Cognitive Biases and Information Retrieval

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Bauhaus-Universität Weimar
webis.de

DLR Colloquium · July 26, 2023

A Concept Learning Task

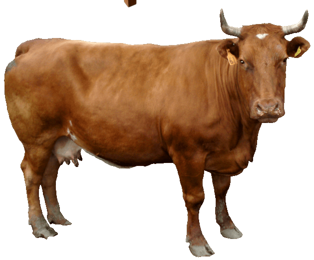
A Concept Learning Task

Chair: four legs,
brown color

A Concept Learning Task



→ Chair: four legs,
brown color



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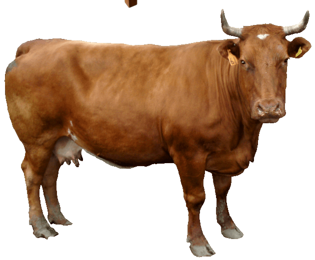

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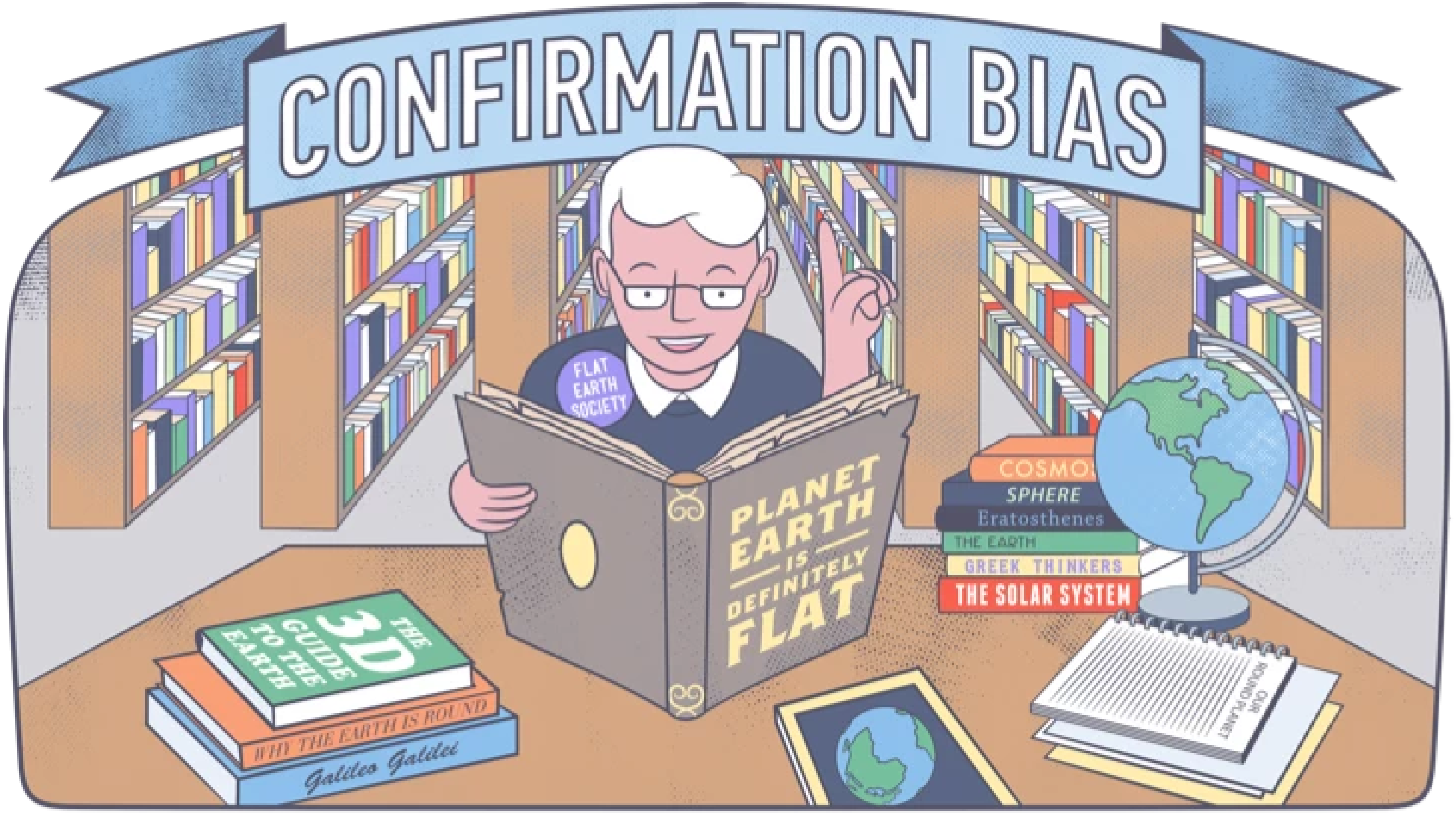
- Economical: We quickly (from few examples) learn to identify many chairs.
- Deficit in precision: We classify non-chairs as chairs.
- Deficit in recall: We cannot identify all chairs.

Outline

1. Meanings of Bias
2. Addressing Cognitive Biases with IR
3. Related Research @ Webis



"AHA! I KNEW IT!"

https://www.towergateinsurance.co.uk/liability-insurance/cognitive-biases (2016)

Meanings of Bias

“Bias” has Acquired a Derogatory Definition

A leaning of the mind; inclination; prepossession; propensity towards an object, not leaving the mind indifferent; as, education gives a bias to the mind. [Webster’s Dictionary 1913: bias]

An inclination of temperament or outlook especially; a personal and sometimes unreasoned judgment; prejudice [Merriam-Webster 2022: bias]

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Synonyms [Merriam-Webster 2022] :

Bias, Nonobjectivity, Prejudice, One-Sidedness, Tendentiousness

Synonyms [e.g. Kahneman et al. 1982, Gigerenzer et al. 2000, Roberts 2022] :

Heuristic, Rule-of thumb, Cognitive Bias

Meanings of Bias

Bias: Two Camps of Interpretation

Based on the following (and other) authorities . . .

- H. Simon (1955). A behavioral model of rational choice.
- A. Tversky, D. Kahneman (1974). Judgment under uncertainty: Heuristics and biases.
- D. Kahneman, P. Slovic, A. Tversky (1982). Judgment under uncertainty: Heuristics and biases.
- G. Gigerenzer, P. Todd, ABC Research Group (2000). Simple heuristics that make us smart.
- G. Gigerenzer, R. Hertwig, T. Pachur (2011). Heuristics: The foundation of adaptive behavior.

. . . Cleotilde Gonzalez defines:

> ***Heuristics are the “shortcuts”*** *that humans use to reduce task complexity in judgment and choice, and* ***biases are the resulting gaps*** *between normative behavior and the heuristically determined behavior.*
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> [Oxford Handbooks Online 2017]

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$\rightsquigarrow$ When talking about bias,

(a) distinguish between the procedure or algorithm and its effect or impact,

(b) think twice before implying a negative, neutral, or positive assessment.

Meanings of Bias

Bias: A Neutral Interpretation

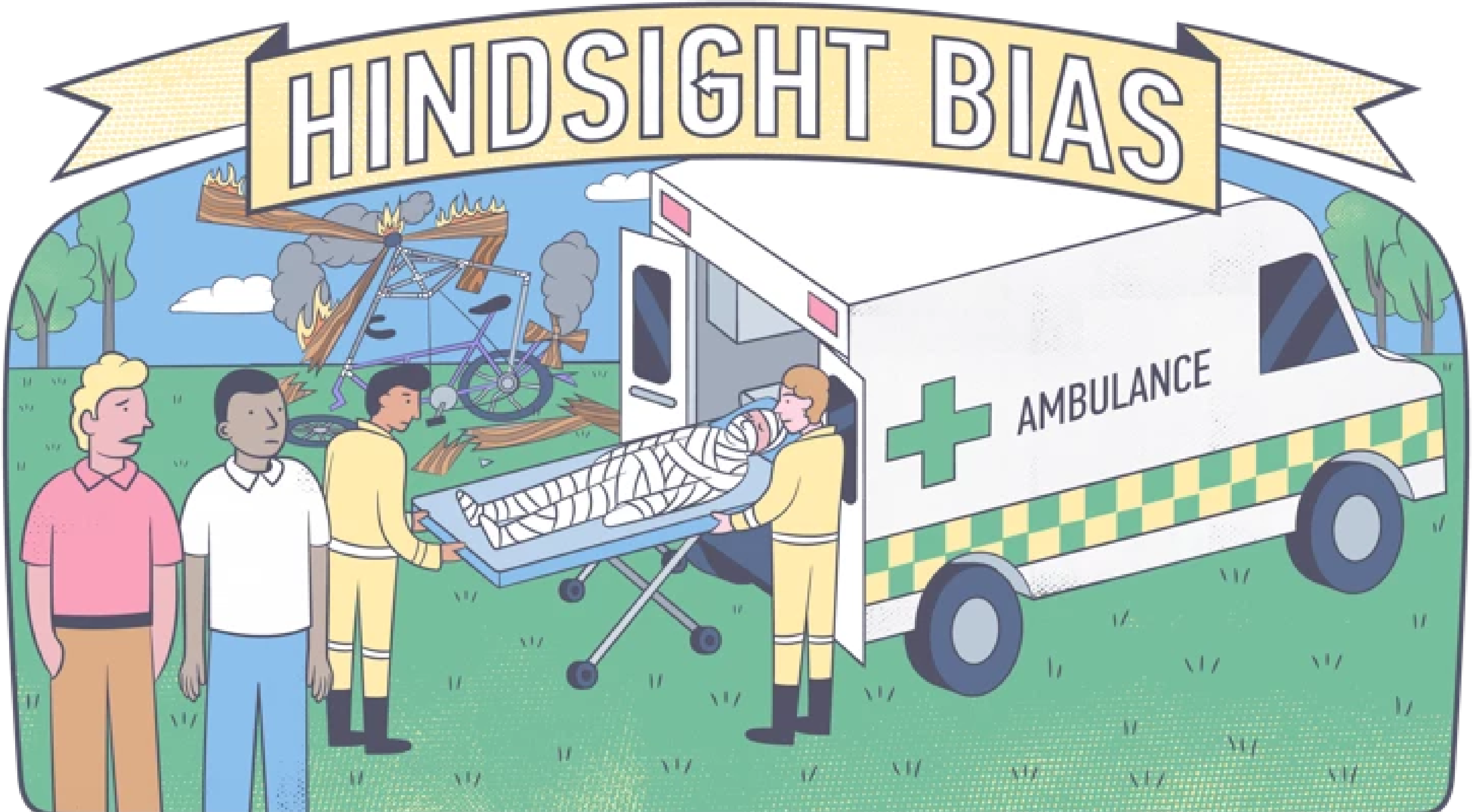
Heuristic:[1]

A procedure, algorithm, calculus, which is not complete or not sound.

Systematic error, Bias:

The incurred consequences for not being complete or sound.

[1] Various authors use the term "cognitive bias" for a heuristic that is applied by humans to judge.



"ALTHOUGH WE GAVE HIM ALL OF THAT MONEY AND SUPPORT, I ALWAYS HAD MY DOUBTS THAT JIM COULD BUILD HIS OWN HELICOPTER."

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Meanings of Bias

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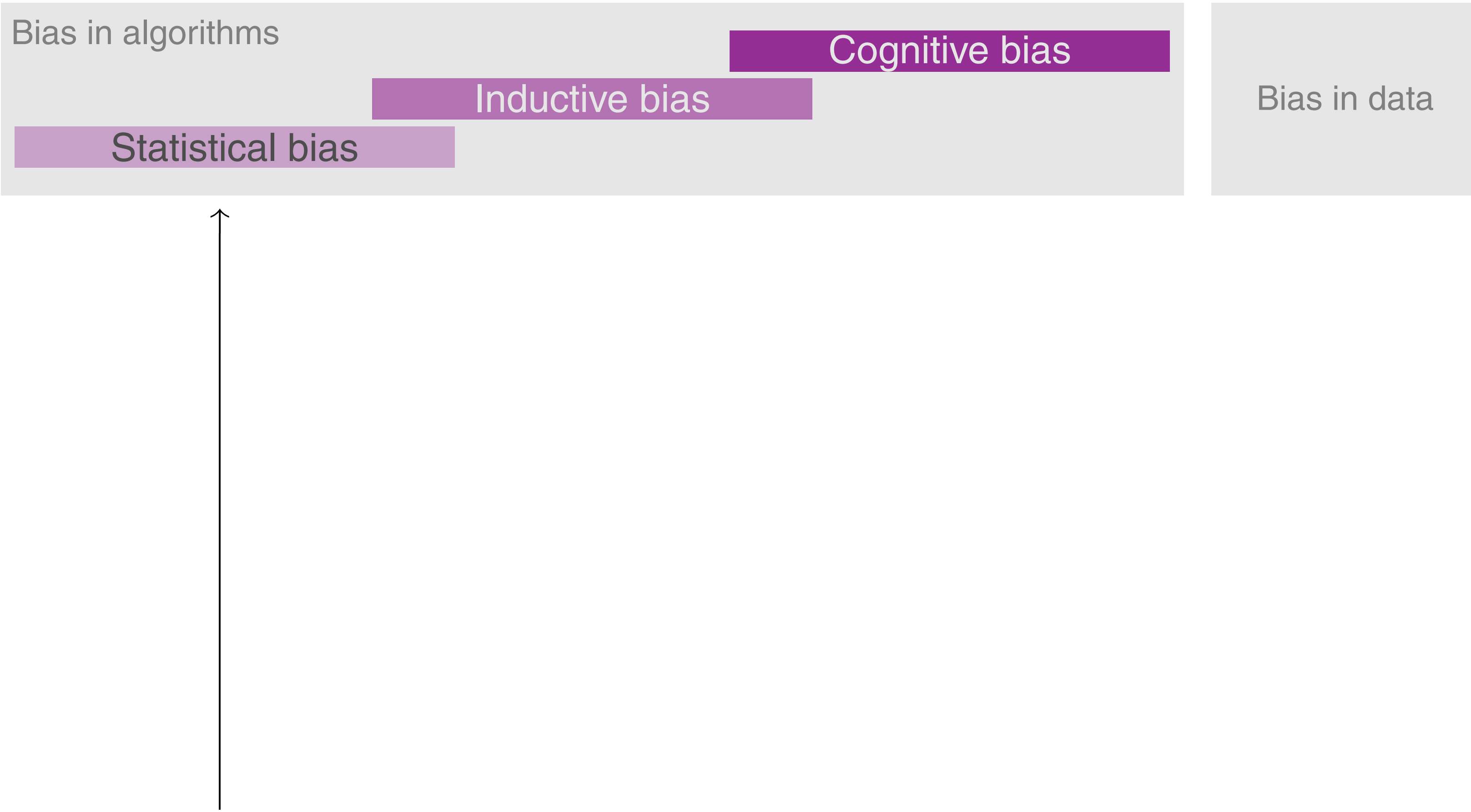

Deviation of a random variable / statistic from its true value.

Meanings of Bias

Bias in algorithms

Cognitive bias

Inductive bias

Statistical bias

Bias in data

Principles for the search in the hypothesis space (machine learning).

Deviation of a random variable / statistic from its true value.

Meanings of Bias

Bias in algorithms

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Bias in data

Rational deviations from logical thought.

Principles for the search in the hypothesis space (machine learning).

