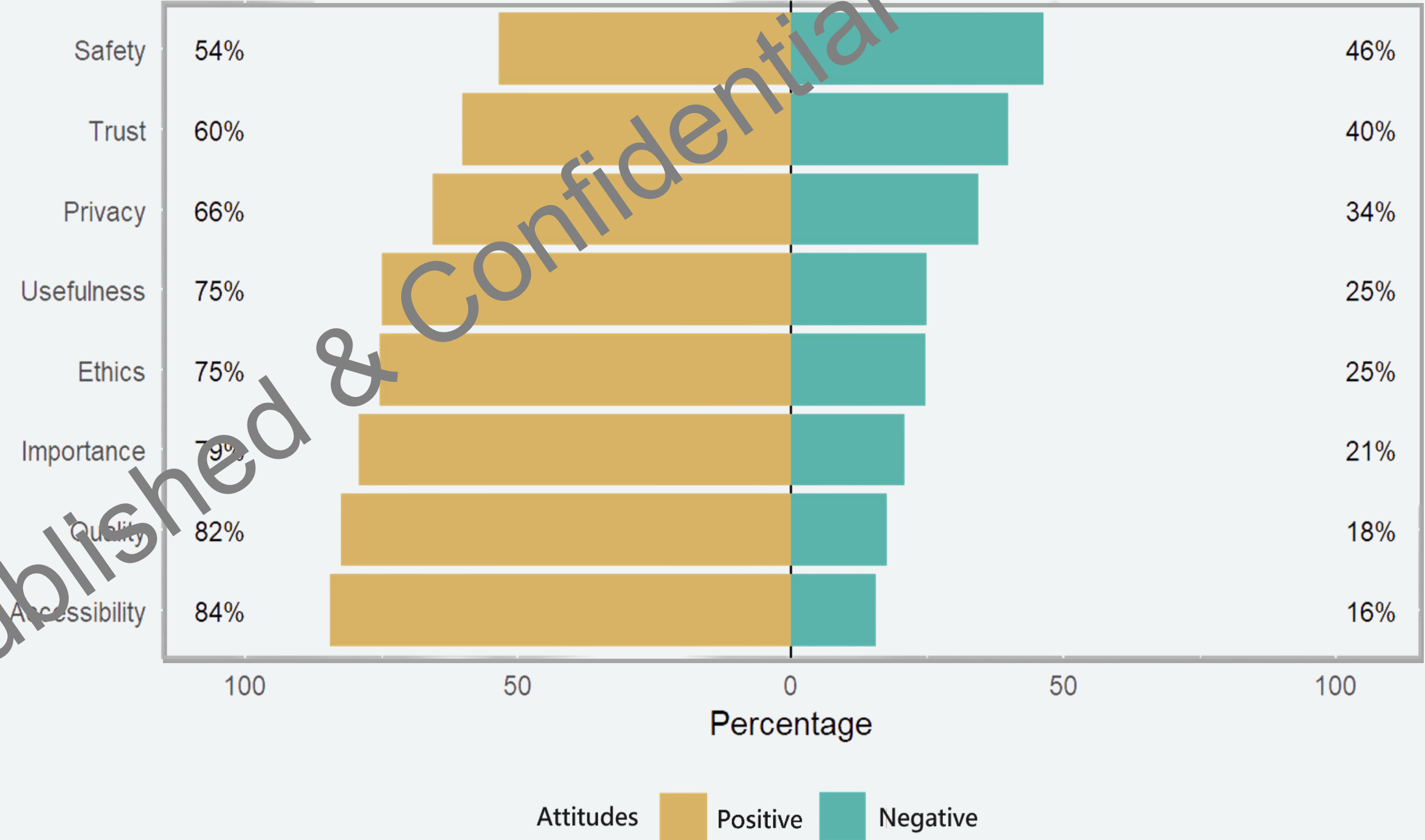


Global Sentiment around AI

Eight indices of public attitudes towards AI.

Individuals are **least confident that AI is safe** but **most confident that AI is accessible** and **easily integrated into daily life.**

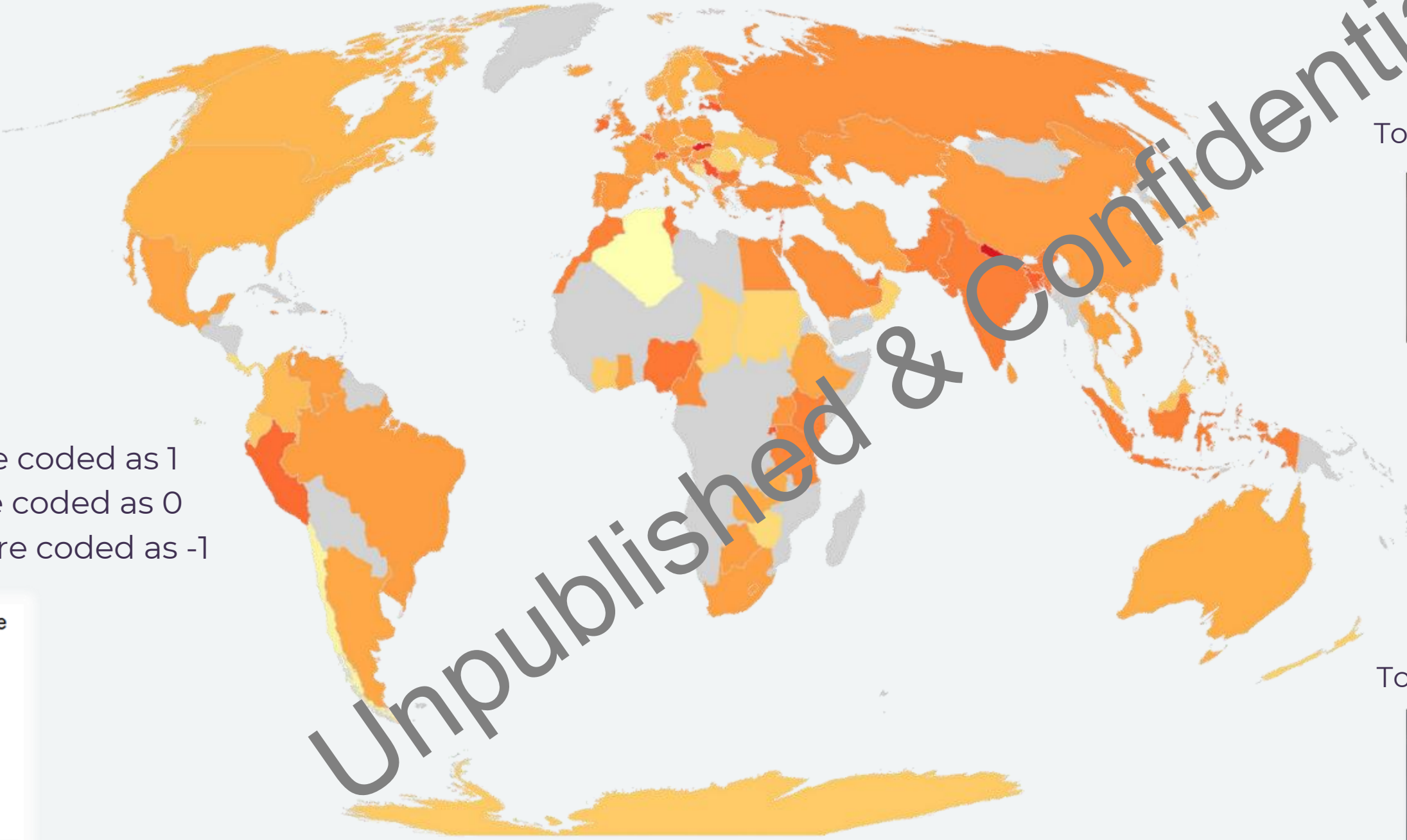
All indices reflect an overall confidence in AI.



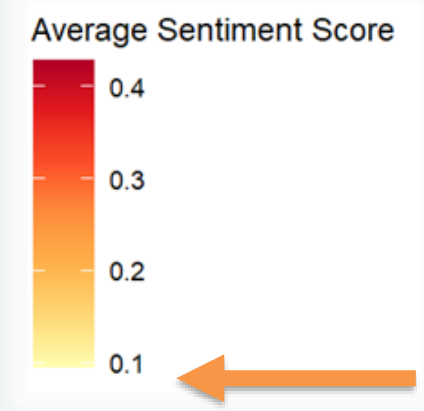
Data: 235,785 global AI-related Twitter posts from Oct 1st, 2022, to June 30th, 2023

Global Sentiment around AI

Average Sentiment Score by Country



“Positive” posts are coded as 1
“Neutral” posts are coded as 0
“Negative” posts are coded as -1



Top 5 Countries with High Sentiment Score

Country	Average Sentiment Score
Malta	0.429
Nepal	0.381
Slovakia	0.364
Luxembourg	0.322
Lebanon	0.318

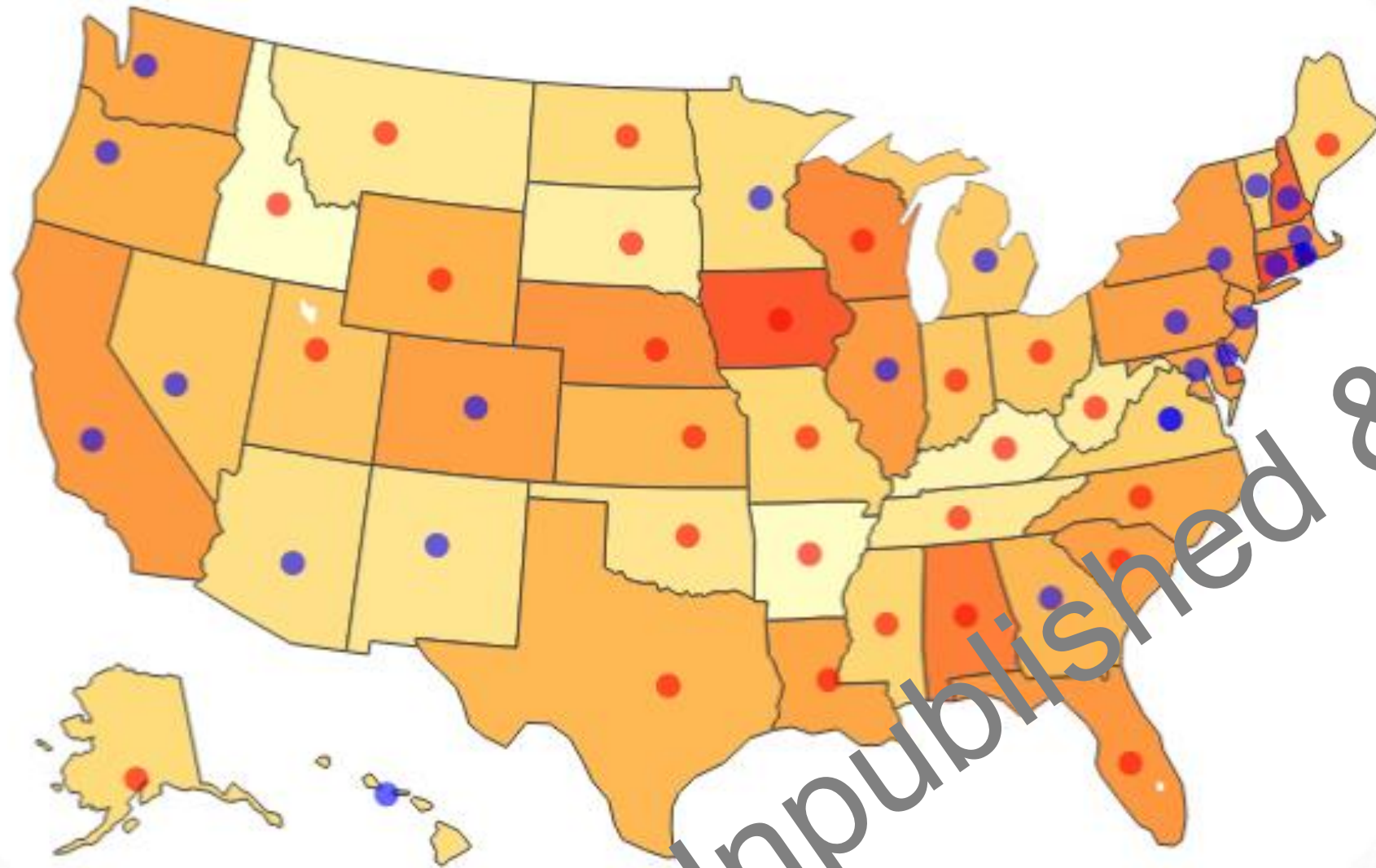
Top 5 Countries with Low Sentiment Score