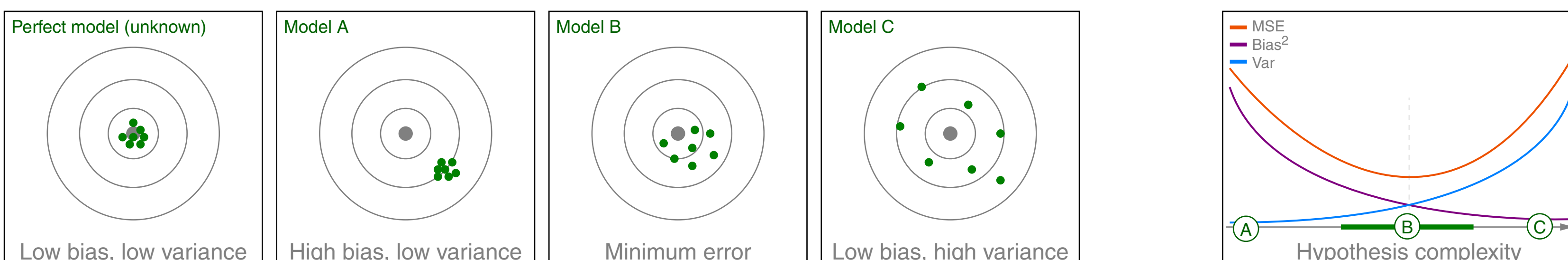
Deviation of a random variable / statistic from its true value.

Meanings of Bias

Statistical View

Trade unbiasedness for error reduction when learning from samples.

E.g., bias-variance decomposition for squared error: $\text{MSE} = \text{Bias}(\hat{f})^2 + \text{Var}(\hat{f}) + \sigma^2$



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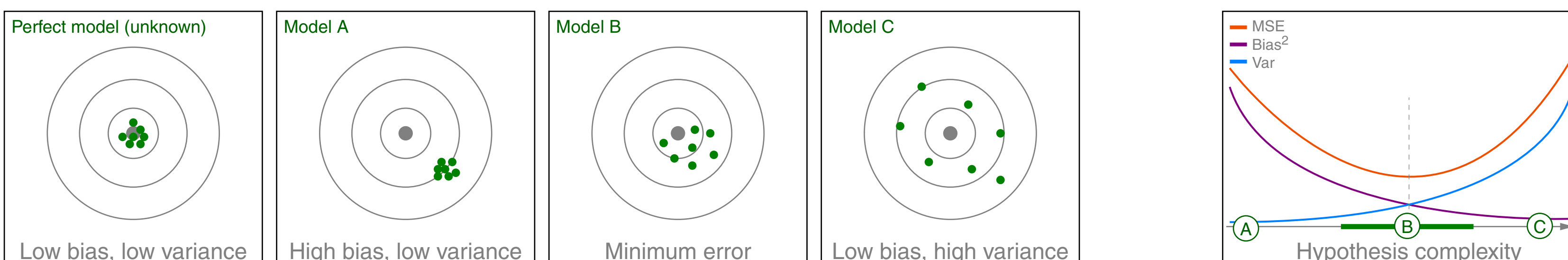
Compare to bias definition of C. Gonzales (2017):

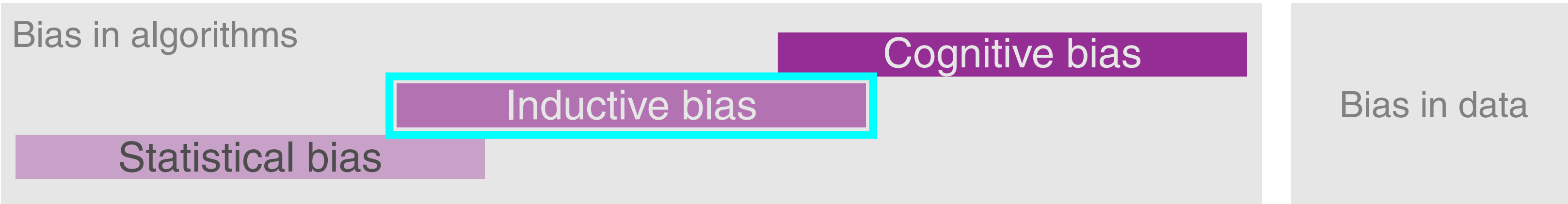
- **Reduce task complexity** by analyzing small samples.
- Applying **heuristics entail bias** but reduce risk of poorly representing unseen data.

Gigerenzer et al. (2009). Homo heuristicus: Why biased minds make better inferences.



Meanings of Bias

Machine Learning View

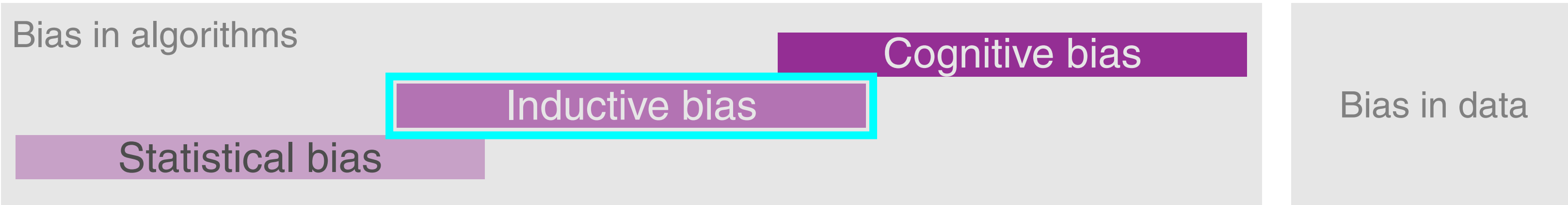


Set of assumptions used to perform induction (= predict outputs for unseen inputs).

E.g., preference rules for hypotheses spaces, model parameters, data exploitation.

Meanings of Bias

Machine Learning View



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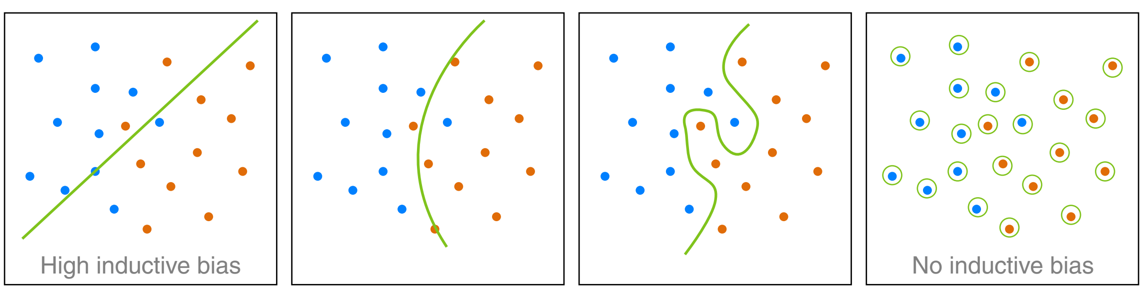

"Learning without bias is futile."

- T. Mitchell (1980)
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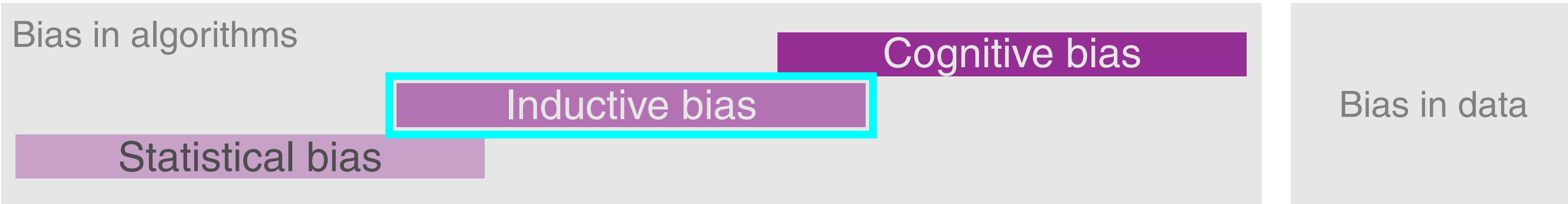
- G. Montañet et al. (2019)

Meanings of Bias
Machine Learning View



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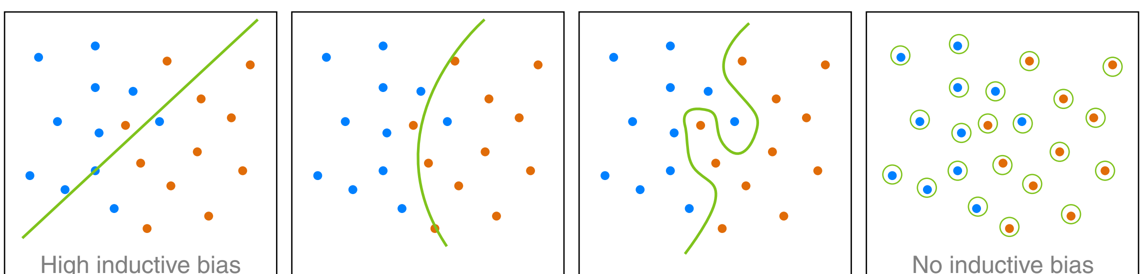
E.g., preference rules for hypotheses spaces, model parameters, data exploitation.

Examples of inductive biases:

- principle of parsimony, small is quick (search), nearest neighbors, maximum margin
- group equivariance, structured perception, drop out (deep learning)
- data augmentation, priors in Bayesian models (learning setup)



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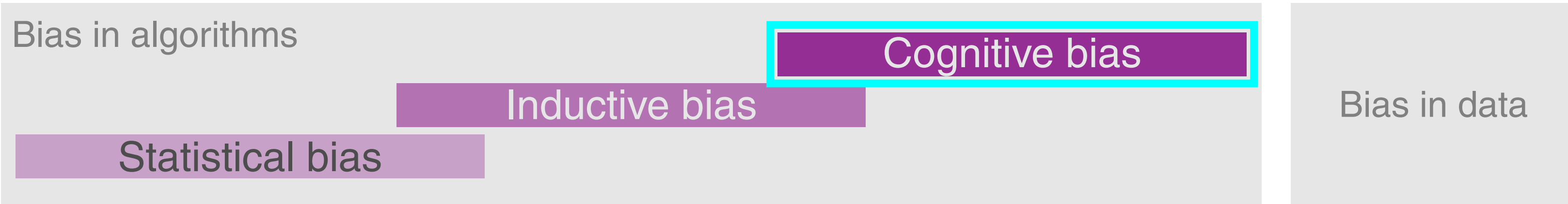
Meanings of Bias

Behavioral Economics View

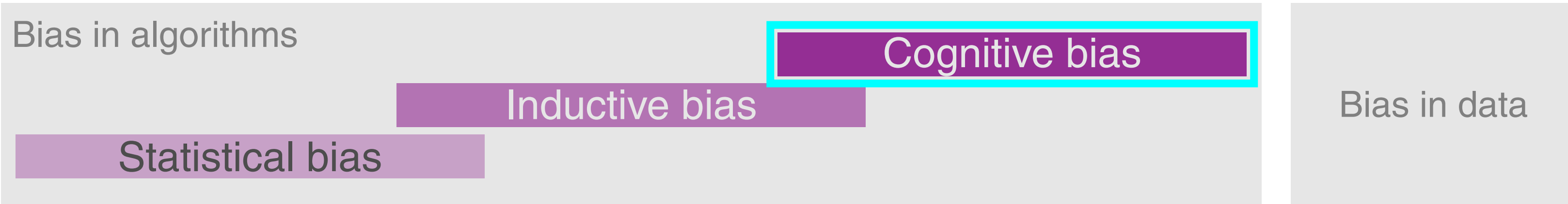


Systematic patterns of deviation from norm and/or rationality in judgment.

Mental shortcuts (heuristics) that the brain uses to produce decisions or judgments.

Meanings of Bias

Behavioral Economics View



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A classification scheme oriented at the addressed problems [B. Benson, 2016-2022] :

Problem 1: Too much information.

Problem 2: Not enough meaning.

Problem 3: Need to act fast.

Problem 4: What should we remember?

Meanings of Bias

Behavioral Economics View

Bias in algorithms

Cognitive bias

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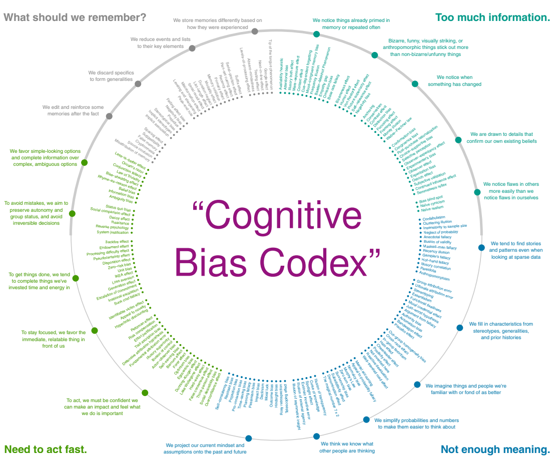
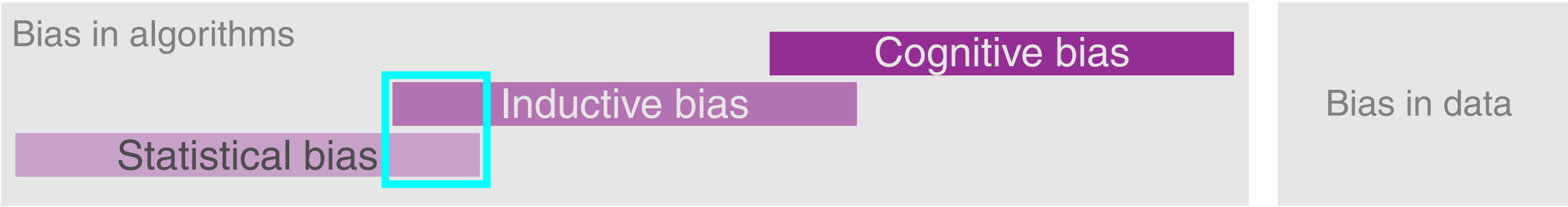


Meanings of Bias

Connections between the Meanings of Bias (a)



(a) Inductive and statistical bias can entail each other.

- Introducing statistical bias may be explained in terms of inductive bias.

$\updownarrow$

- Operationalization of inductive bias may entail statistical bias.

- Keyword: *regularization*

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↕

- Operationalization of inductive bias may entail statistical bias.

- Keyword: *regularization*

Example: LASSO (least absolute shrinkage and selection operator)

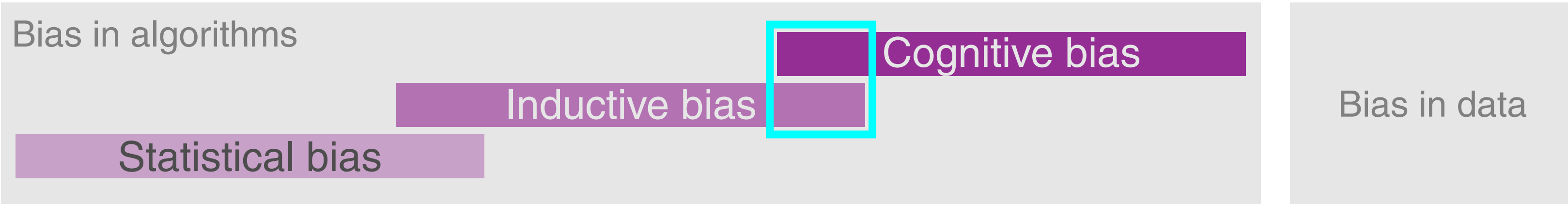
- Inductive bias: minimize feature number

↕

- Statistical bias: constrain absolute value of model parameters

Meanings of Bias

Connections between the Meanings of Bias (b)



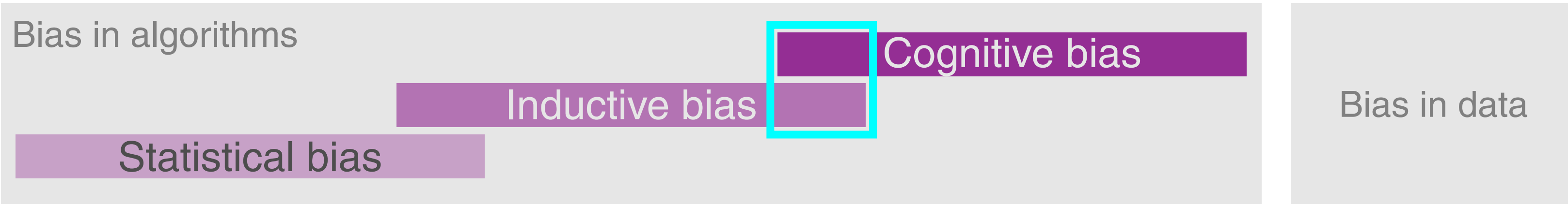
(b) Cognitive and inductive bias can entail each other.

- Ensuring inductive bias will become manifest as a cognitive bias.
- Certain cognitive biases inspired inductive biases in machine learning.

- Keyword: *concept learning*

Meanings of Bias

Connections between the Meanings of Bias (b)



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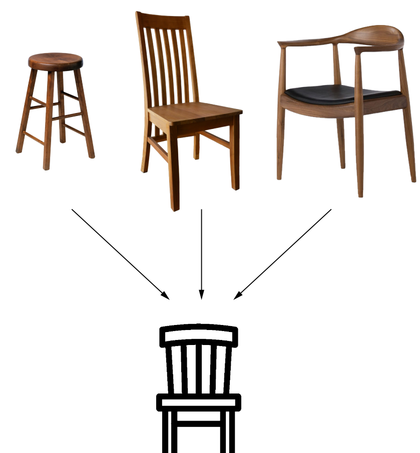


Example: CART (classification and regression tree)

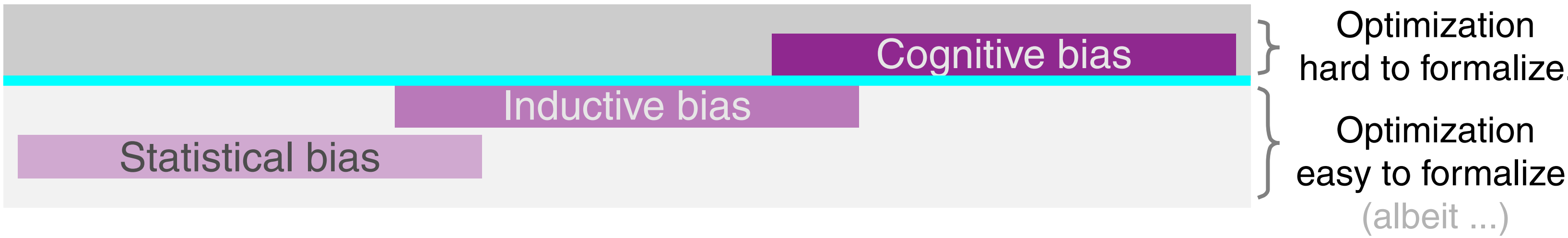
- Cognitive bias: representativeness heuristic, stereotyping

↕

- Inductive bias: minimize description length

Meanings of Bias

Connections between the Meanings of Bias



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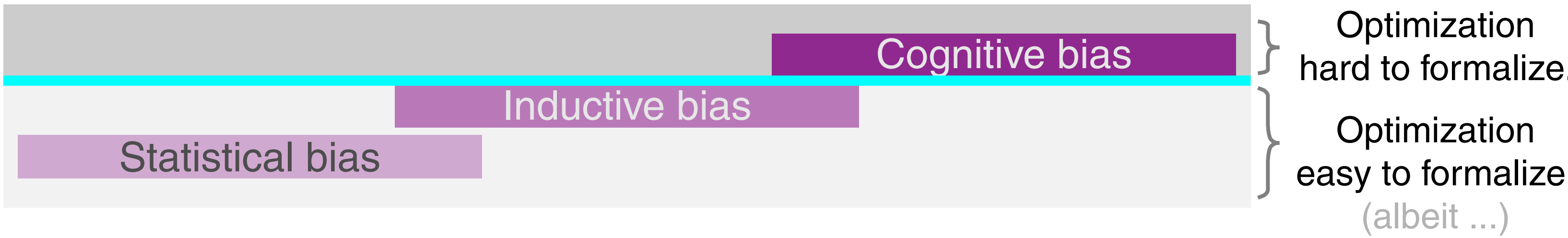

(a) Inductive and statistical biases . . .

- are optimized against a (mathematical) loss function—but,
- trading bias against variance is an alchemical discipline.

(b) Cognitive biases depend on . . .

- cultural backgrounds,
- the zeitgeist,
- they are individually experienced, and, in particular,
- there is no unified value system for their mathematical quantification.

Meanings of Bias

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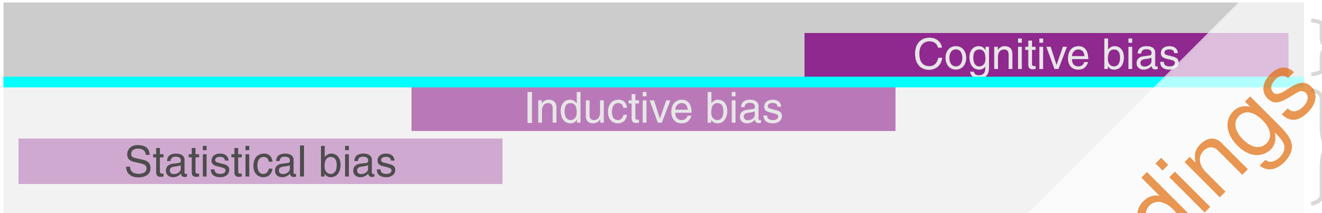

Optimization hard to formalize.

Optimization easy to formalize, (albeit ...)

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Source of misunderstandings

Meanings of Bias

Connections to Information Retrieval

②

Addressing Cognitive Biases with IR

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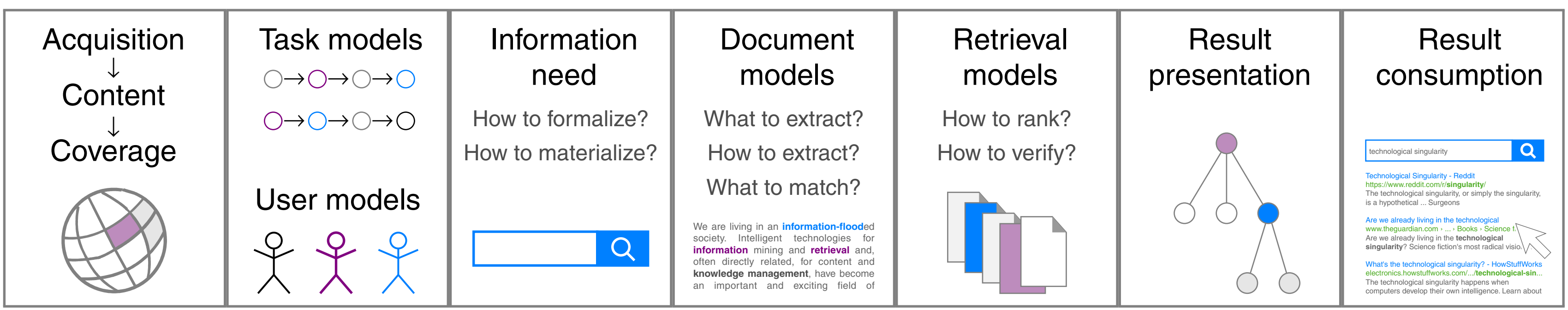
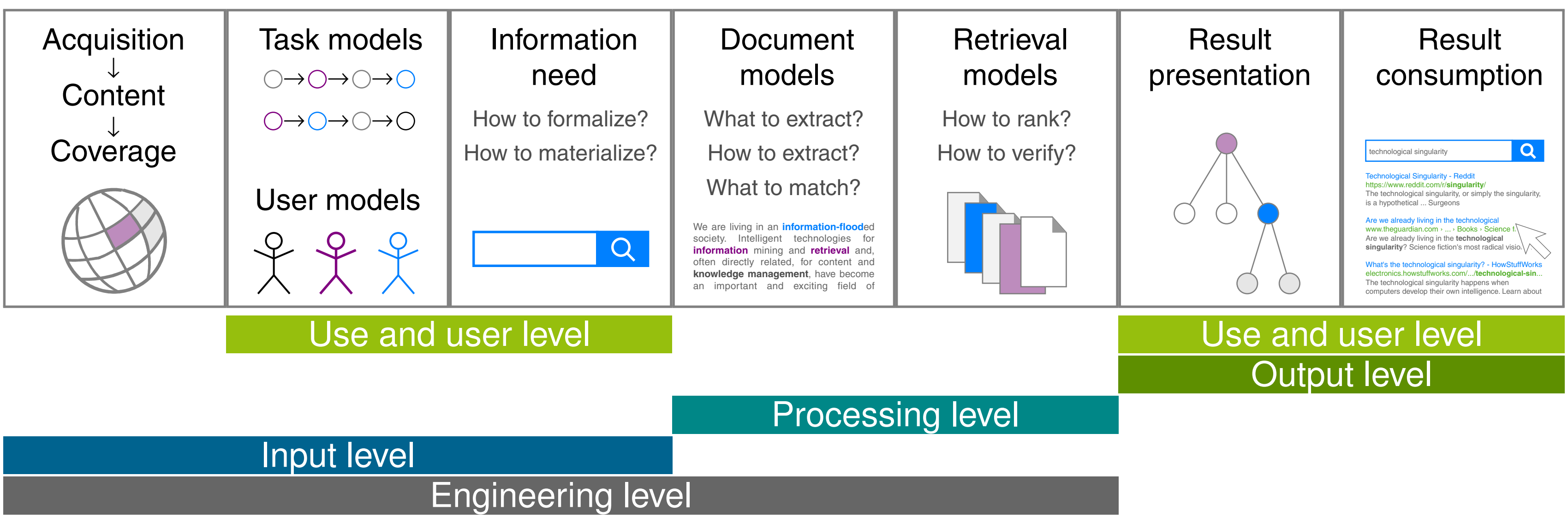


Addressing Cognitive Biases with IR

The Heart of IR is Evaluation

- Brenda Dervin, Michael Nilan (1986). Information needs and uses.
- ∗ Tefko Saracevic (1995). Evaluation of evaluation in information retrieval.
- Ellen Voorhees (2001). The philosophy of information retrieval evaluation.
- William Webber (2009). When did the Cranfield tests become the “Cranfield paradigm”?



Addressing Cognitive Biases with IR

IR Technology can Amplify Cognitive Biases

Examples from search behavior* :

- Rely on retrieving information via search engines, rather than remembering (Google effect).
- Initial result presented may color the person's opinion on the topic (anchoring bias).
- Taking a query suggestion (bandwagon effect).
- Selection of result items from known sources (ambiguity effect).
- Overestimate the ability to find relevant items (Dunning-Kruger effect).
- Results returned in response to a query may prime the search (priming effect).
- Given more weight to information presented earlier in a list (order effect).

Prominently affected domains:

- health, medicine
- politics, society

* Leif Azzopardi (2021). Cognitive biases in search: a review and reflection of cognitive biases in information retrieval.

Addressing Cognitive Biases with IR

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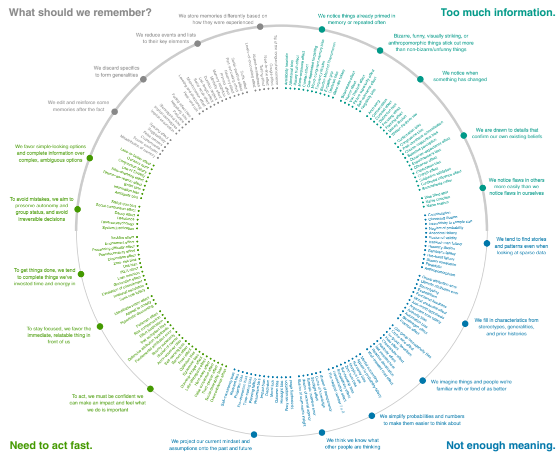
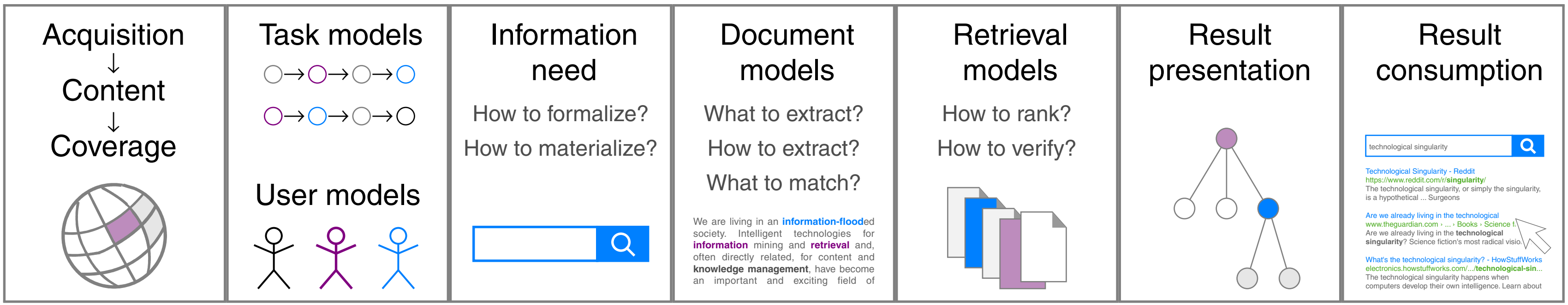
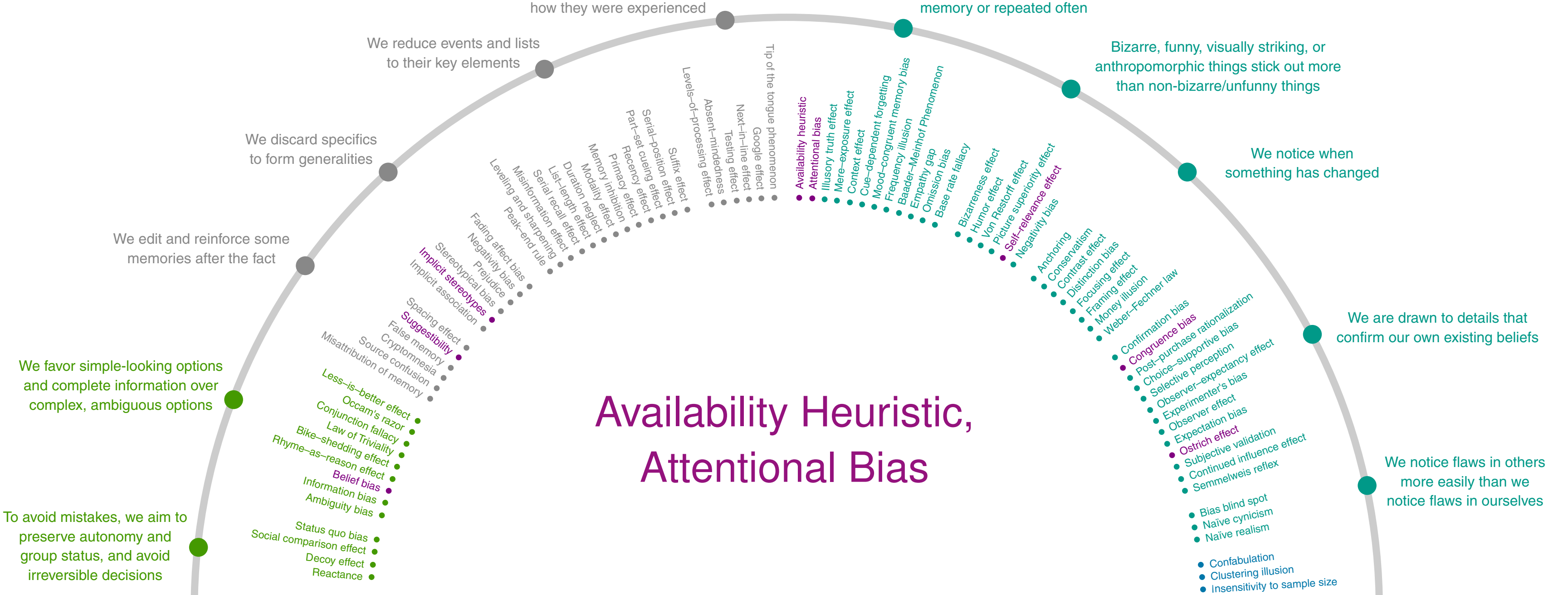




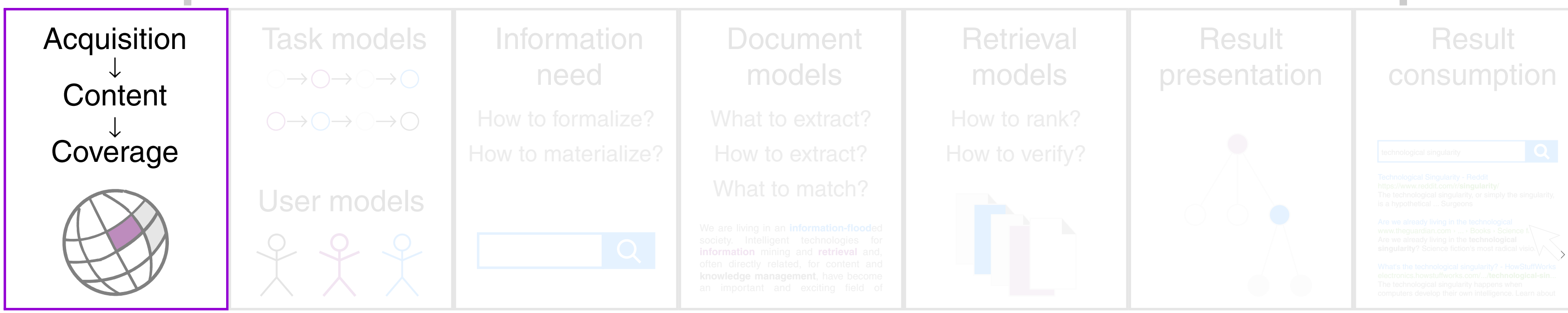
1. We mapped around 100 cognitve biases on the seven phases in the IR pipeline.
2. We analyzed publications from relevant IR venues on technologies to address cognitive biases.