Country	Average Sentiment Score
Algeria	0.095
Chile	0.111
Bosnia and Herzegovina	0.139
Qatar	0.141
Costa Rica	0.143

Data: 235,785 global AI-related Twitter posts from Oct 1st, 2022, to June 30th, 2023

US Sentiment around AI

Darker colored states reflect a higher average positive sentiment towards AI



Point-Biserial Correlation: -0.3519, P-Value: 0.0113

Political affiliation explains 12.4% of the variance of AI confidence by state; sentiment scores are significantly higher in blue states than in red states

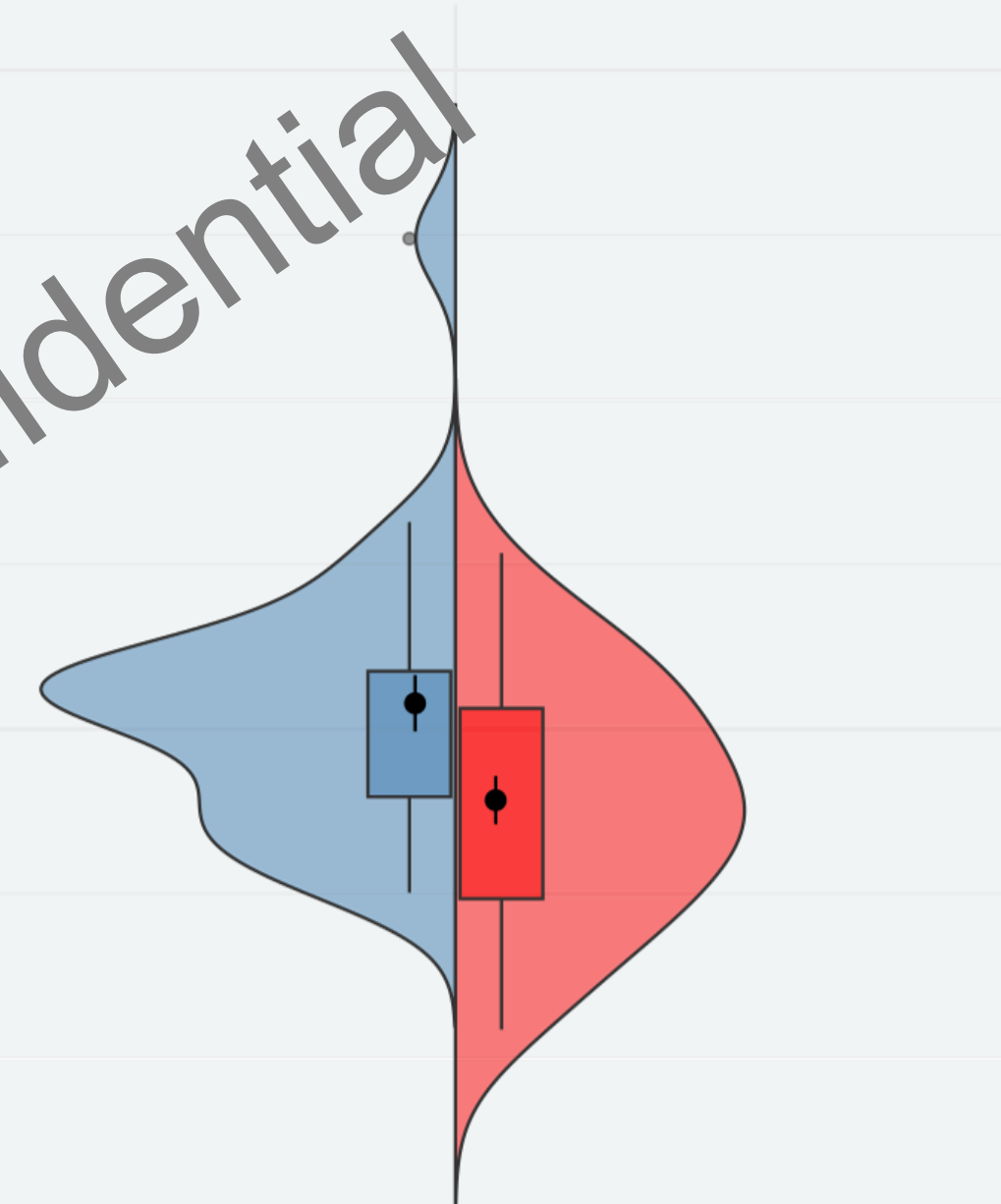
0.4

0.3

Average Sentiment Score

0.2

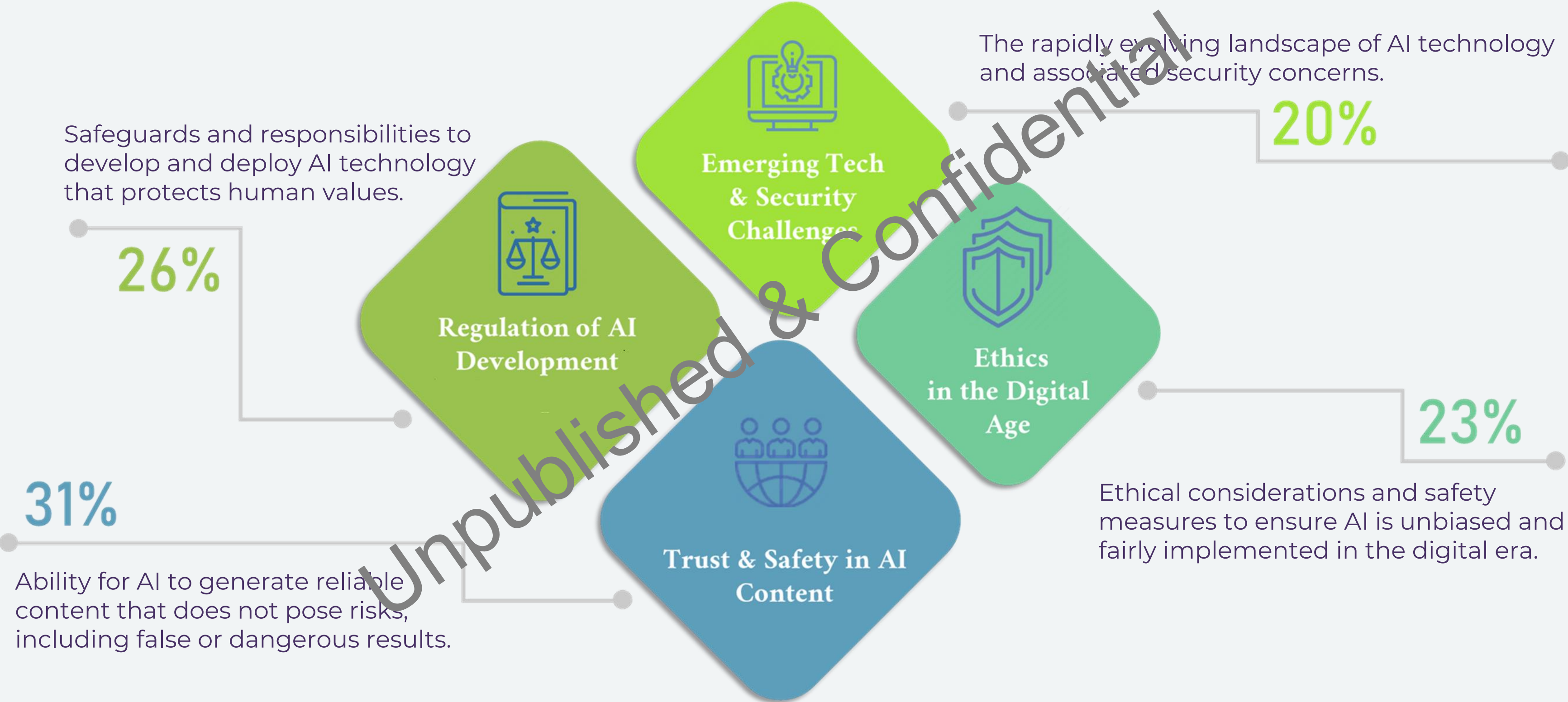
0.1



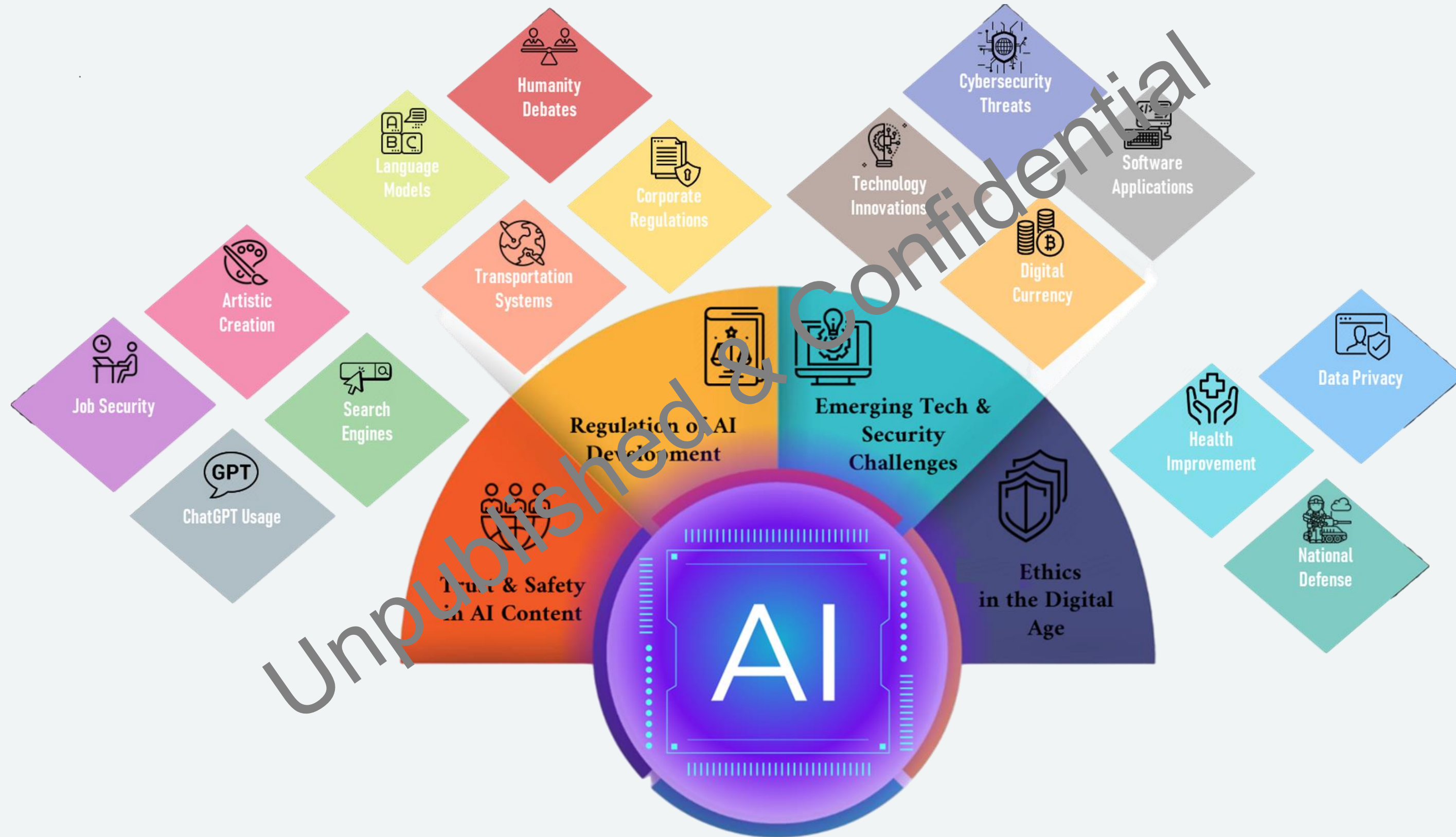
Political Affiliation
Democrat
Republican

Democratic-majority states are significantly **more positive** about AI than **Republican states**

Main Themes



Themes & Topics



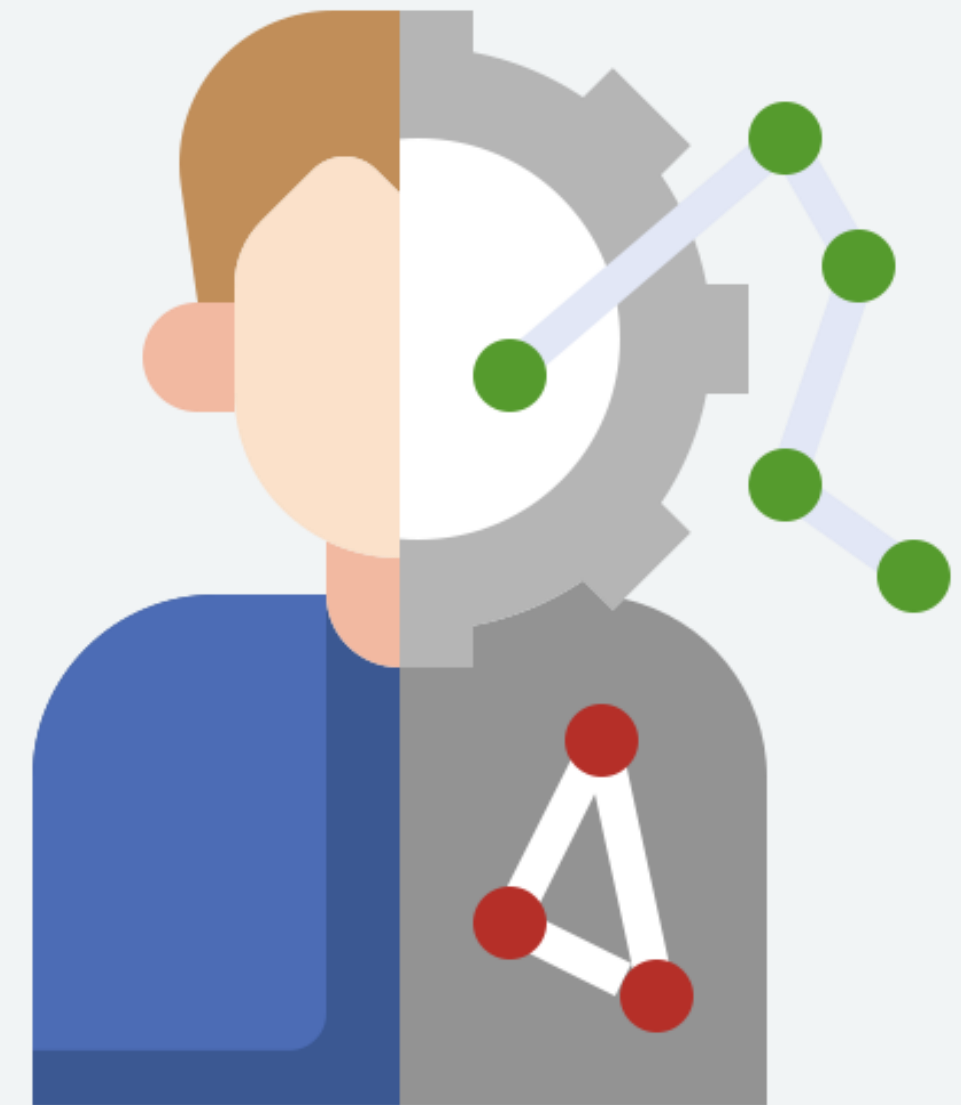
Twitter Examples: Humanity Debates

@ [redacted] ...Some think that we should be afraid of AI being decentralized because it **poses a serious existential risk to humanity** and centralization is safer. Not saying I agree, I'm not sure what the answer is.

(Spain, 20/03/2023 2:36)

@ [redacted]: ...The fact that there is **such a massive debate over humanity's safety** is a testament to how **amazing and scary AI is at the same time**. what a time to be alive. Which side are you on?

(US, 02/04/2023 7:37)



Twitter Examples: Job Security

@ [REDACTED]: **AI is also not close to replacing humans**, it is a great assisting tool not a replacement tool. **Your jobs are safe, for now...**

(Nigeria, 29/05/2023 2:50)

@ [REDACTED]: If you think this shit is **going to take over your job**, you must be really bad at your job.

(Australia, 17/04/2023 8:49)



Twitter Examples: Data Privacy

@ [REDACTED]: How do we strike a **balance** between utilizing data for AI advancements while **safeguarding individuals' privacy rights & preventing misuse of personal information?**

(UK, 04/06/2023 5:49)

@ [REDACTED]: Great potential with great challenges and it includes building a **responsible AI system that is safe, ethical and fair.**

(Philippines, 21/02/2023 11:25)



Twitter Examples: Health Intervention

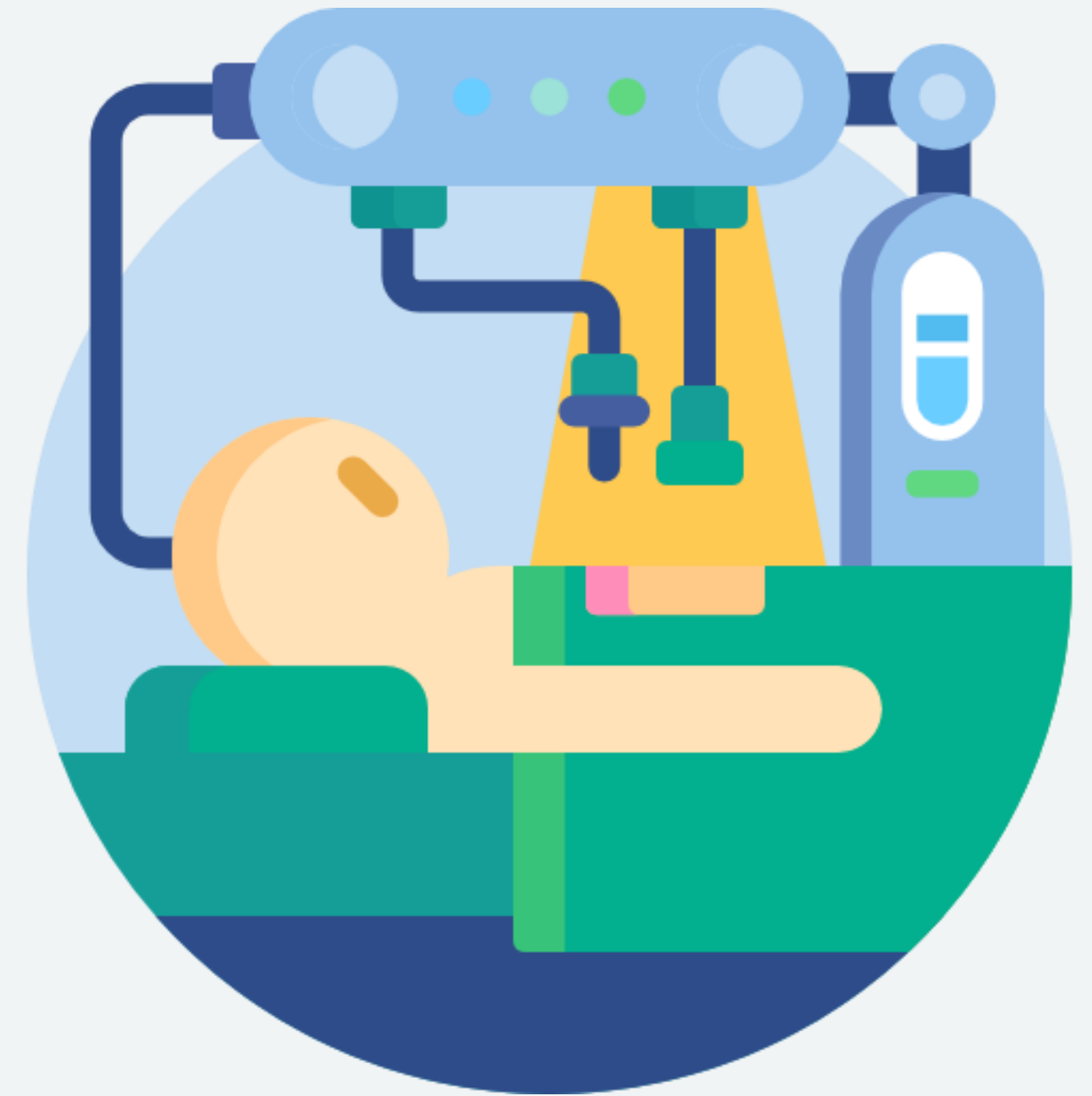
@ [REDACTED]: From **drug and vaccine development and disease identification** to data processing and analysis, **#AI is transforming the pharmaceutical industry**. The benefits of this include higher efficiency, improved safety, and better accuracy.

(US, 07/10/2022 12:00)

@ [REDACTED]: **AI-enhanced drug safety monitoring** systems analyze adverse event data to **identify potential risks** and **improve pharmacovigilance** efforts.

#medtwitter #STEMeducation

(India, 22/05/2023 3:40)





4. AI Driven Innovations



Systematic Review: AI for Health

Empirical evidence on:

- The impact of **AI technology on enhancing health knowledge, attitudes, and behaviours?**

💡 60 studies identified from Jan 2010 – Sept 2023

- Comparing **the effectiveness of AI to human performance** in enhancing health outcomes and automating tasks?