What should we remember?

Too much information.

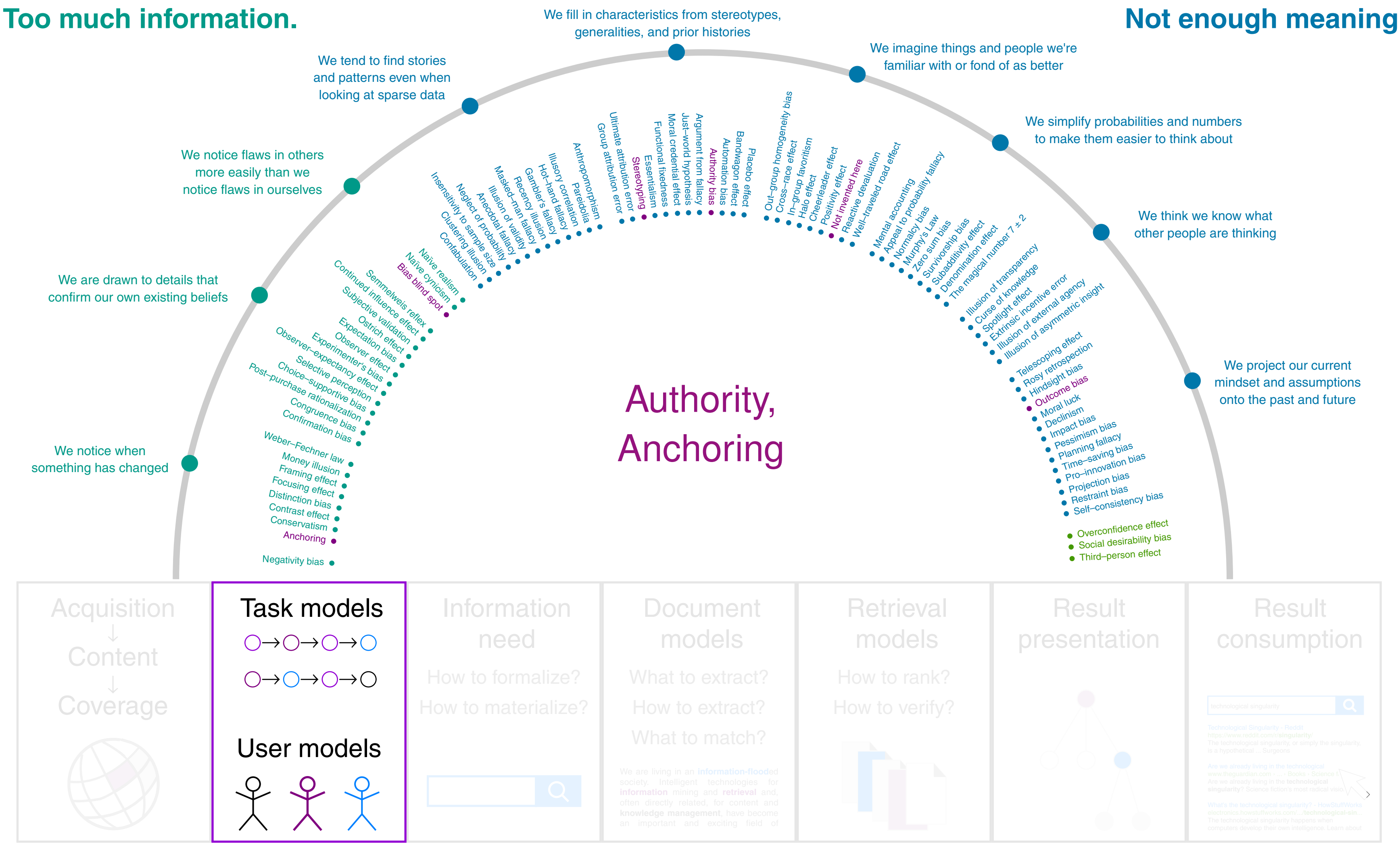


Availability Heuristic, Attentional Bias



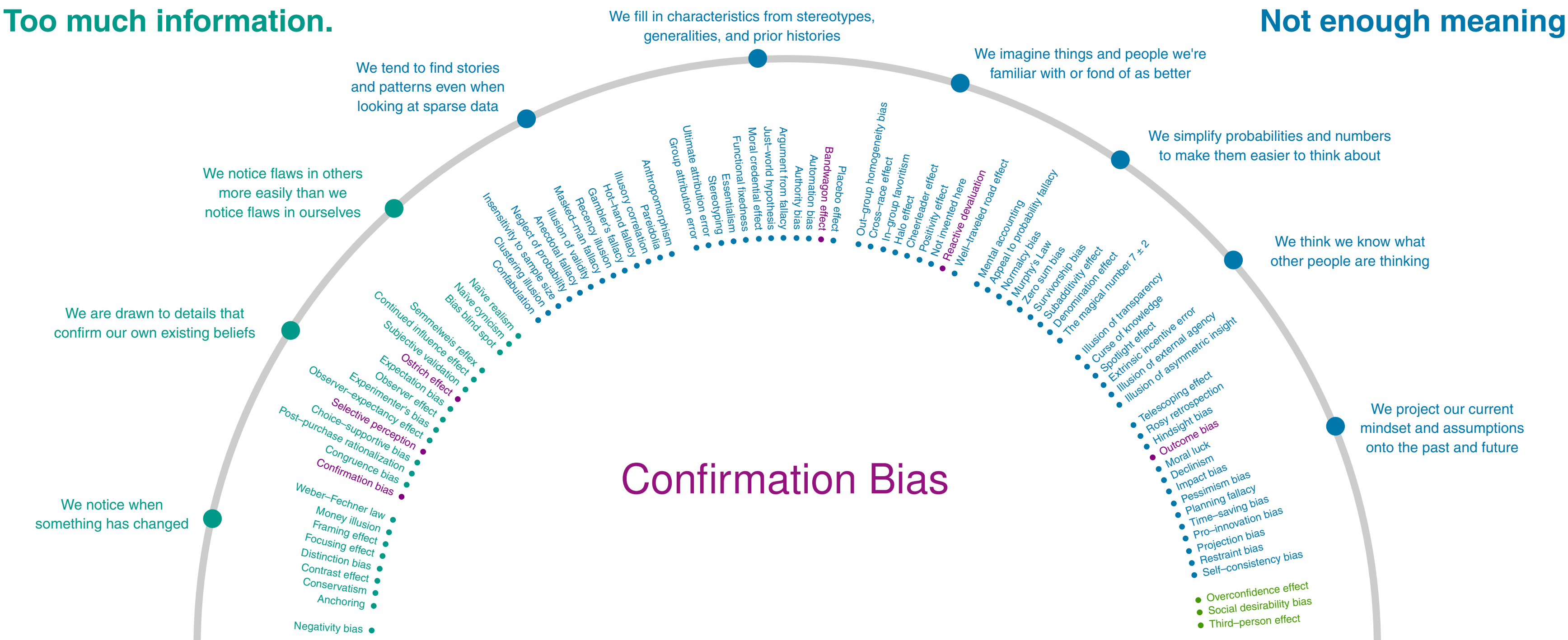
IR systems can assist in systematic and fair review.

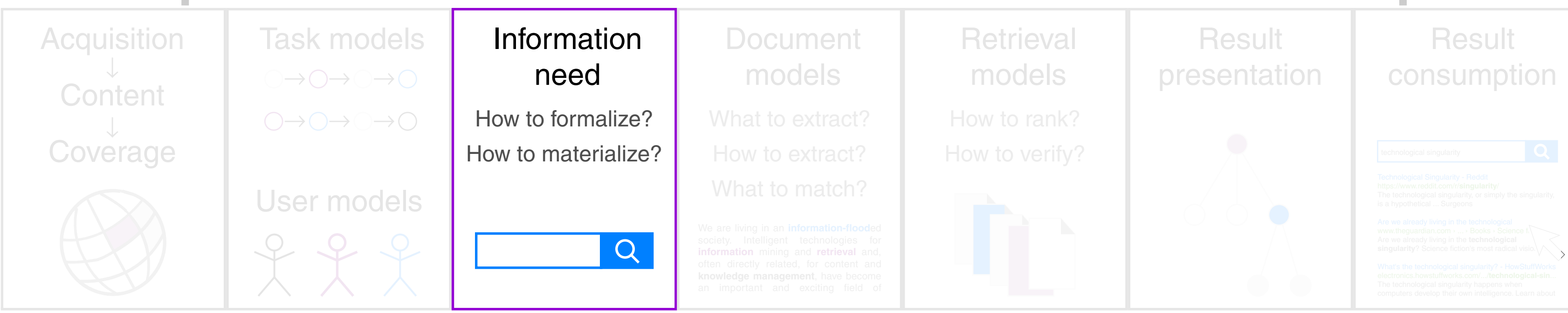
- M. Grossman, G. Cormack, A. Roegiest (2016). TREC 2016 total recall track overview.
- A. Olteanu et al. (2021). FACTS-IR: Fairness, accountability, confidentiality, transparency, and safety in IR.



User models can incorporate biases.

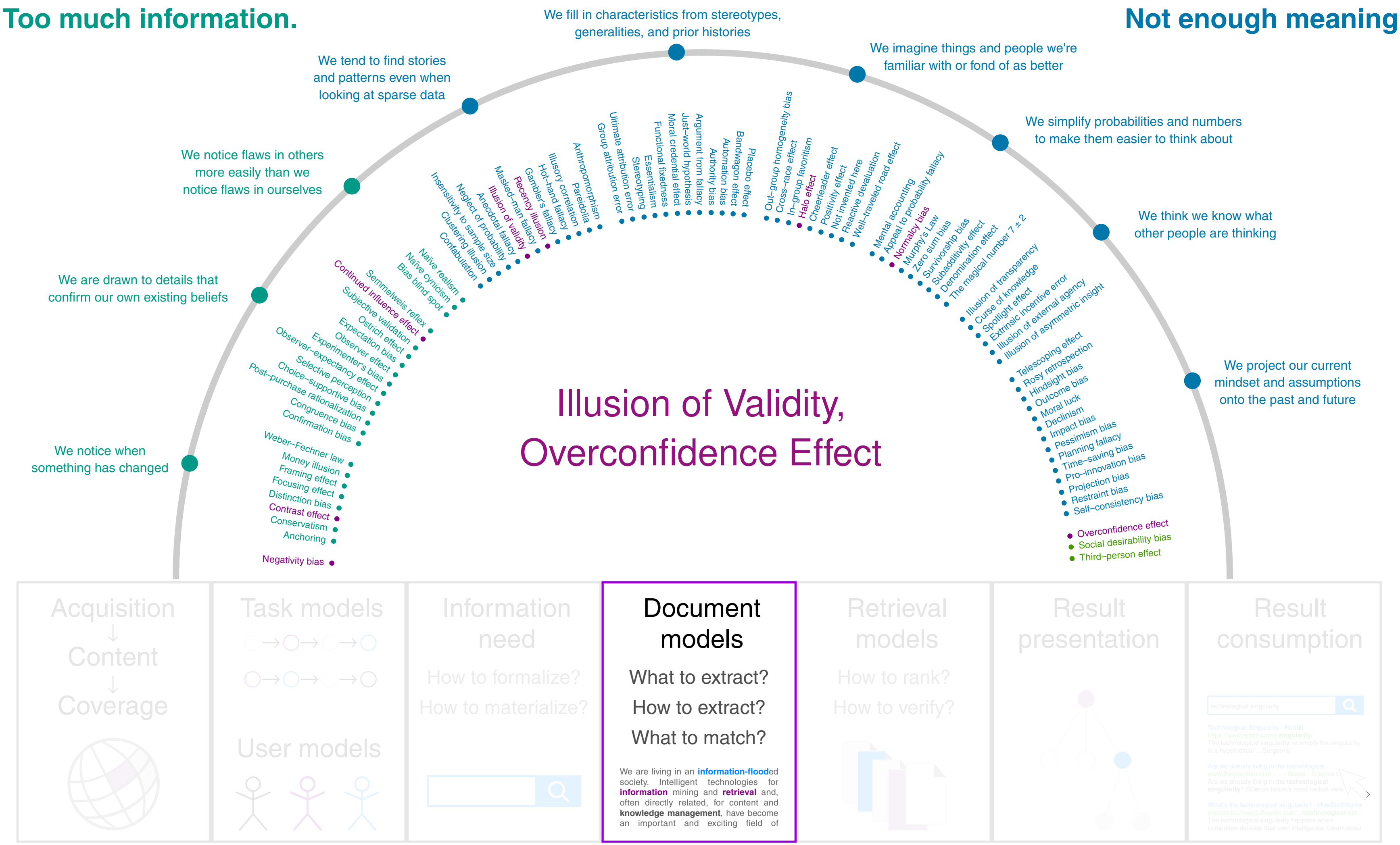
- T. Joachims et al. (2005). Accurately interpreting clickthrough data as implicit feedback.
- N. Chen et al. (2022). Constructing better evaluation metrics by incorporating the anchoring effect into the user model.