AI Interventions for Health Improvement

Medical Query Response

Quality responses to medical queries

(75.4%, n=10)

Medication prescribing

Precise medicine administration to appropriate disease

(61.8%, n=1)

Mis/Dis-information detection

Capabilities for identifying false statements in brief messages through text analysis and inconsistency flagging

(89.0%, n=1)

Diagnosis precision

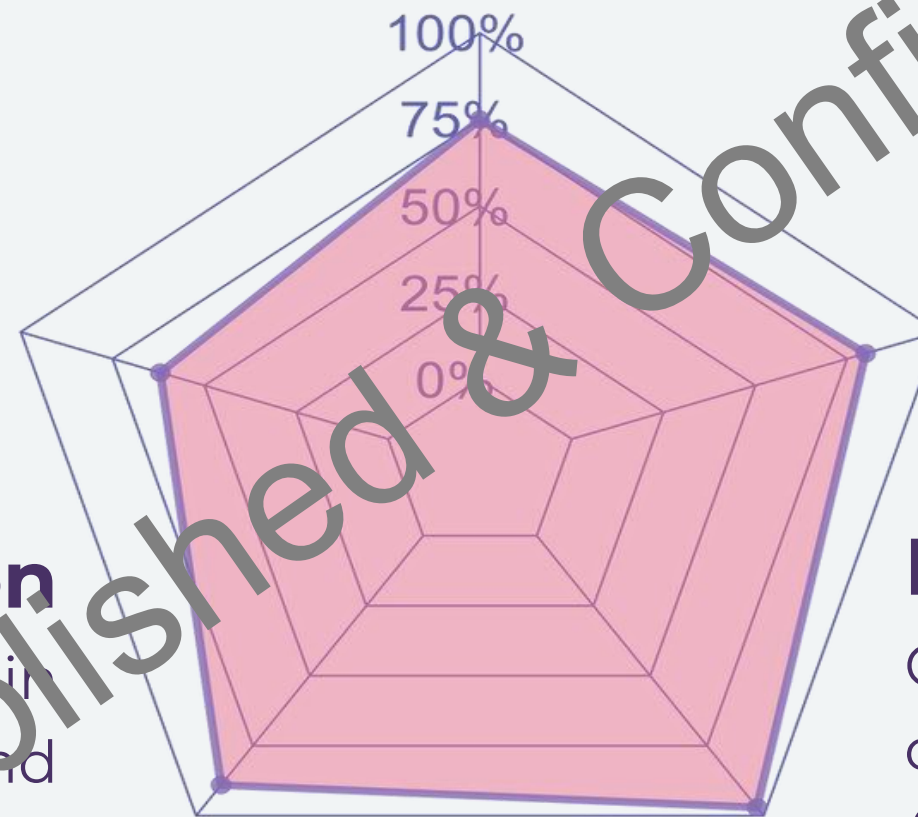
Successful diagnosis and recommendations based on system assessment

(80.0%, n=1)

Emotional awareness

Correct classification of emotion based on 20 scenarios

(97.0%, n=1)

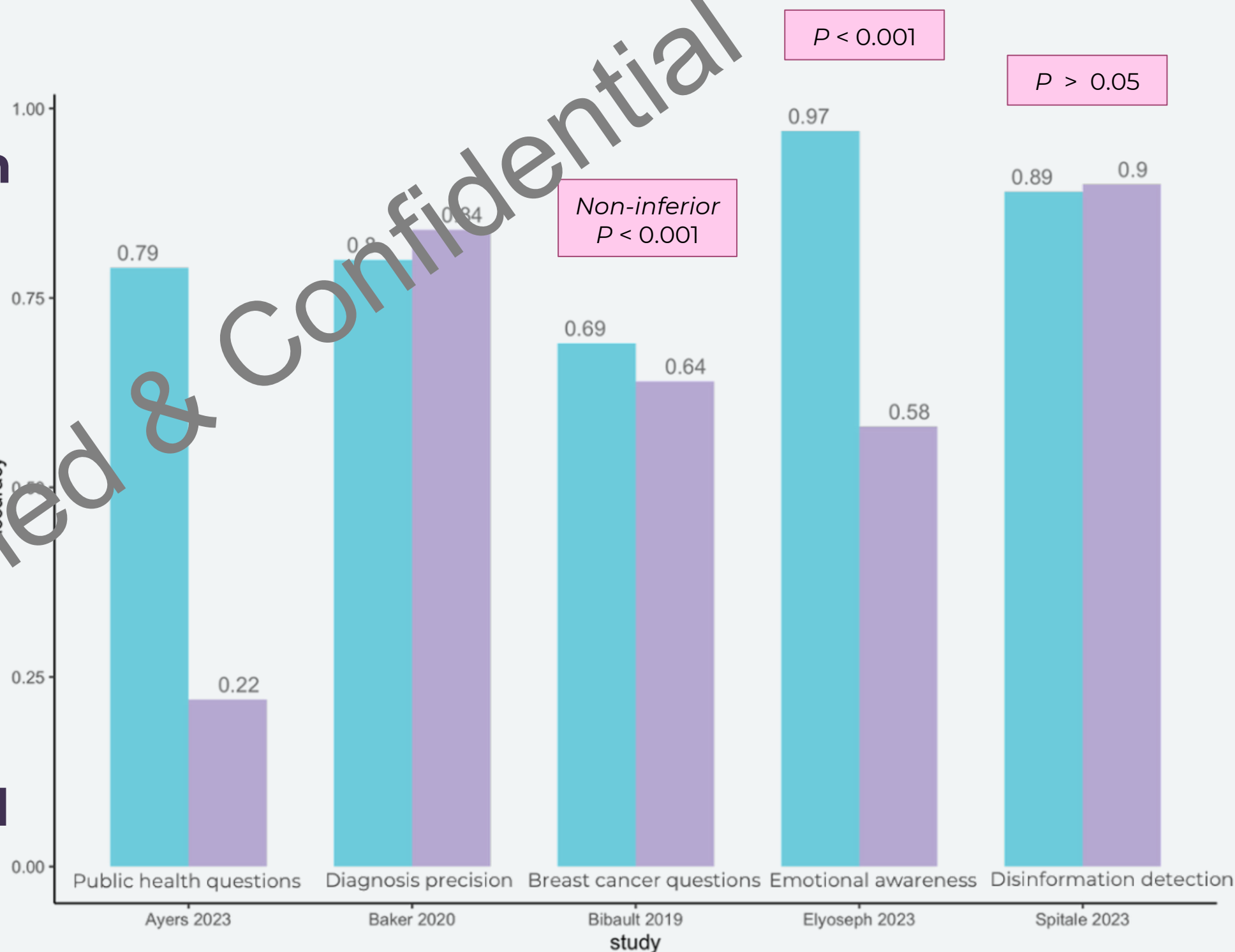


Estimates represent the accuracy or success rate

AI has strengths in **emotional understanding, detecting false statements,** and **diagnostic capabilities** but potential gaps remain, notably in **medication prescribing.**

Comparing AI with Humans

- AI and humans are equally good at recognizing mis/dis-information
- AI's triage and diagnostic precision is just below human doctors
- AI demonstrated stronger emotional awareness and outperforms humans in responding to both specialized and general medical queries

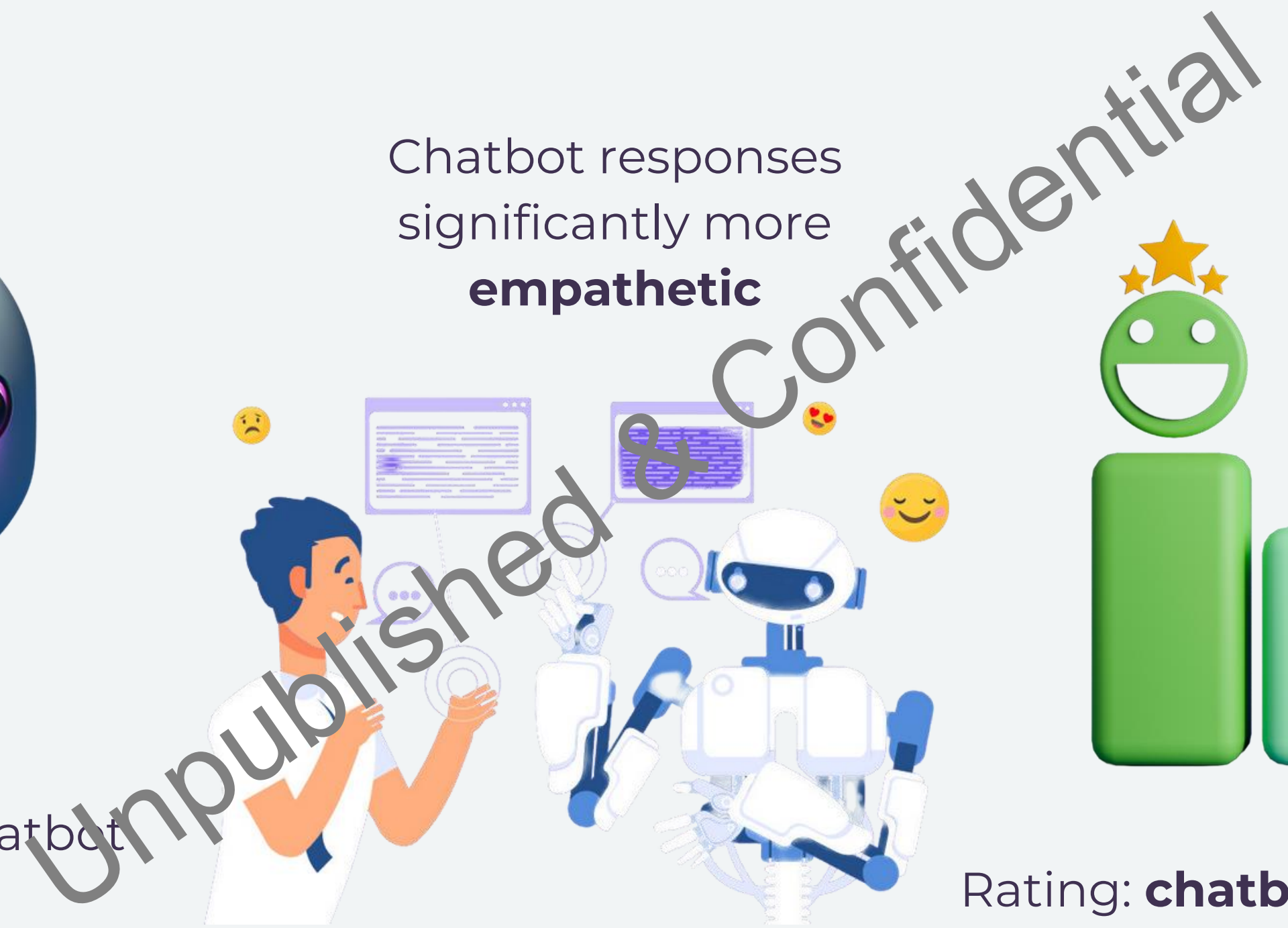


AI vs Human Response to Inquiries



78.6% preferred the chatbot response

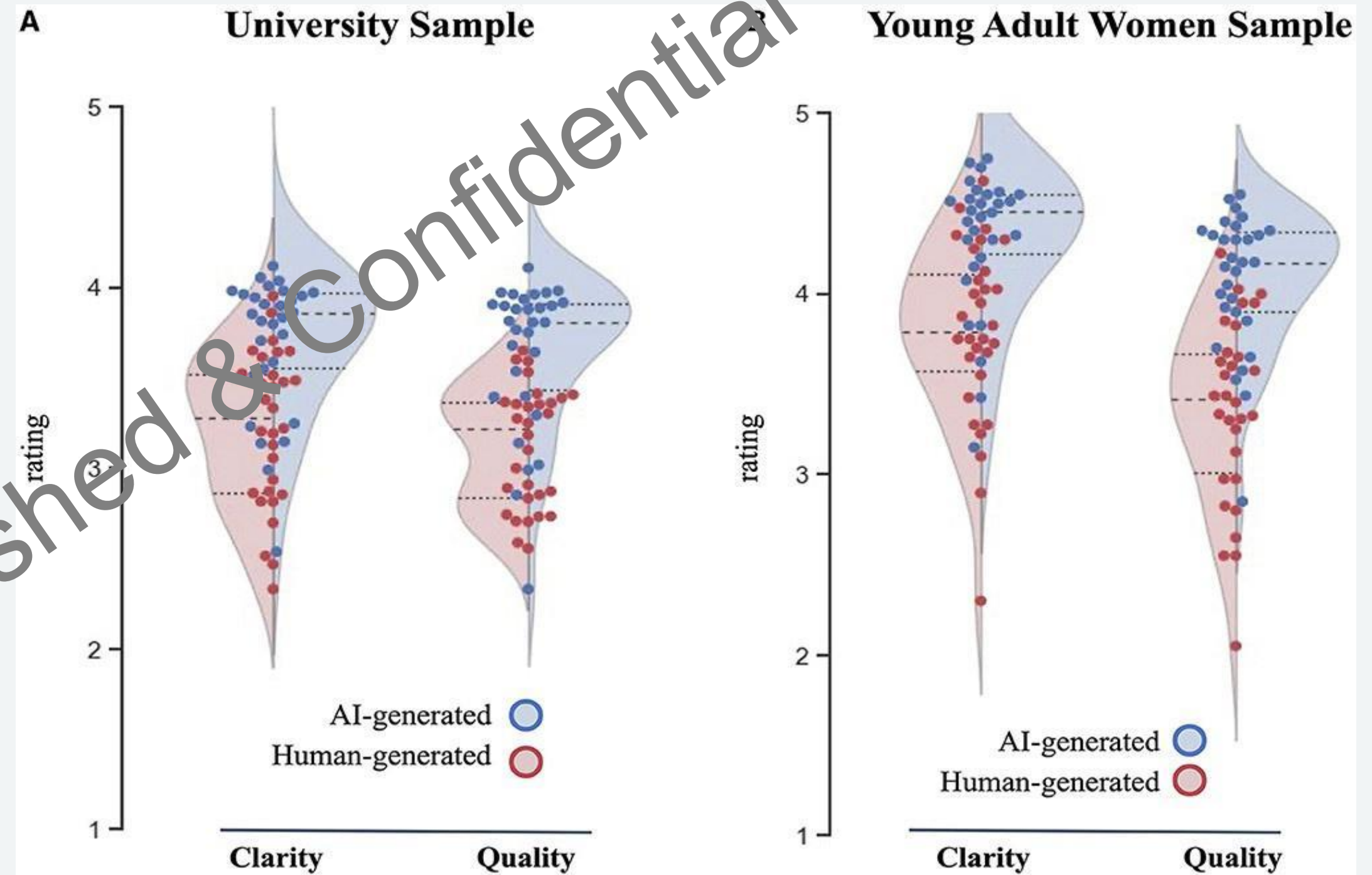
Chatbot responses significantly more **empathetic**



Rating: **chatbot 4.12** VS physician 3.26

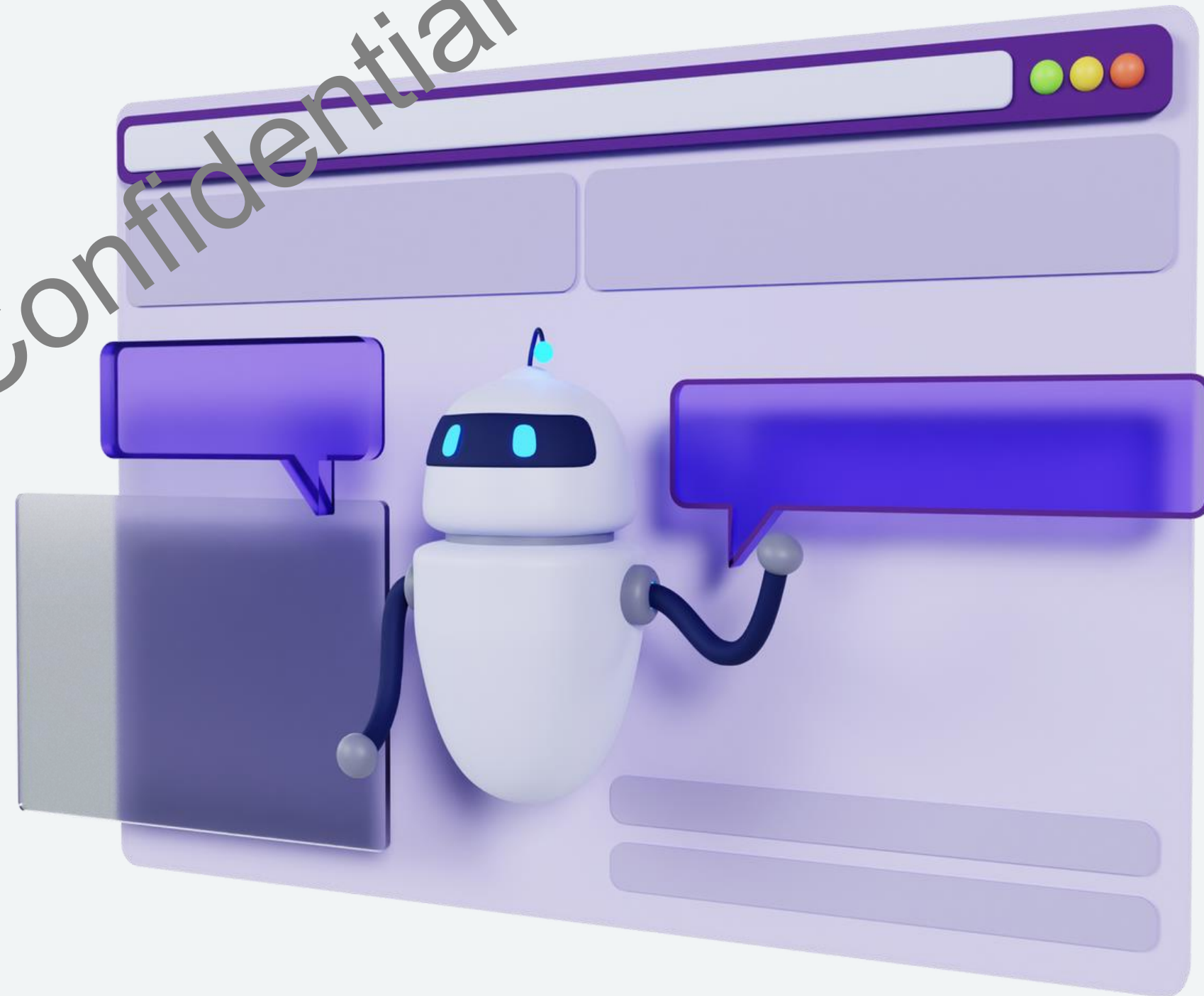
AI for Health Message Generation

- Highly preferred in **quality** and **clarity**
- Slightly higher **reading ease score**
- Demonstrated **adaptability** for health communication **in diverse settings**, depending on **audience**



AI for Health Message Generation

- While **humans** are still essential for refining messages, **AI is an asset for rapidly generating creative ideas for health awareness campaigns**
- AI-generated messages rank higher in **empathy, quality, clarity, and persuasiveness**
- Successful uses of AI message generation for **COVID-19 vaccine campaigns**



Karinshak et al., (2023), Working with AI to persuade: Examining a large language model's ability to generate pro-vaccination messages. Association for Computing Machinery.

Lim and Schmalzle (2023), Artificial intelligence for health message generation: an empirical study using a large language model (LLM) and prompt engineering. Front Commun.



5. AI and Misinformation



The Role of Emotion in Misinformation

Content with “**angry**” words leads to **increased sharing** (IRR = 1.20); **reliance on emotions over reason increases belief of fake news** ($d = 0.32$)

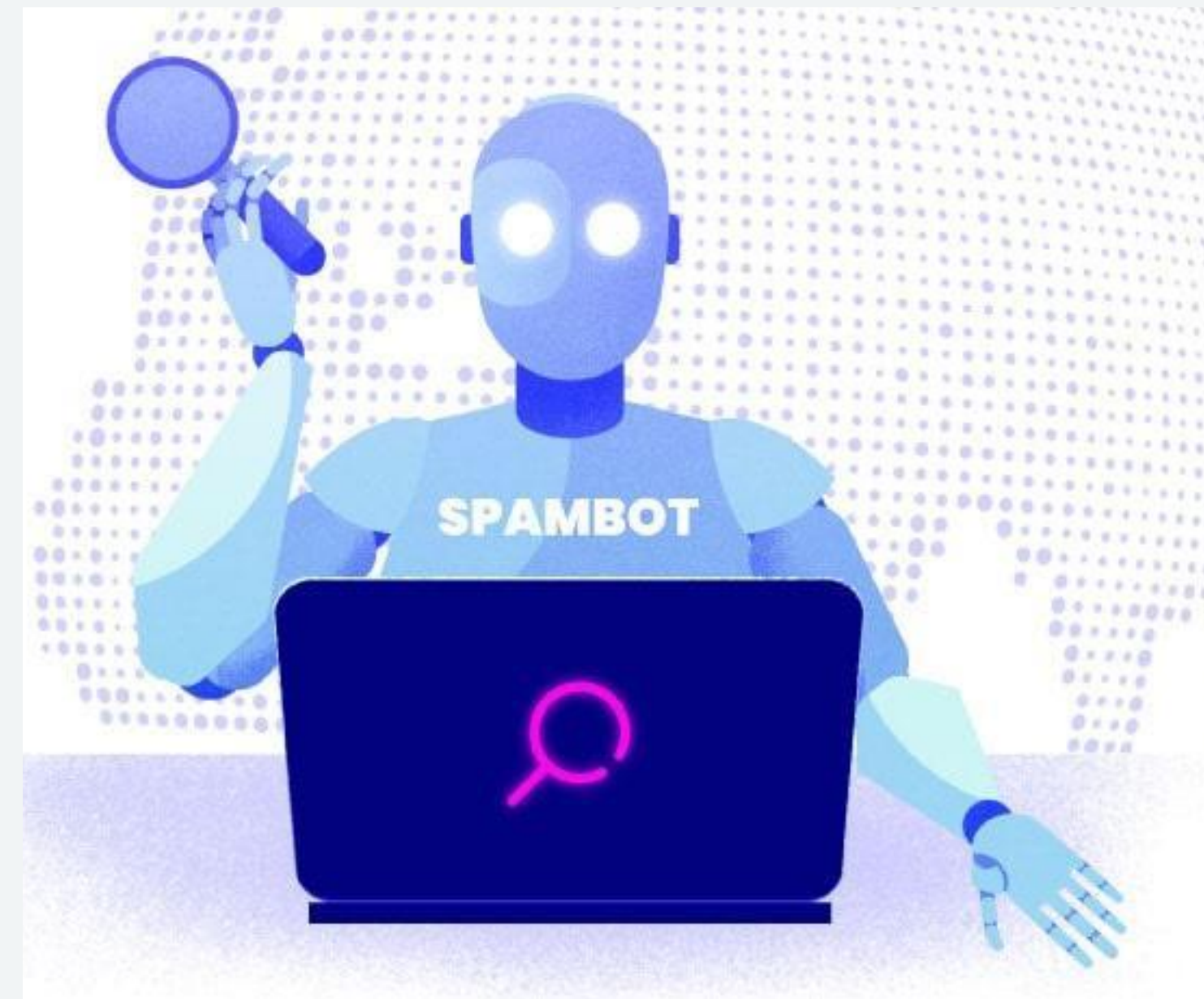


Angry individuals believe and share more misinformation ($b = -0.12$, $P < 0.05$), including COVID-19 rumors, and especially among **conservatives**

Han et al., (2020), Anger contributes to the spread of COVID-19 misinformation. Harvard Misinformation Review.
Ecker et al., (2022), The psychological drivers of misinformation belief and its resistance to correction. Nat Rev Psychol.
Martel et al., (2020), Reliance on emotion predicts belief in fake news. Cogn Research.

The Role of Bots in Misinformation

- **Social spambots** act as human social media users to **circulate misinformation**
 - COVID-19 and vaccine rumors
- **33%** of top sharers of **low-quality information** were bots
- **Highly deceiving:** human accounts identified spambots < **25%** of the time



Himelein-Wachowiak et al., (2021), Bots and misinformation spread on social media: Implications for COVID-19. J Med Internet Res.
Shao et al., (2018), The spread of low-credibility content by social bots. Nat Commun.