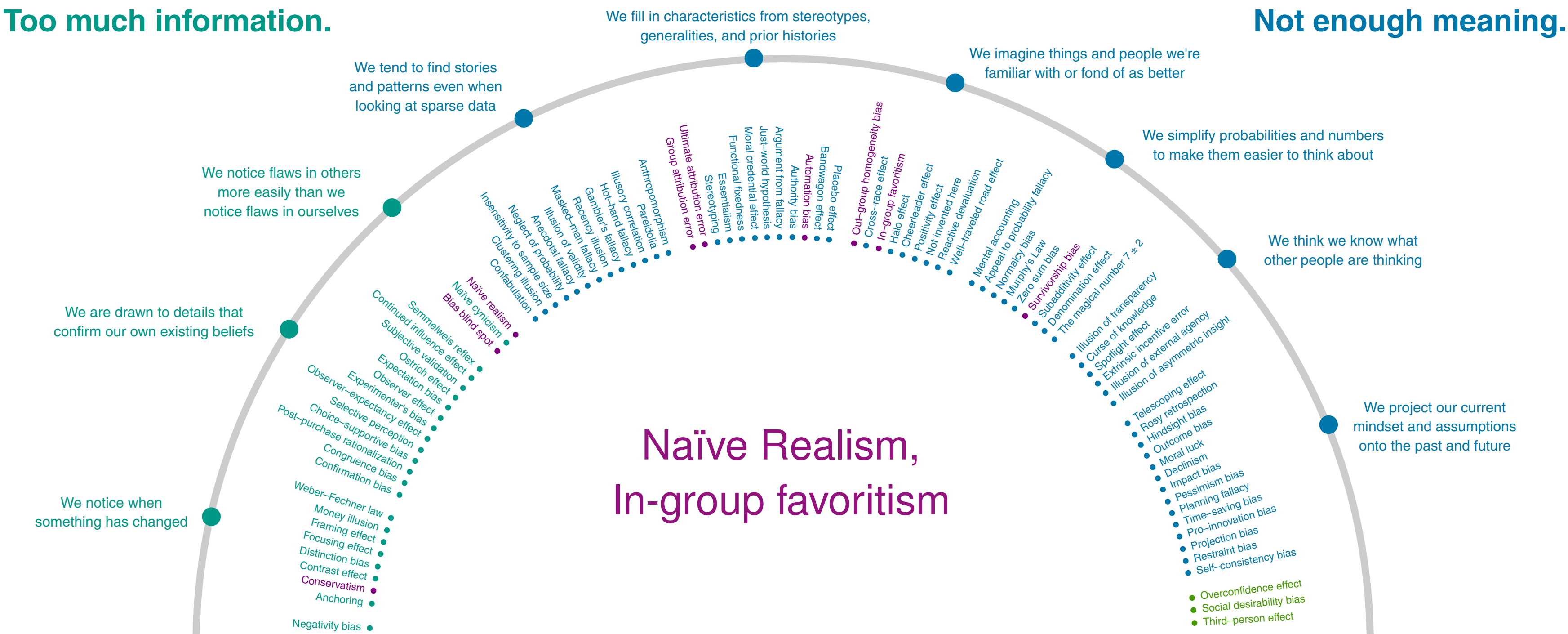
Query assistance (auto-completion, suggestion) can nudge searchers towards critical queries.

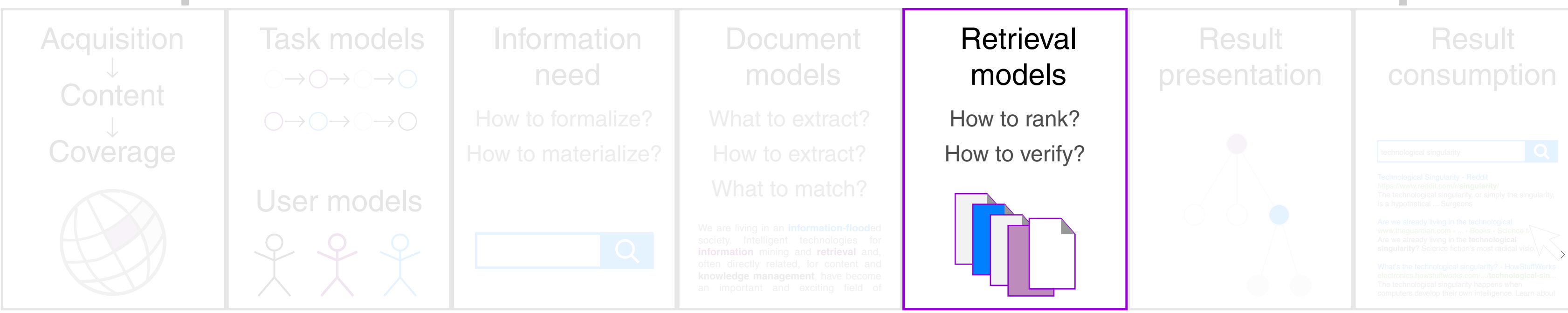
- Y. Yamamoto, T. Yamamoto (2018). Query priming for promoting critical thinking in web search.
- S. Pothirattanachaikul et al. (2020). Analyzing the effects of “People also ask” on search behaviors and beliefs.



IR systems can assist in checking claim veracity.

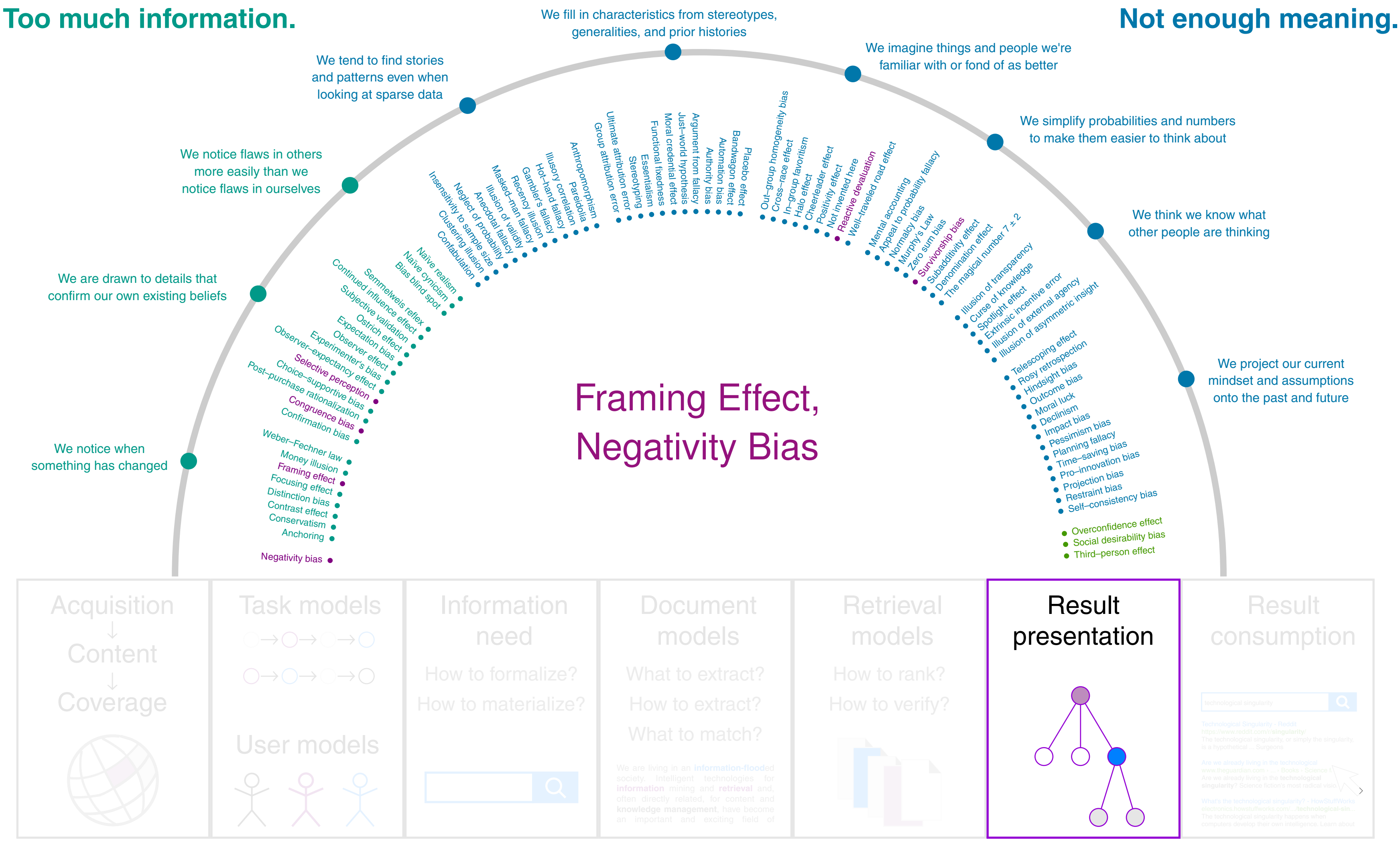
- P. Nakov et al. (2022). Overview of the CLEF’22 CheckThat! lab task on detecting previously fact-checked claims.
- Y. Qu et al. (2021). Human-in-the-loop systems for truthfulness: A study of human and machine confidence.





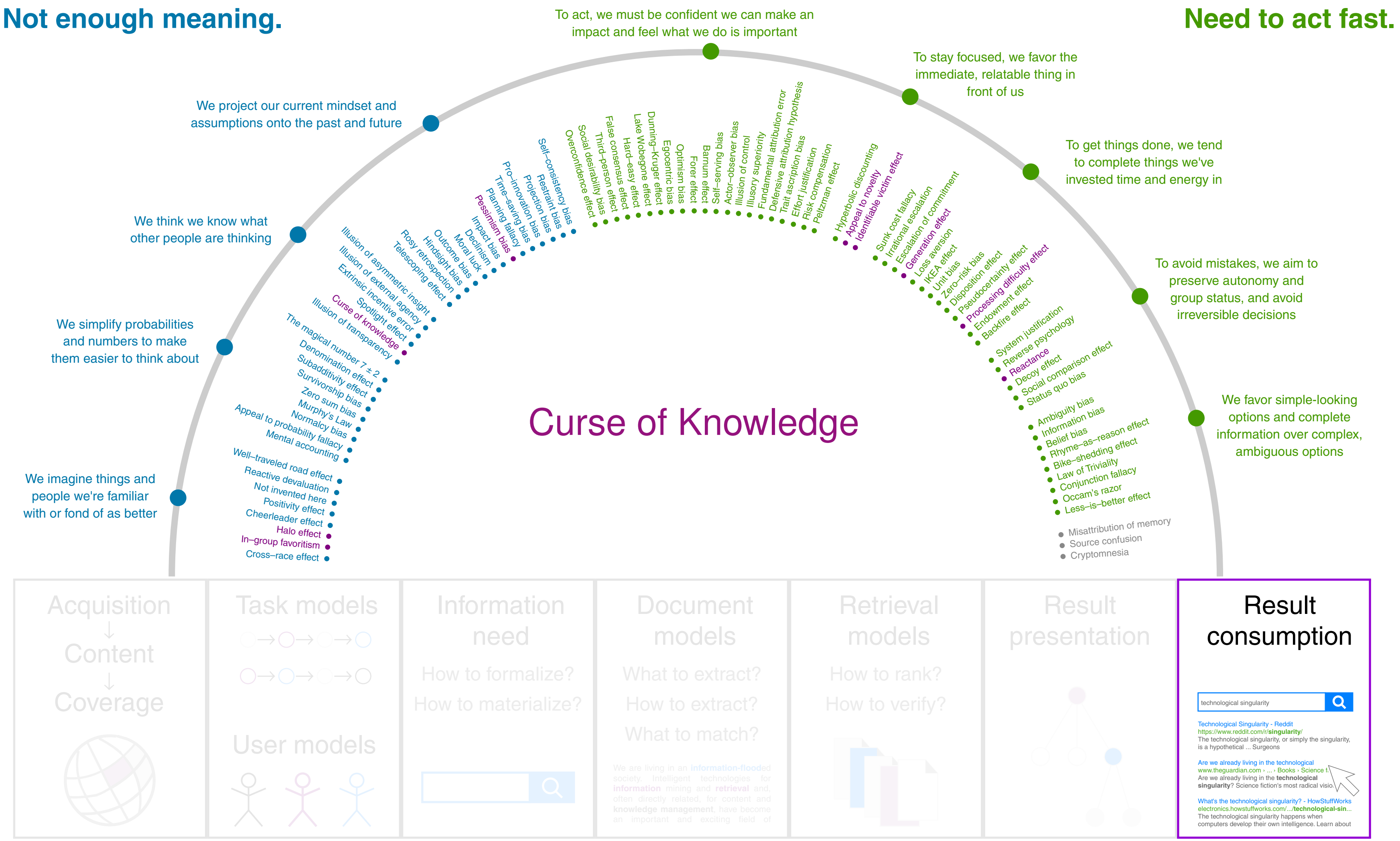
Result lists can be tweaked to reflect normative distributions.

- M. Ekstrand et al. (2022). Overview of the TREC'21 fair ranking track.
- P. Sapiezynski et al. (2019). Quantifying the impact of user attention on fair group representation in ranked lists.



Result captions (title + snippet + URL in a SERP) can be changed to influence user behavior.

- C. Clarke et al. (2007). The influence of caption features on clickthrough patterns in web search.
- R. W. White (2013). Beliefs and biases in web search.



Complex documents can be simplified to make them more accessible.

- L. Ermakova et al. (2022). Overview of the CLEF’22 SimpleText task on query biased simplification of scientific texts.
- M. Maddela et al. (2021). Controllable text simplification with explicit paraphrasing.

③

Related Research @ Webis

Google

how long do cats live

Cat / Lifespan

15 years

Domesticated

Feedback

[How Long Do Cats Live? | petMD](www.petmd.com/blogs/thedailyvet/.../how_long_do_cats_live-11496)
www.petmd.com/blogs/thedailyvet/.../**how_long_do_cats_live**-11496 ▾
Aug 8, 2011 - This question, typically rephrased as, "**How long** will my **cat** (or dog, horse, etc.) **live**," is something veterinarians hear on a daily basis.

Aging Cats: Changes, Health Problems, Food, and More
pets.webmd.com/**cats**/guide/aging-**cats**-qa ▾
WebMD veterinarian experts answer common questions **cat** owners have ... What else can you expect as your **cat** ages? ... Q: **How long do cats** usually **live**?

What Is the Life Span of the Common Cat? - Cats - About.com
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How long is the common **cat** supposed to **live**? Questions and answers from the About Guide to **Cats**.

Ageing - How long do cats live | Adelaide Animal Hospital
adelaidevet.com.au/pet.../**how-long-do-cats-live**-ageing-and-your-feline ▾
Life expectancy depends on many things, including one important factor - whether your cat is an indoor-only cat or an outdoor cat. Indoor cats generally live from **12-18 years** of age. Many may live to be in their early 20s. The oldest reported cat lived to be an

Cat

Animal

The domestic cat or the feral cat is a small, typically furry, carnivorous mammal. They are often called house cats when kept as indoor pets or simply cats when there is no need to distinguish them from other felids and felines. Wikipedia

Scientific name: Felis catus

Lifespan: 15 years (Domesticated)

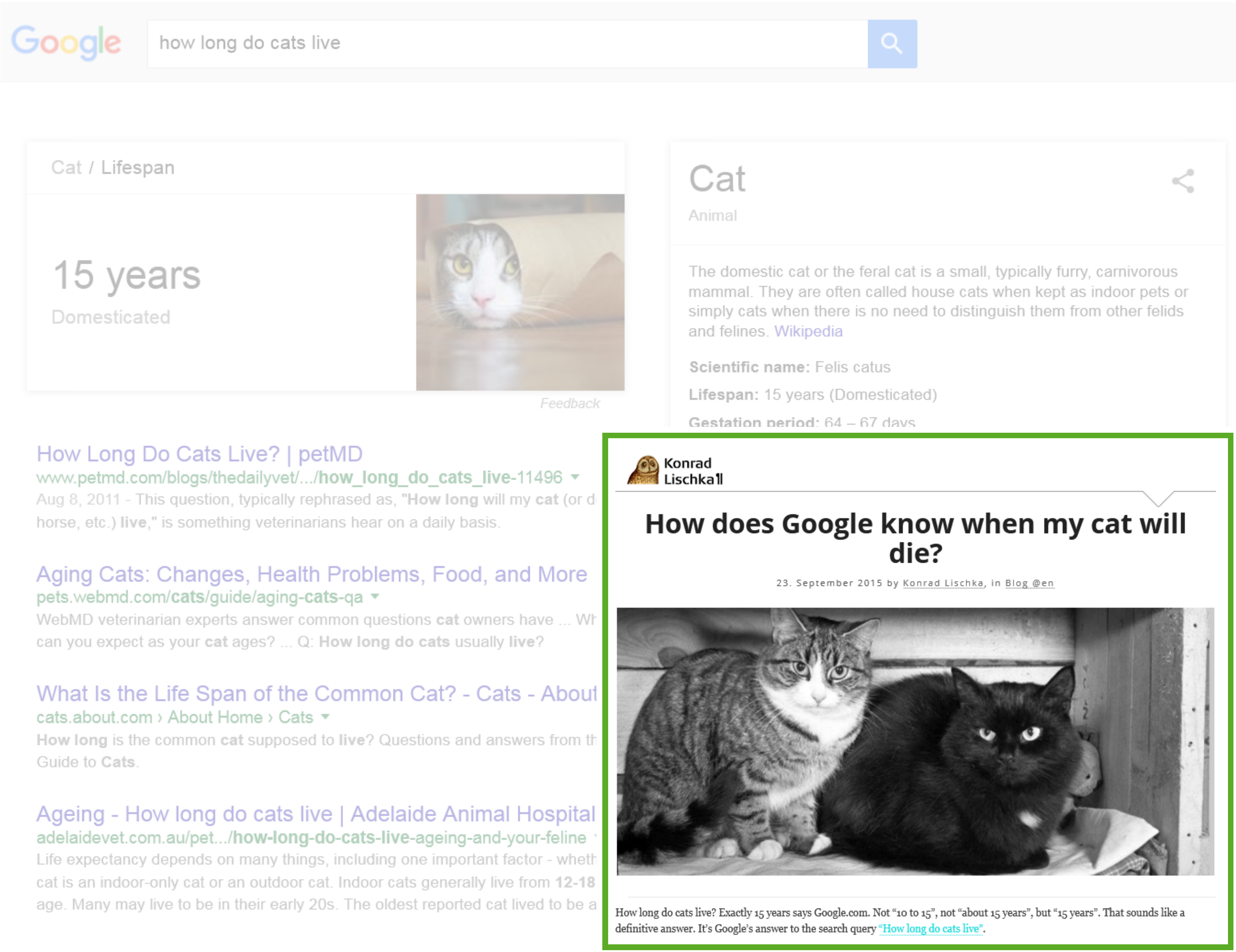
Gestation period: 64 – 67 days

Higher classification: Felis

Daily sleep: 12 – 16 hours

Mass: 3.6 – 4.5 kg (Adult)

Feedback


Google
how long do cats live
Cat / Lifespan
15 years
Domesticated
Feedback
Cat
Animal
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cat is an indoor-only cat or an outdoor cat. Indoor cats generally live from 12-18
age. Many may live to be in their early 20s. The oldest reported cat lived to be a
Konrad
Lischka
How does Google know when my cat will die?
23. September 2015 by Konrad Lischka, in Blog @en
How long do cats live? Exactly 15 years says Google.com. Not "10 to 15", not "about 15 years", but "15 years". That sounds like a definitive answer. It's Google's answer to the search query "How long do cats live".

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Dilemma of the Direct Answer

“A user’s choice between convenience and diligence when using an information retrieval system.”

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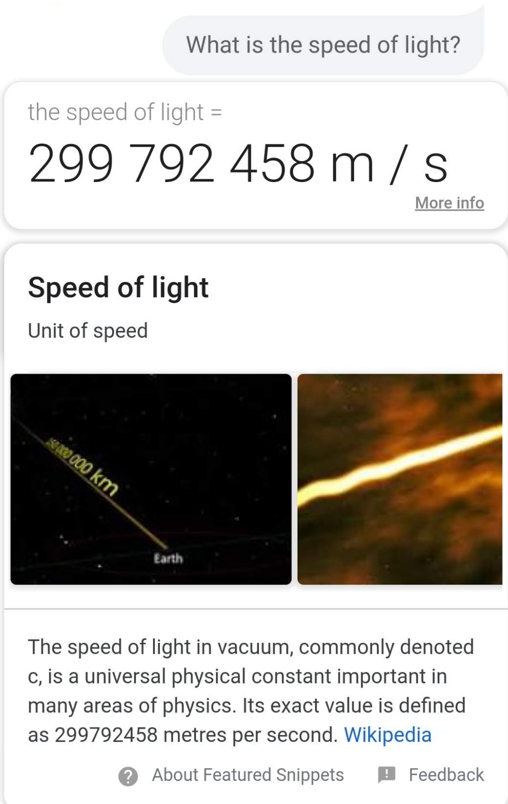
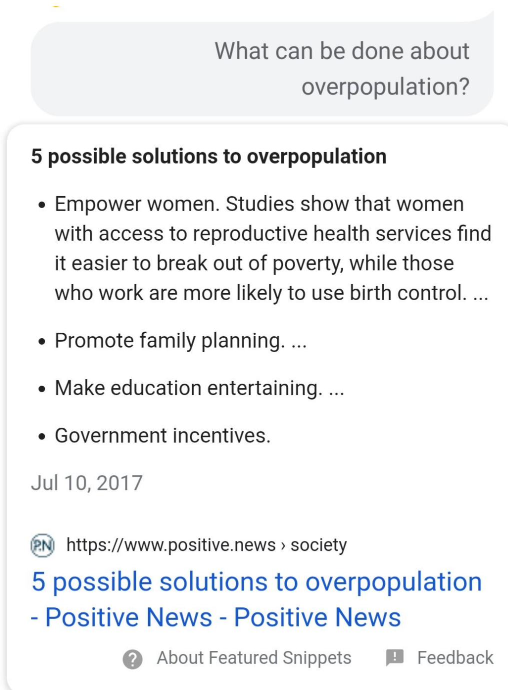
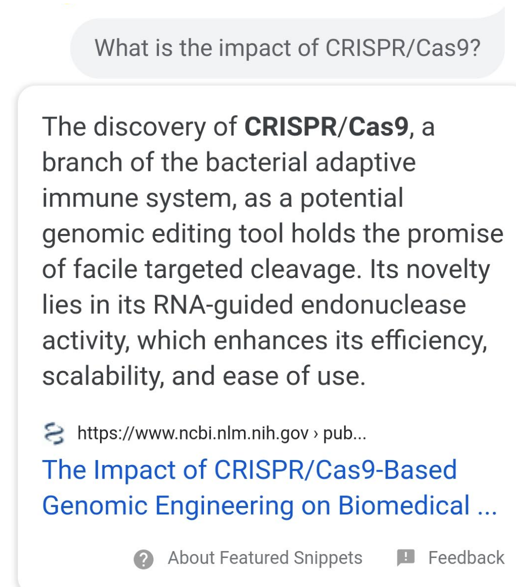
Dilemma of the Direct Answer

“A user’s choice between convenience and diligence when using an information retrieval system.”







- M. Potthast, M. Hagen, B. Stein (2020). The dilemma of the direct answer.

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Dilemma of the Direct Answer (continued)

Direct answers amplify various cognitive biases, among others:

1. Authority bias.
   Puts forward the single result with the authority of the search engine.
2. Confirmation bias / overconfidence.
   Likely the most prominent answer, thus confirming people already believing in it.
3. Naive realism / survivorship bias.
   Suggests a “simple” one-answer truth.
4. Mere-exposure effect / illusory truth effect.
   Exposes users to just one answer (mere exposure increases the liking of ideas).
5. Outgroup homogeneity bias.
   Implies a well-accepted opinion.
6. Reactance.
   If the direct answer not the one that one beliefs in, it can cause reactance in users.

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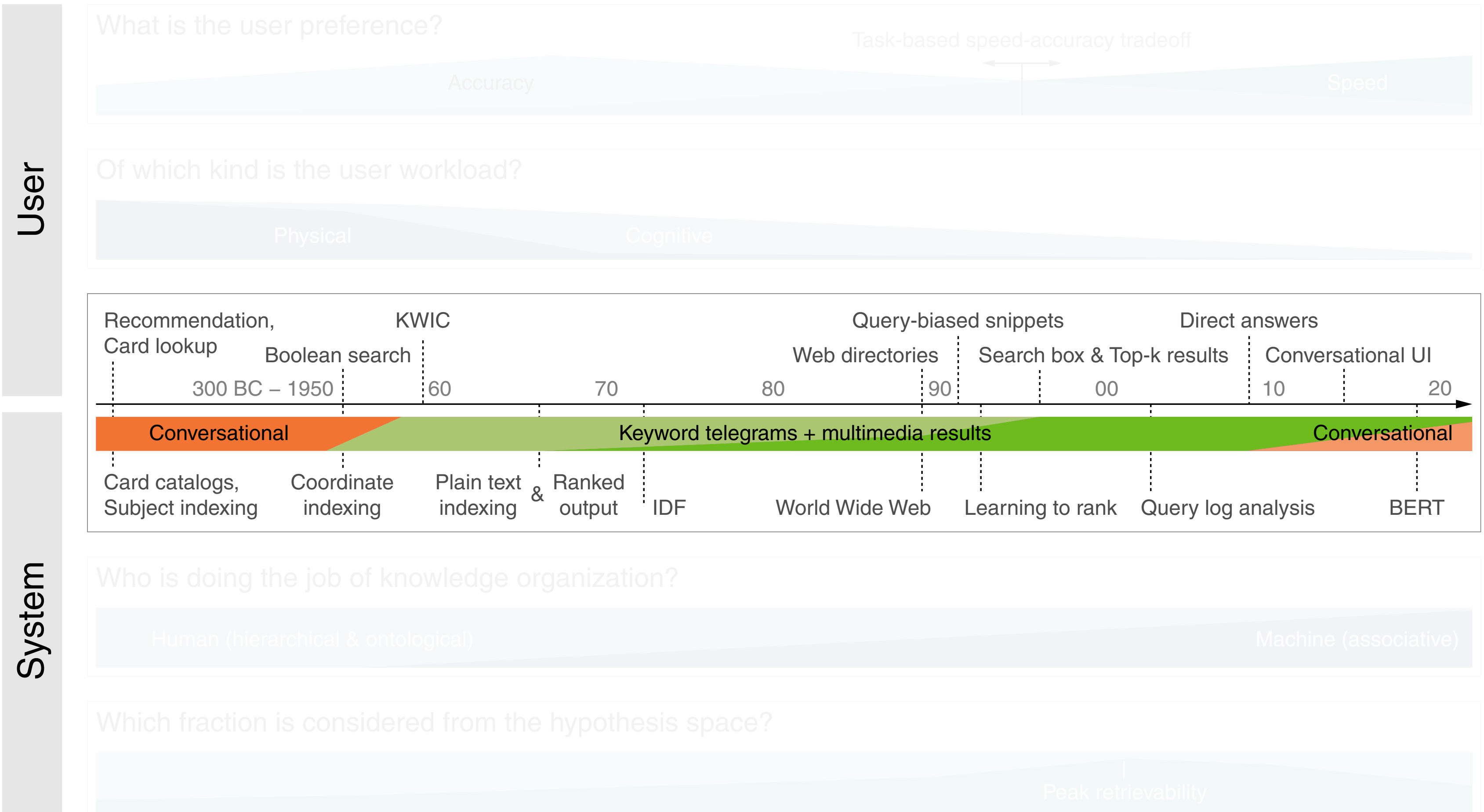
Dilemma of the Direct Answer (continued)



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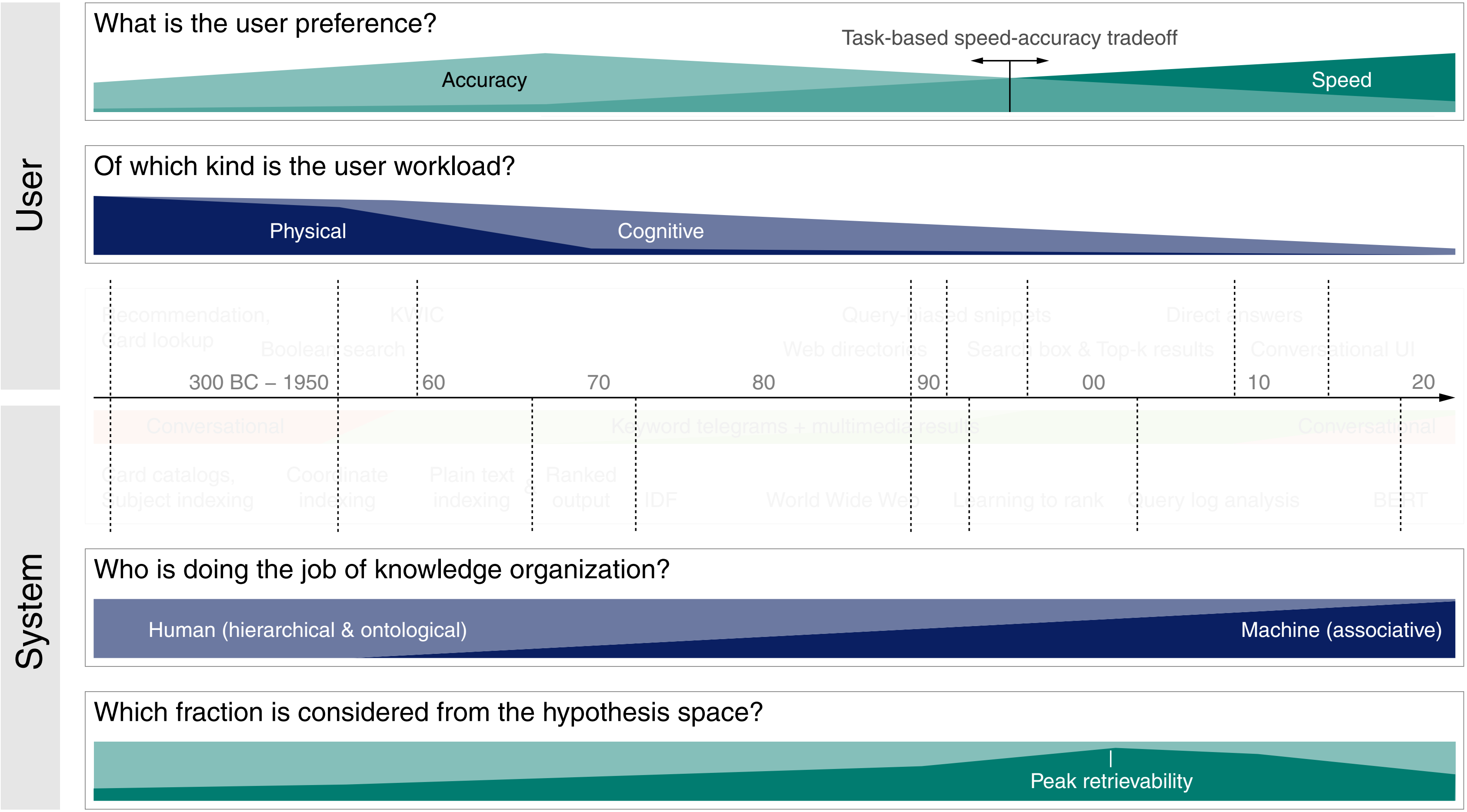