AI Misinformation Example

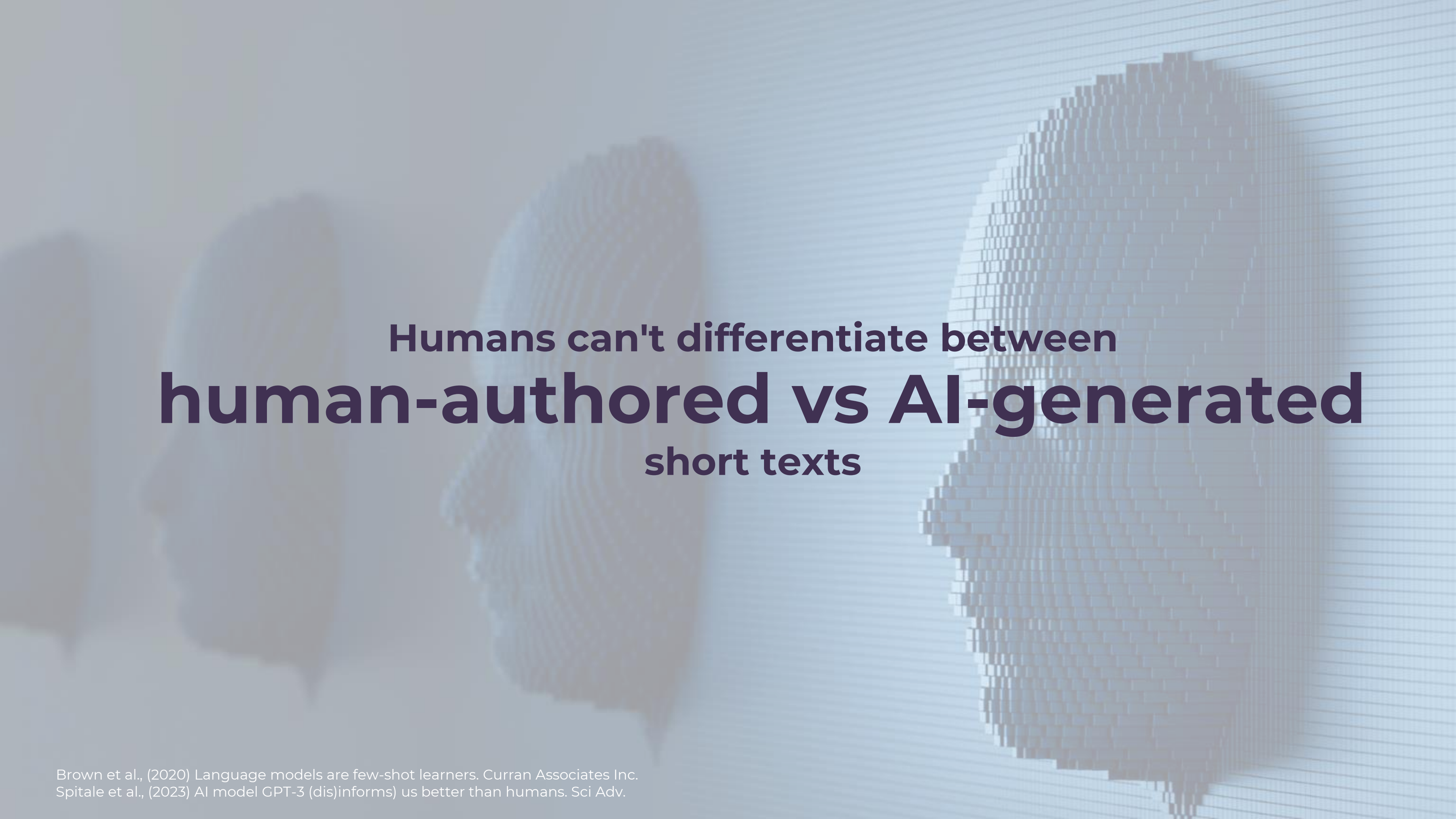
Deepfakes

Falsified images or videos using deep learning to **mimic** an individual's **appearance**, **behavior** and **speech patterns**



University of California, Berkeley

AI can evoke our emotions and influence beliefs when generating highly believable misinformation



Humans can't differentiate between
human-authored vs AI-generated
short texts

Humans can't differentiate between
human-authored vs AI-generated
short texts

AI Dis-informs Us Better !!

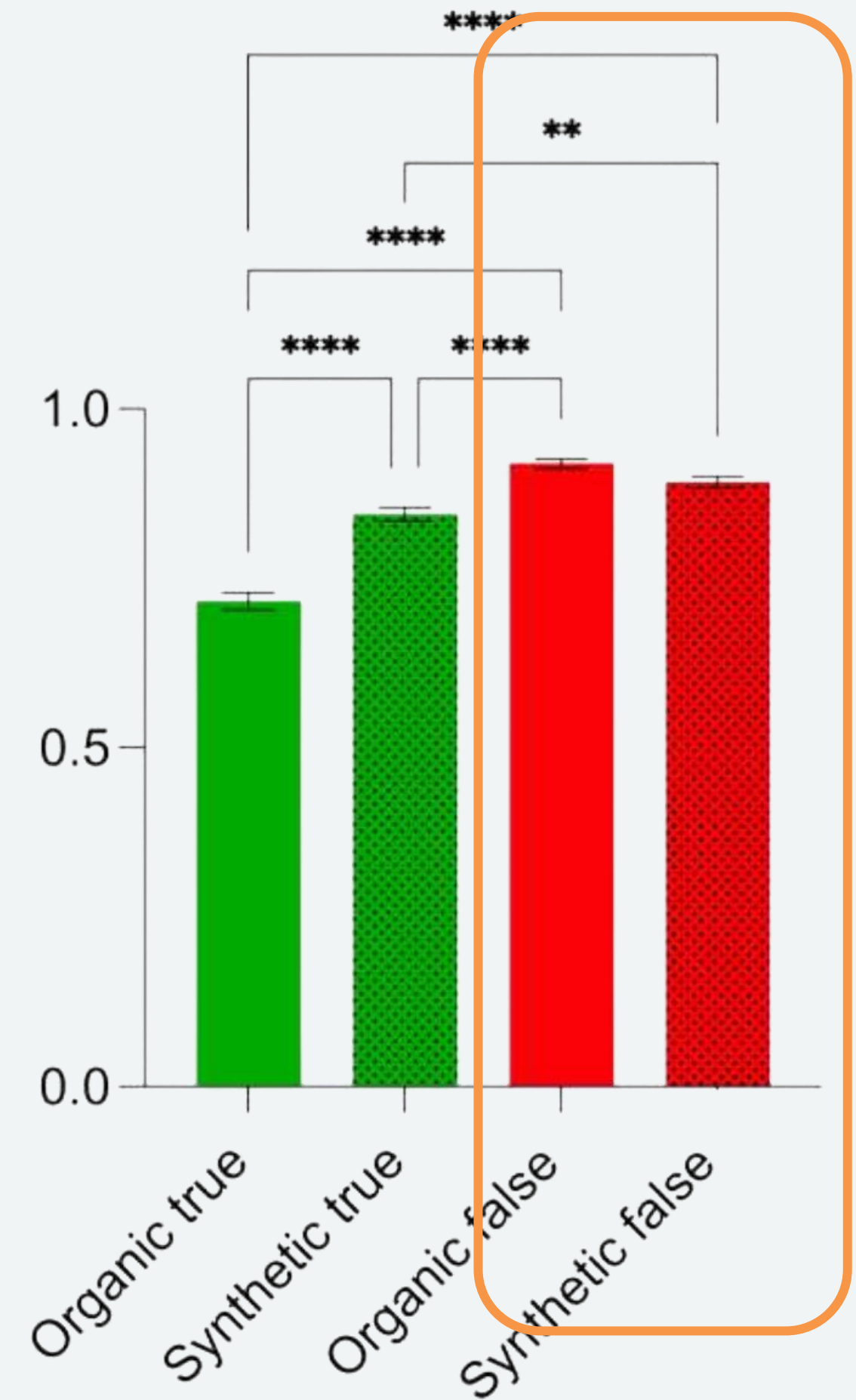
AI Dis-informs Us Better

Participants successfully **identified 92%** of **human disinformation** as **FALSE**, yet their ability to recognize **AI disinformation** as **FALSE** was **89%** ($P = 0.0032$).

Spitale et al., (2023) AI model GPT-3 (dis)informs us better than humans. Sci Adv.

C

Disinformation recognition score (0–1)



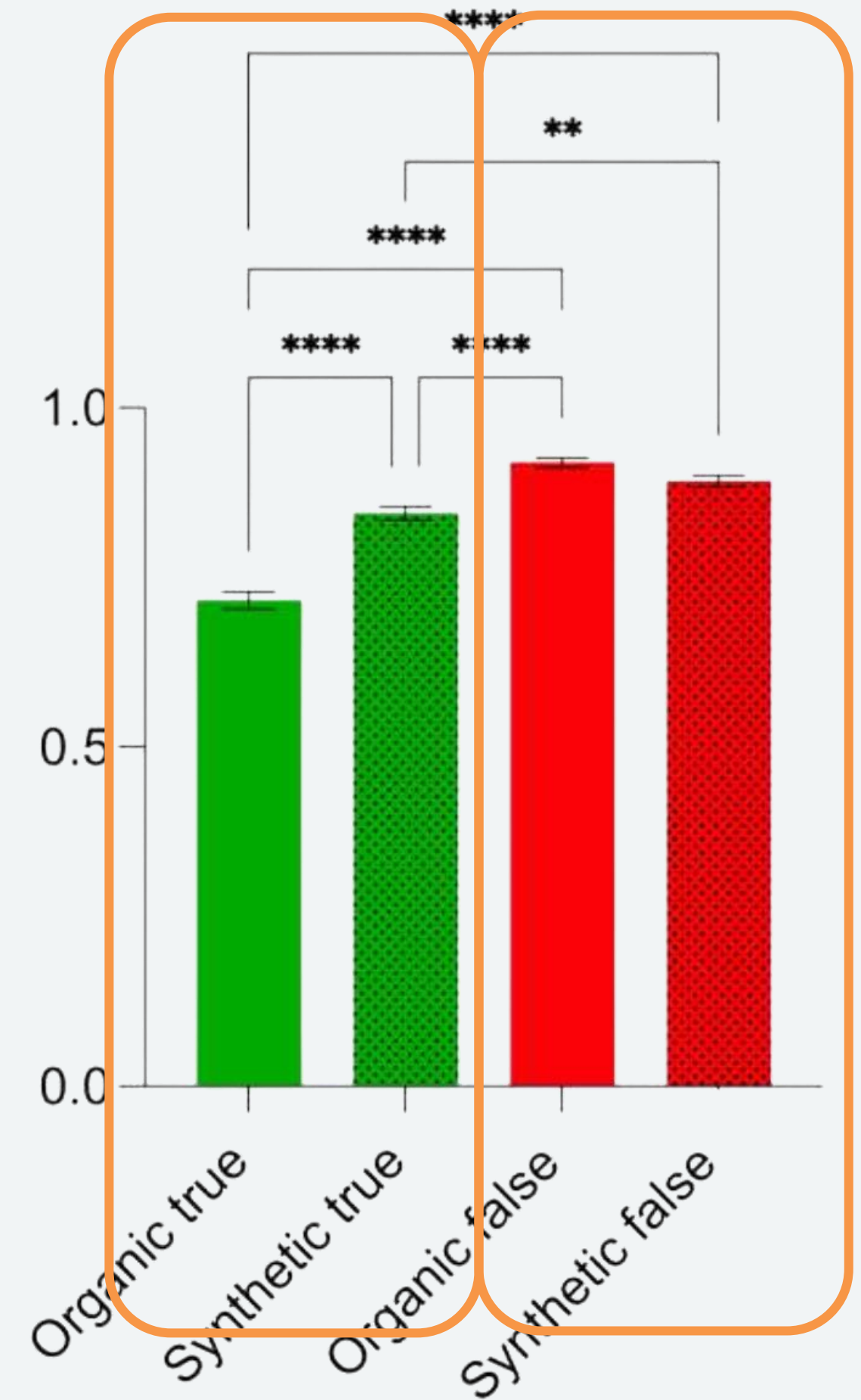
AI **Informs** Us Better

However, **AI also informs humans**: participants **recognized 84% of TRUE AI information** as factual, compared to **72% of TRUE human information** ($P < 0.0001$).