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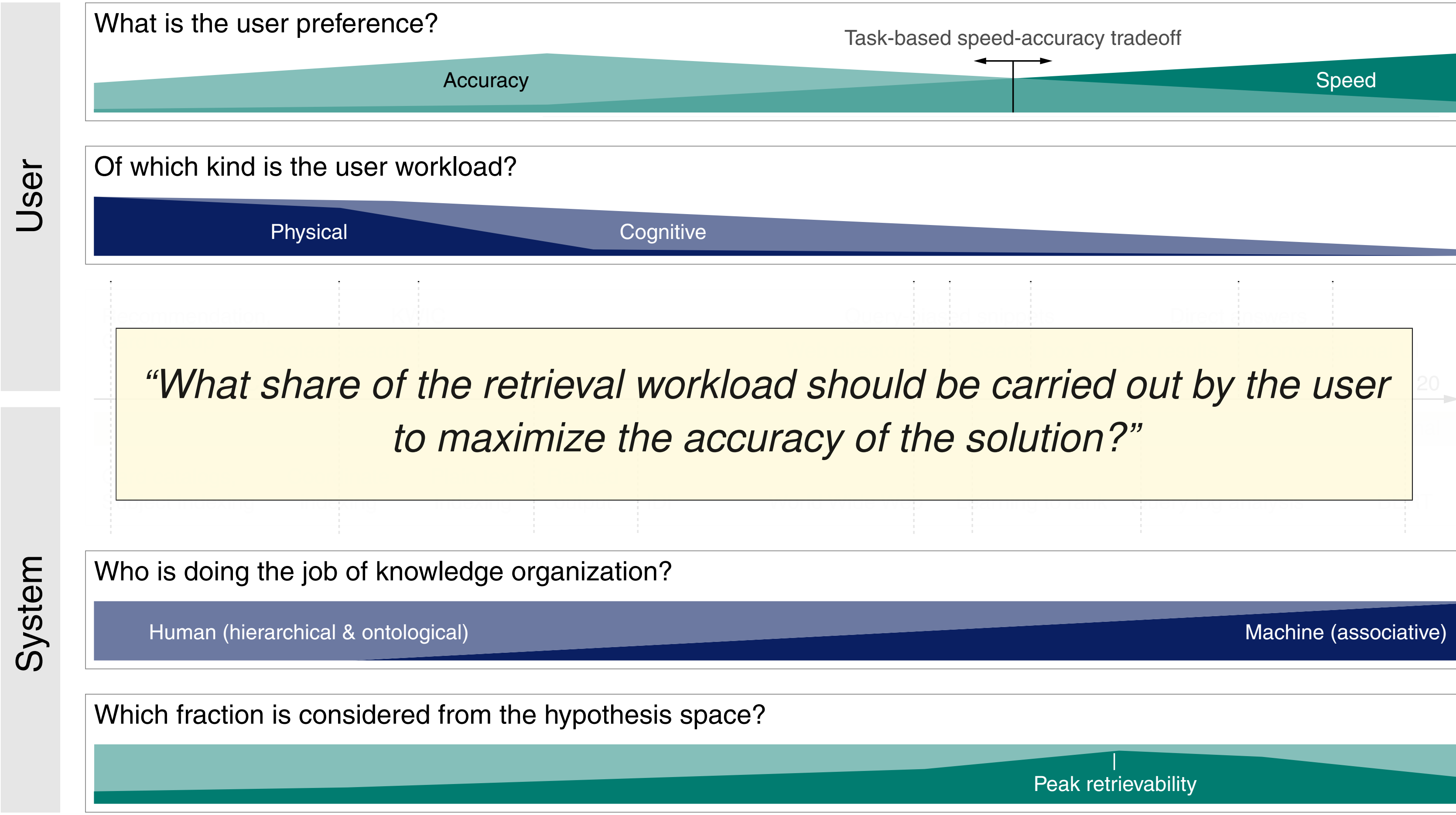
Dilemma of the Direct Answer (continued)



“What share of the retrieval workload should be carried out by the user to maximize the accuracy of the solution?”

- M. Potthast, M. Hagen, B. Stein (2020). The dilemma of the direct answer.

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Information Retrieval and the Balance of Responsibilities

More power to the machine?

Empower the user?

- support deliberation
- raise awareness
- demonstrate mechanisms
- provide meta information
- . . .

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- An argument search engine for the web. [args.me]

  Released: 2017.

  About 350,000 arguments over 1,200 topics.

  Evidence types: discussions, news, people.

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  CLEF’22 & CLEF’23: Touché shared task on image retrieval for arguments.

  About 70,000 images over 100 topics.

- What are the values behind arguments? [values.args.me]

  Basis: Schwartz et al. value continuum (2012).

  SemEval’23: Shared task on human value detection.

  About 10,000 arguments reflecting 20 values.

  Forthcoming: ValueEval’24 with EU Commission’s JRC.

- H. Wachsmuth et al. (2017). Building an argument search engine for the web.
- J. Kiesel et al. (2021). Image retrieval for arguments using stance-aware query expansion.
- J. Kiesel et al. (2022). Identifying the human values behind arguments.

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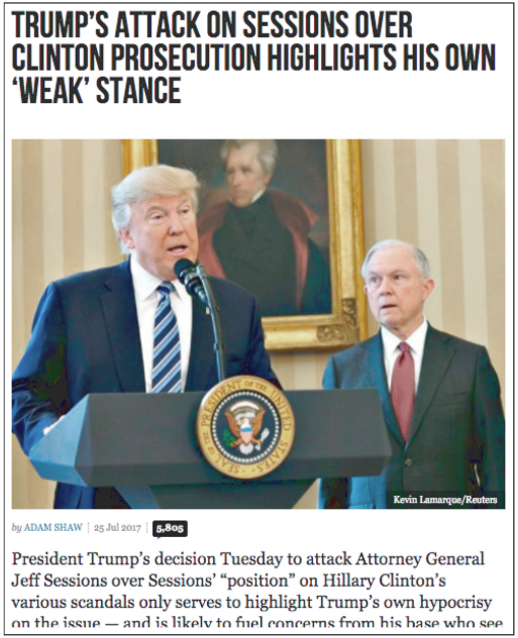

TRUMP'S ATTACK ON SESSIONS OVER CLINTON PROSECUTION HIGHLIGHTS HIS OWN 'WEAK' STANCE

Kevin Lamarque/Reuters

by ADAM SHAW | 25 Jul 2017 | 5,805

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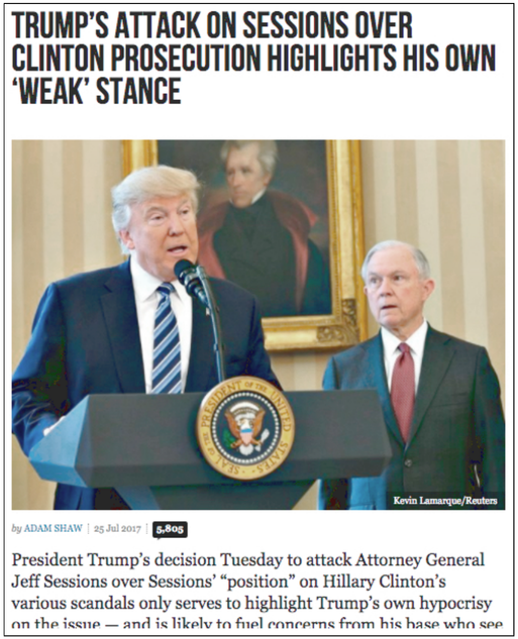
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INFORMATION NUTRITION LABEL		
Best before: Jan 1, 2018		
Per 1,000 words		**Recommended daily allowance**
Fact	30%	60%
Opinion	40%	20%
Controversy	9.0	–
Emotion	6.7	1.3
Topicality	8.7	5.0
Reading level	4.0	8.0
Technicality	2.0	–
Authority	4.3	9.0
Viralness	–	1.0
Additional substances: advertising, subscription, invective, images (2), tweets, video clips		
Traces: product placement		

- T. Gollub, M. Potthast, B. Stein (2018). Shaping the information nutrition label.
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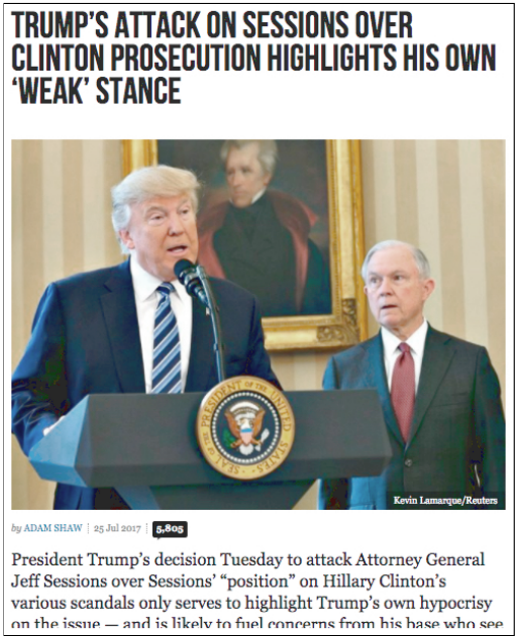
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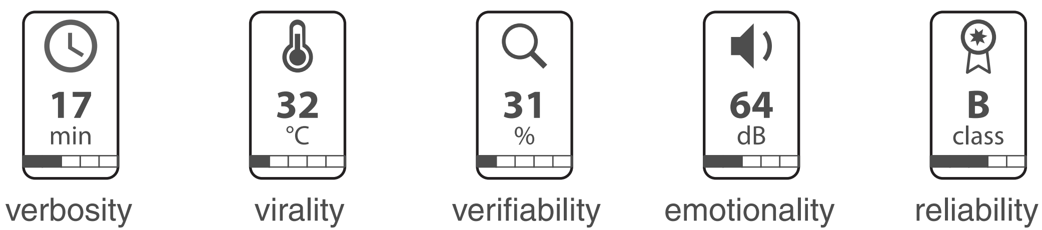

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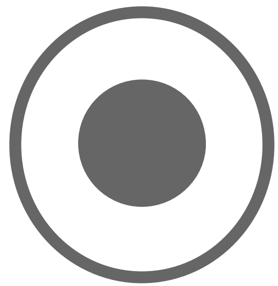
(4) An Information Nutrition Label

"It is not our intention to say what is true or what is false, right or wrong, and in particular not what is good or bad.*

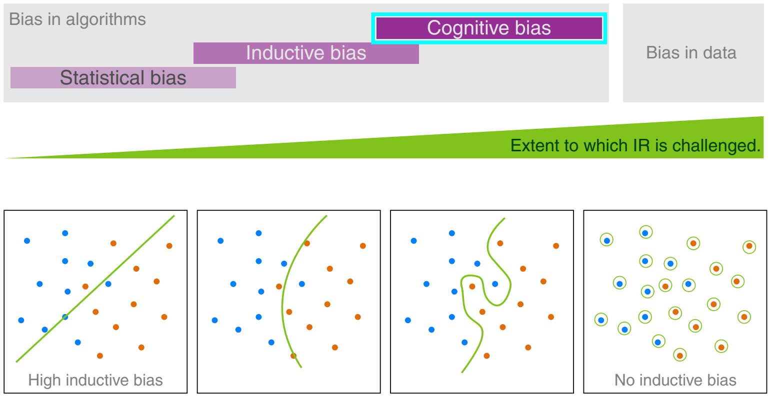
That is, an Information Nutrition Label is not a substitute for a moral compass."

---

* Norbert Fuhr, Anastasia Giachanou, Gregory Grefenstette, Iryna Gurevych, Andreas Hanselowski, Kalervo Jarvelin, Rosie Jones, Yiqun Liu, Josiane Mothe, Wolfgang Nejdl, Isabella Peters, Benno Stein @ Schloss Dagstuhl (2017)

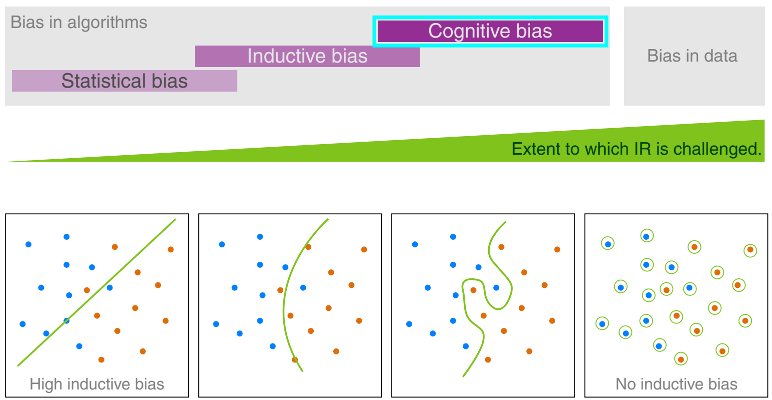


Summary

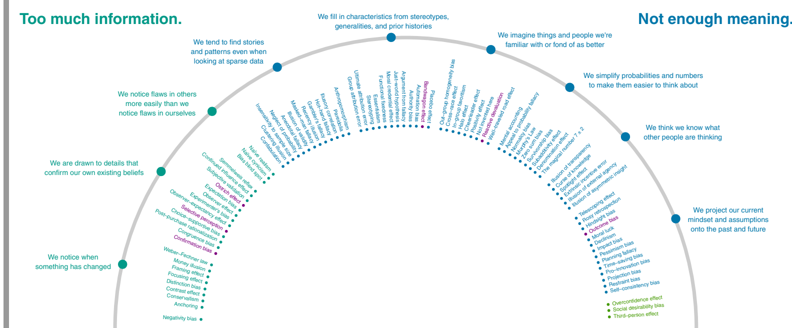


The meanings of bias, and their connections.

Summary

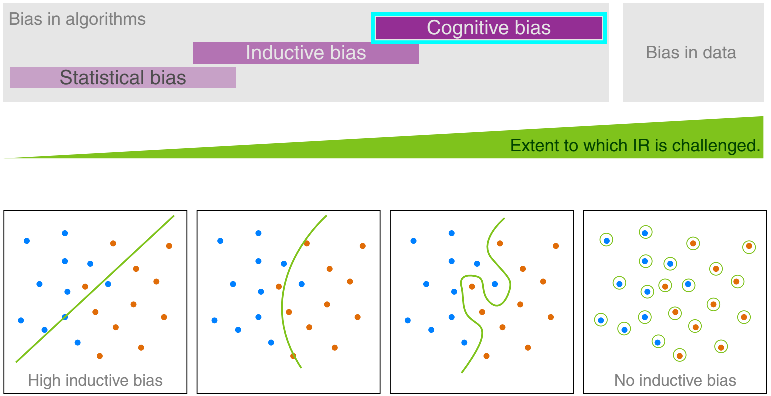


The meanings of bias, and their connections.

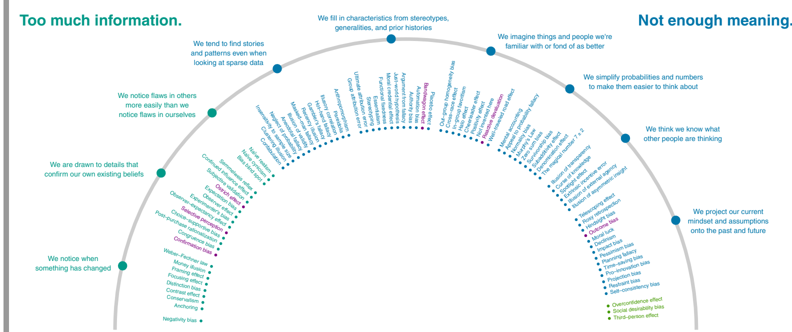


Addressing cognitive biases with IR.

Summary



The meanings of bias, and their connections.