Spitale et al., (2023) AI model GPT-3 (dis)informs us better than humans. Sci Adv.

C

Disinformation recognition score (0–1)



Humans can't differentiate between
human-authored vs AI-generated
short texts

~~AI Disinforms us~~ **Better** ✓ **!!**



6. Future Research: Challenges and Opportunities



Global Concerns Around AI

Reproduction of bias,
stereotypes, prejudice

Surveillance, data
privacy threats



Political influence,
militarization

Disinformation

Job security

Improper use, Lack of oversight

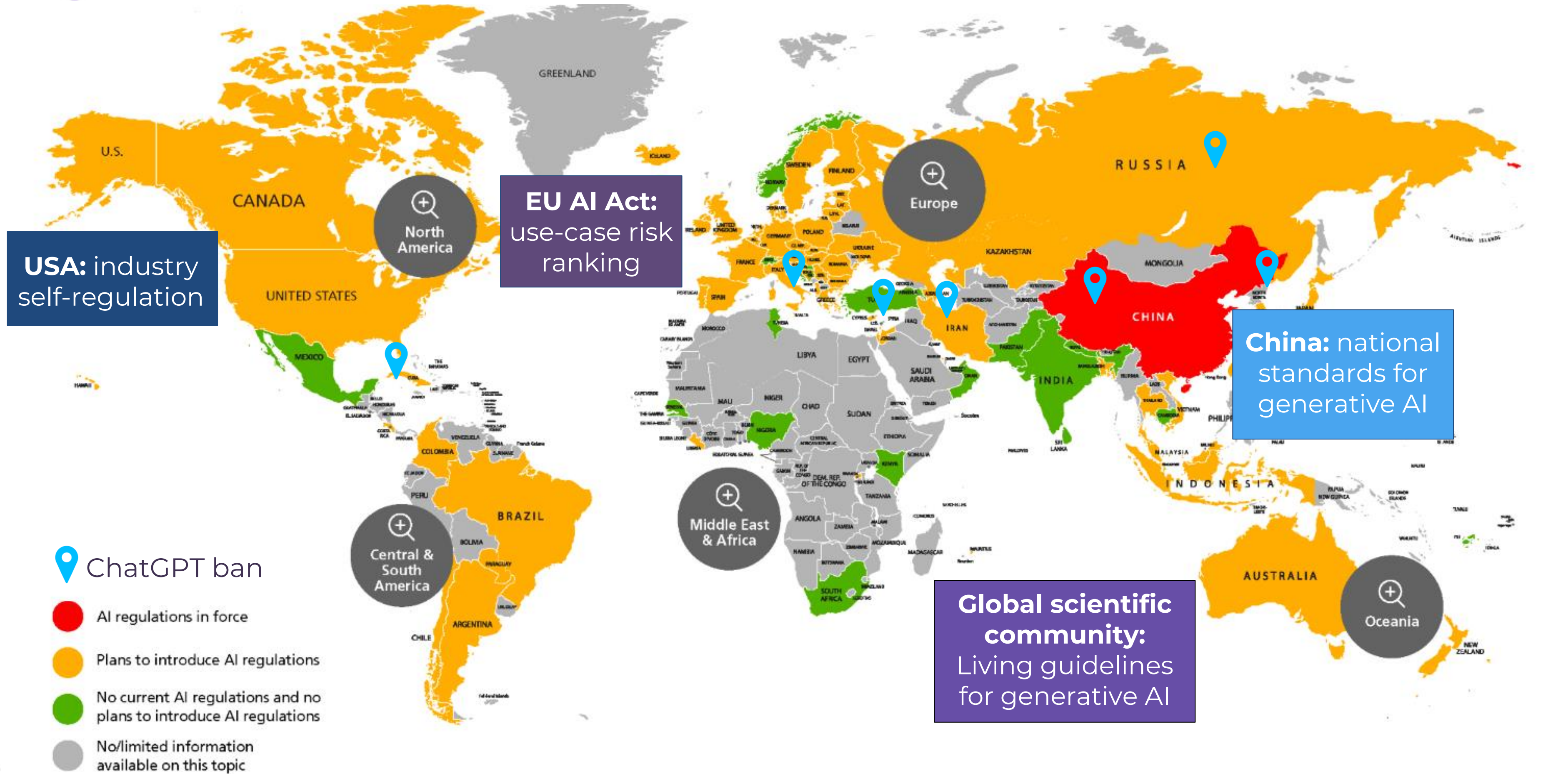
Responsible Use of AI

Responsible AI (RAI) is the practice of **designing, developing, and deploying AI with good intention.....**
—allowing companies to engender trust and scale AI with confidence

[A multinational IT services and consulting]

Taking a human-centred approach in using Artificial Intelligence to reimagine medicine.

[A multinational pharma]



Growing Opportunities



Impacted Services

Industry	Impact*	Comments
Communication Services		
Education	++	LLMs could drive online learning, writing textbooks and providing online learning modules.
Media	++	LLMs can be used for content generation e.g., writing news articles, social media posts, marketing content, story-writing, summarising text, media planning and advertising.
Legal	++	LLMs can write legal documents and summarise legal cases. ChatGPT is even capable of writing legal essays that passed law exams.
Healthcare		
Telemedicine	++	AI can help doctors make more data-driven decisions that improve the patient experience. It can be used for remote patient monitoring, population health management, health appointment reminders, and more accurate patient diagnoses.
Pharmaceuticals	++	AI can help the initial screening of drug compounds to predict its success rate. It can identify candidates for trials based on their medical history.
Financial		
Banks	++	AI can help analyse the data that banks, diversified financials and insurance companies have to conduct predictive analysis. AI could analyse an individual's credit history and calculate the likelihood of default.
Fintech	++	AI can help fintech companies automate the credit risk assessment process, detect bank fraud, increase safety, automate the customer service experience and analyse user behaviour.

Educate and motivate through content generation and accessible learning modules.

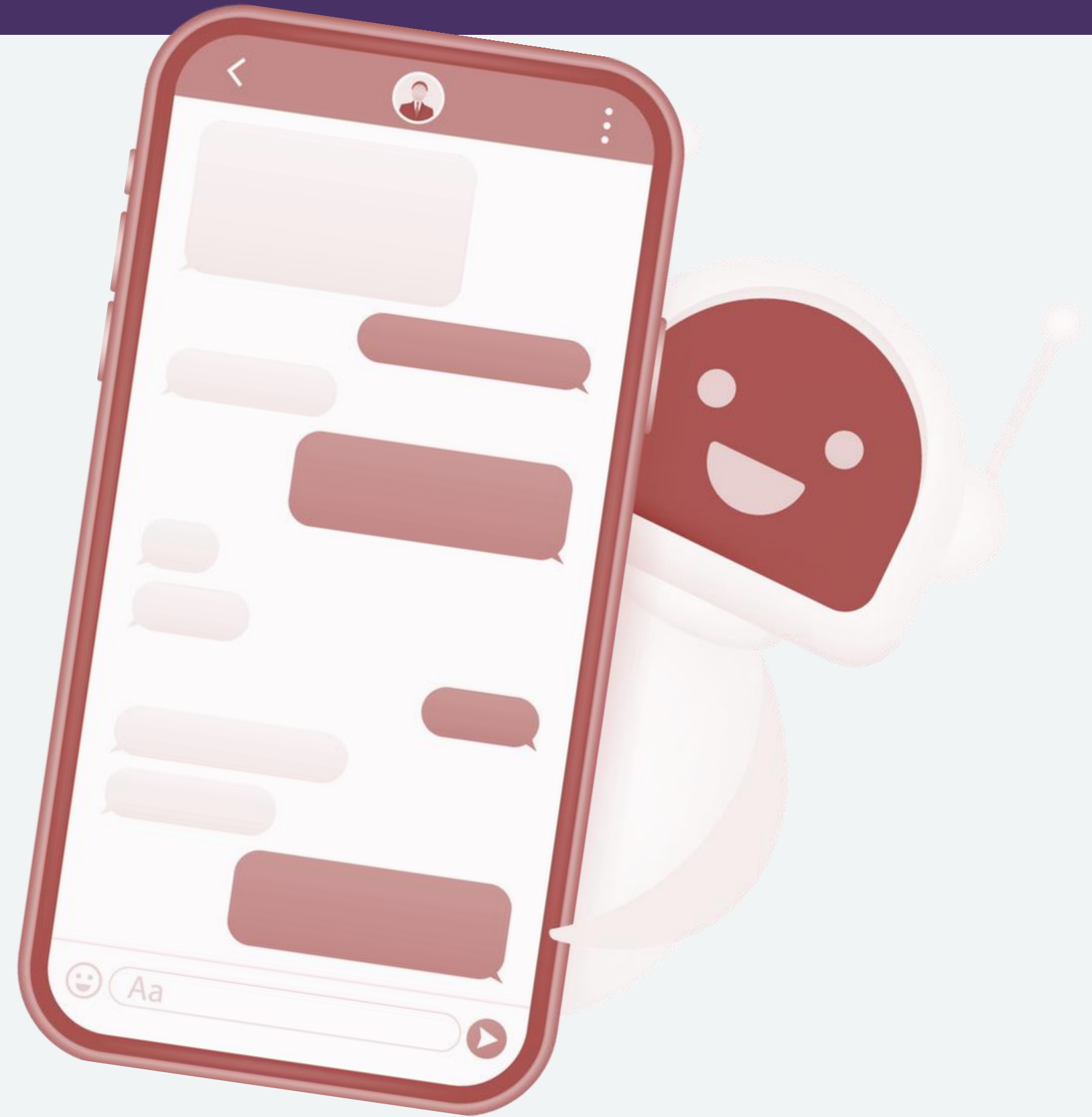
Overcome vaccine accessibility issues by connecting patients to appointments. Chatbots talk patients through their vaccine concerns.

* ++ large positive impact

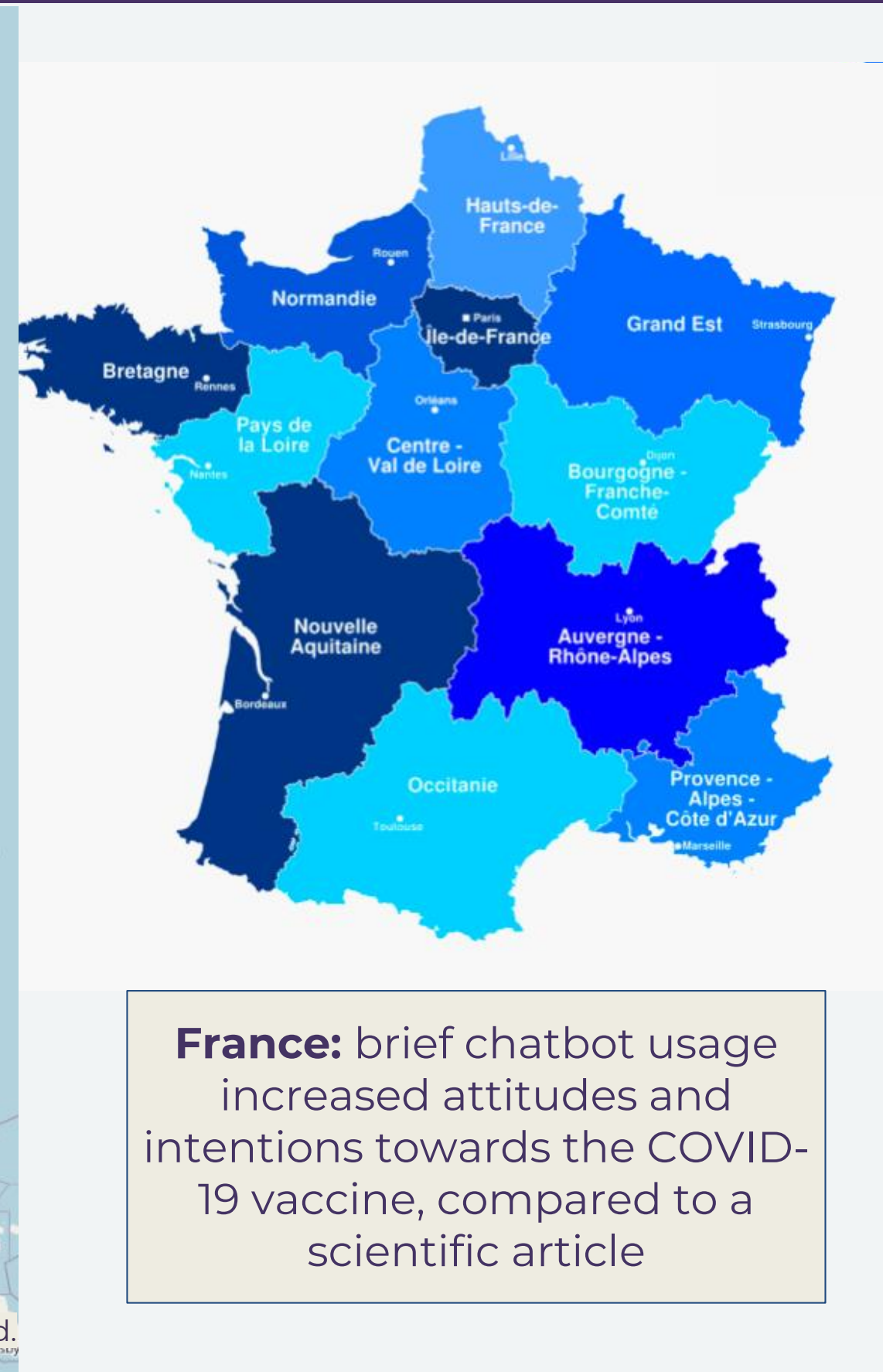
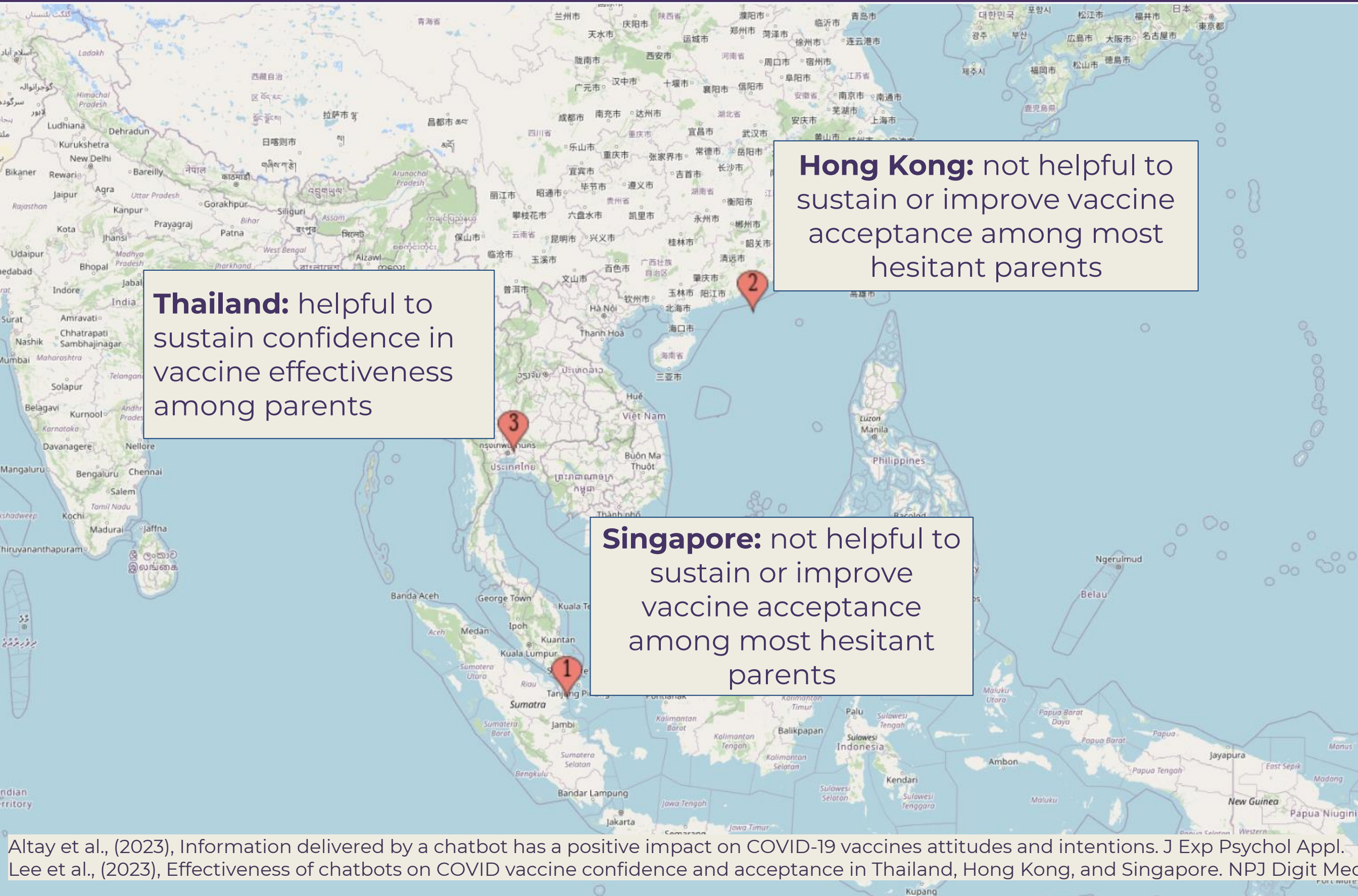
Israel et al., (2023), Me, Myself and AI - Artificial Intelligence Primer. Bank of America Global Research.

COVID-19 Vaccine Chatbots

- **Real-time** conversational tool to address **questions** and **misconceptions** with **evidence-based responses**
- Potential **advantages over other information sources** like scientific articles
- **M&E:** Implementation science + Experimental design



COVID-19 Vaccine Chatbots



Altay et al., (2023), Information delivered by a chatbot has a positive impact on COVID-19 vaccines attitudes and intentions. J Exp Psychol Appl.
Lee et al., (2023), Effectiveness of chatbots on COVID vaccine confidence and acceptance in Thailand, Hong Kong, and Singapore. NPJ Digit Med.

Global Social Listening

Social Listening

Curation and analysis of online mentions of products, topics

- ✓ Understand user trends, marketing/campaign impact, media mentions
- ✓ Detect concerns, rumors and misinformation, and adverse event mentions
- ✓ Inform and assess interventions

Text Annotation Tasks

Zero-shot LLMs outperform crowd workers and trained annotators

- ✓ Label data and train models more efficiently for a fraction of the cost and time
- ✓ Improve capability of social listening studies, qualitative research

Global Social Listening

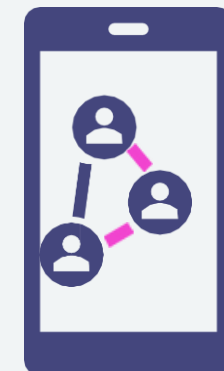
**Global sentiment
around mRNA Tech**

n = 740,533

06/2022 - 05/2023

Acceptance

Trust



Safety

**Global sentiment
around AI**

n = 235,785

10/2022 - 06/2023

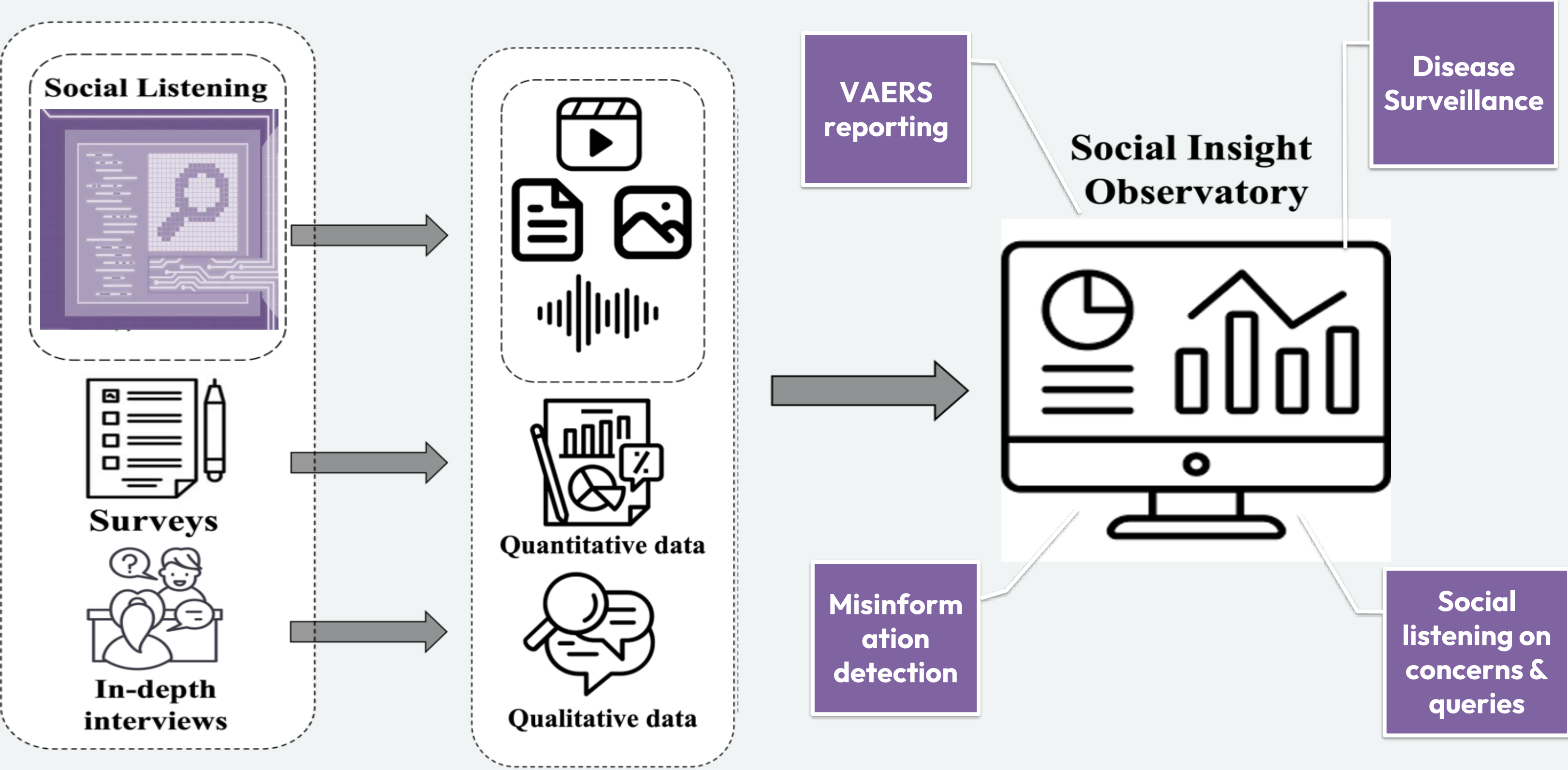
Innovative Approach:

- Employed LLMs to semi-automate the coding and analytical evaluation of extensive datasets

Validation:

- All measures achieved satisfactory results with high accuracy and F1 scores

Social Insight



Future Research Questions



How to...

- Form **responsible collaborations** between AI and humans
- **Regulate** emerging technology to mitigate risks like mis-/dis-information
- Improve research/evaluation **capacity**
- **Enable M&E, and rapid response**
- Foster **trust** in AI-enhanced tools

Thank You!

LONDON
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& TROPICAL
MEDICINE



Vaccine
Confidence
Project™



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