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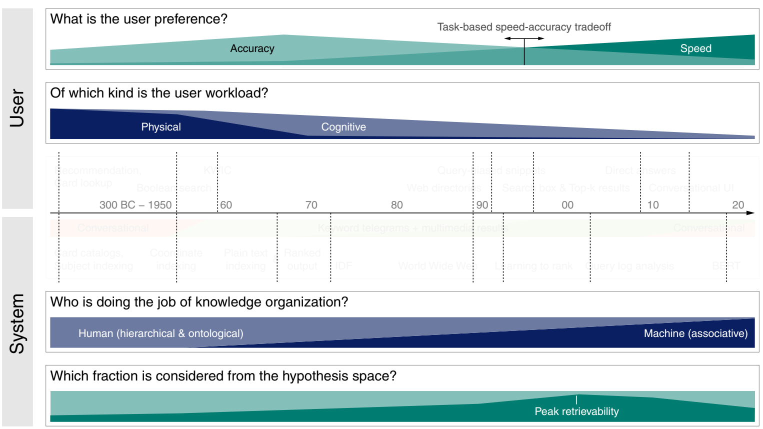
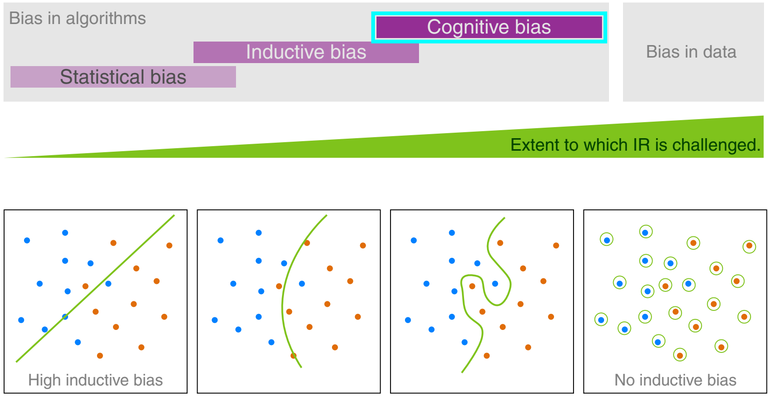
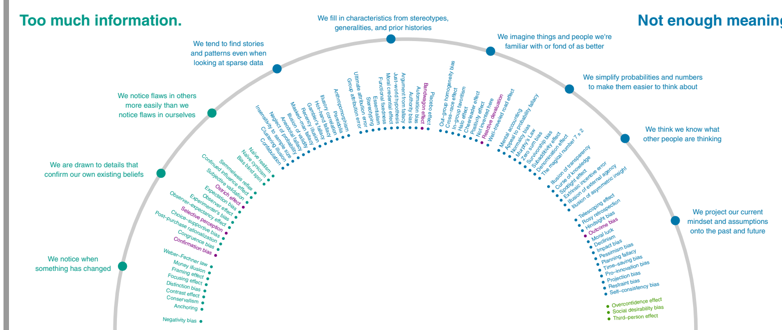


Direct answers—the pride of IR?

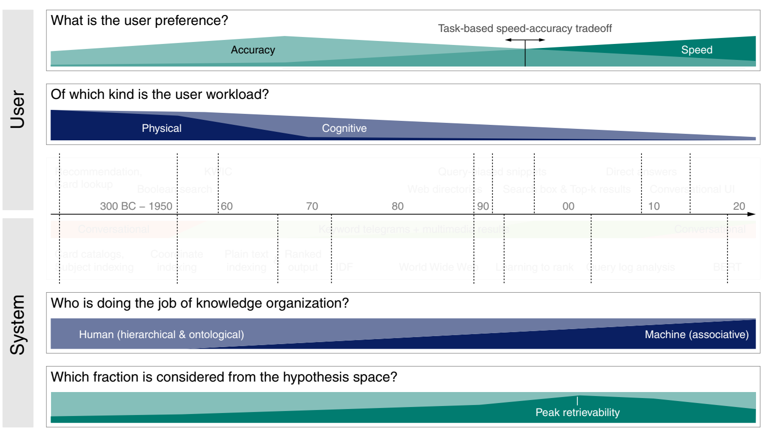
Summary



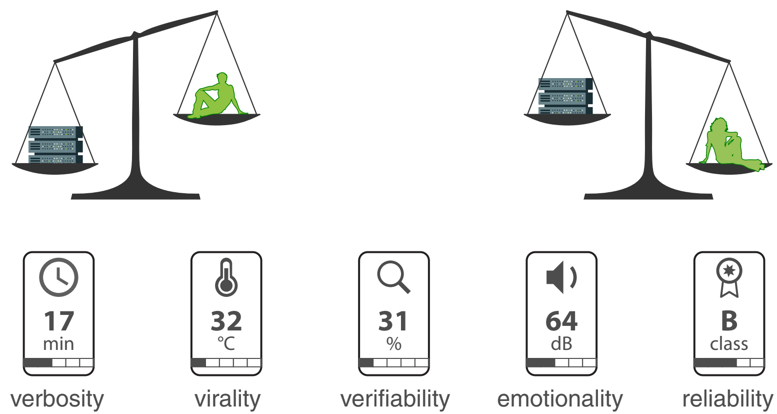
The meanings of bias, and their connections.



Addressing cognitive biases with IR.



Direct answers—the pride of IR?



More power to machines—or, empower the user?

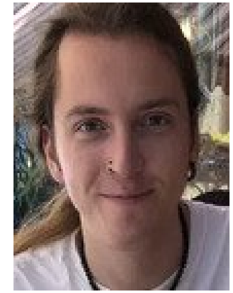

J. Ajjour


J. Bevendorff


A. Bondarenko


W. Chen

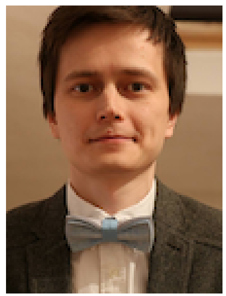

M. Fröbe

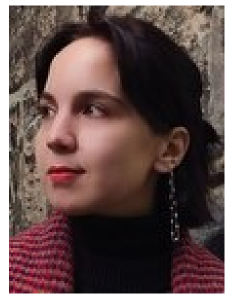

M. Ghosen


T. Gollub

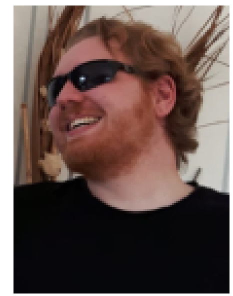

M. Heinrich


J. Kiesel

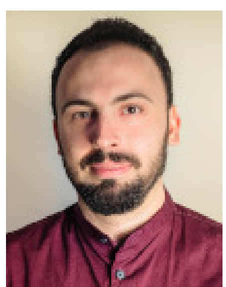

N. Kolyada

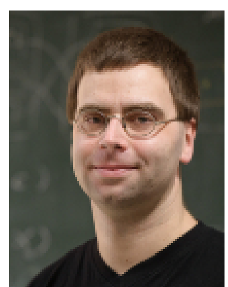

N. Mirzakhmedova


M. Völske

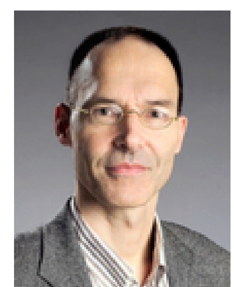

M. Wiegmann


M. Wolska


K. Al-Khatib


M. Hagen


M. Potthast

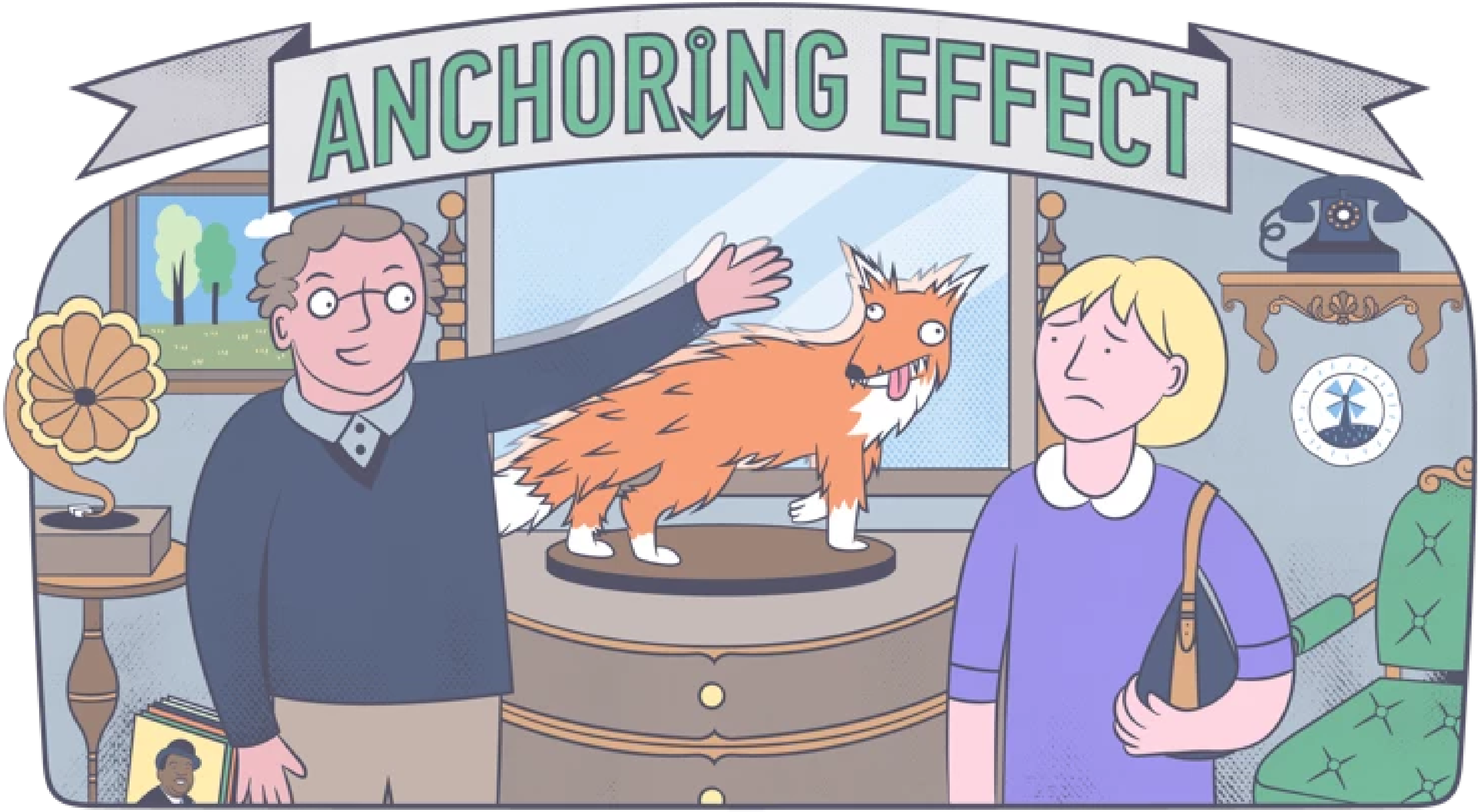

B. Stein


H. Wachsmuth

Thank You!

"THEY MUST HAVE A DEATH WISH TO SWIM IN THAT WATER."

https://www.towergateinsurance.co.uk/liability-insurance/cognitive-biases (2016)



"BREATH-TAKING ISN'T IT? THE SELLER WANTED 5,000 BUT I GOT IT FOR JUST 4,500!"

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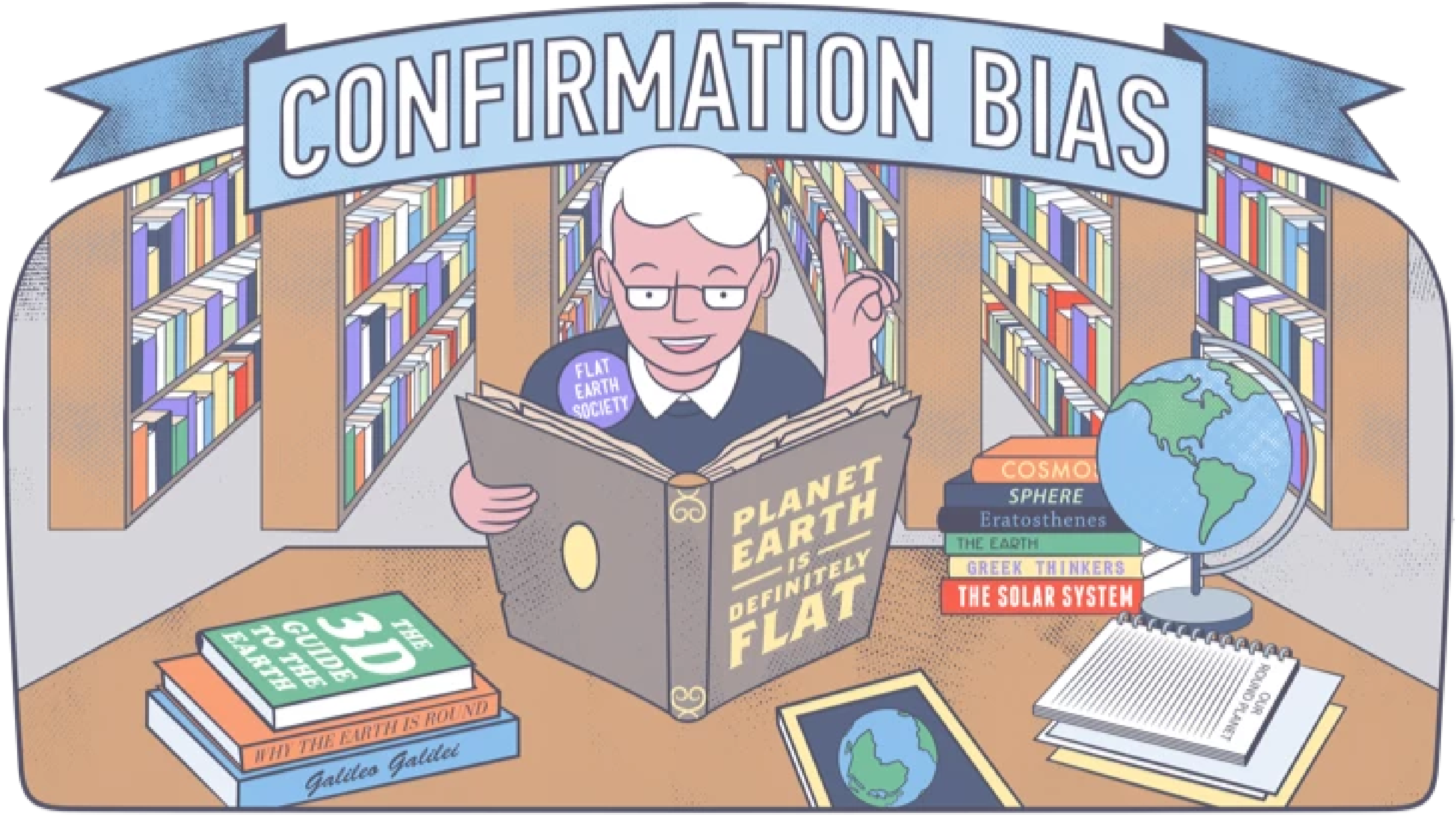


"AHA! I KNEW IT!"

https://www.towergateinsurance.co.uk/liability-insurance/cognitive-biases (2016)

https://www.towergateinsurance.co.uk/liability-insurance/cognitive-biases (2016)

"WELL I DON'T KNOW HOW YOUR LECTURES WENT, BUT I CAN'T SEEM TO GET THROUGH TO THESE PEOPLE!"

https://www.towergateinsurance.co.uk/liability-insurance/cognitive-biases (2016)

Topics in Cognitive Science 1 (2009) 107–143

ISSN: 1756-8757 print / 1756-8765 online
DOI: 10.1111/j.1756-8765.2008.01006.x

Homo Heuristicus: Why Biased Minds Make Better Inferences

Gerd Gigerenzer, Henry Brighton

Max Planck Institute for Human Development

Abstract

Heuristics are efficient cognitive proc
view that less processing reduces accura
putation, and time can in fact improve a
discovery of less-is-more effects; (b) t
examines in which environments a give
from vague labels to computational mod
of heuristics that identifies their buildin
the cognitive system as relying on an ''
methodology that accounts for individu
evidence for people's adaptive use of he
of the available information, yet a biase
than an unbiased mind relying on more r

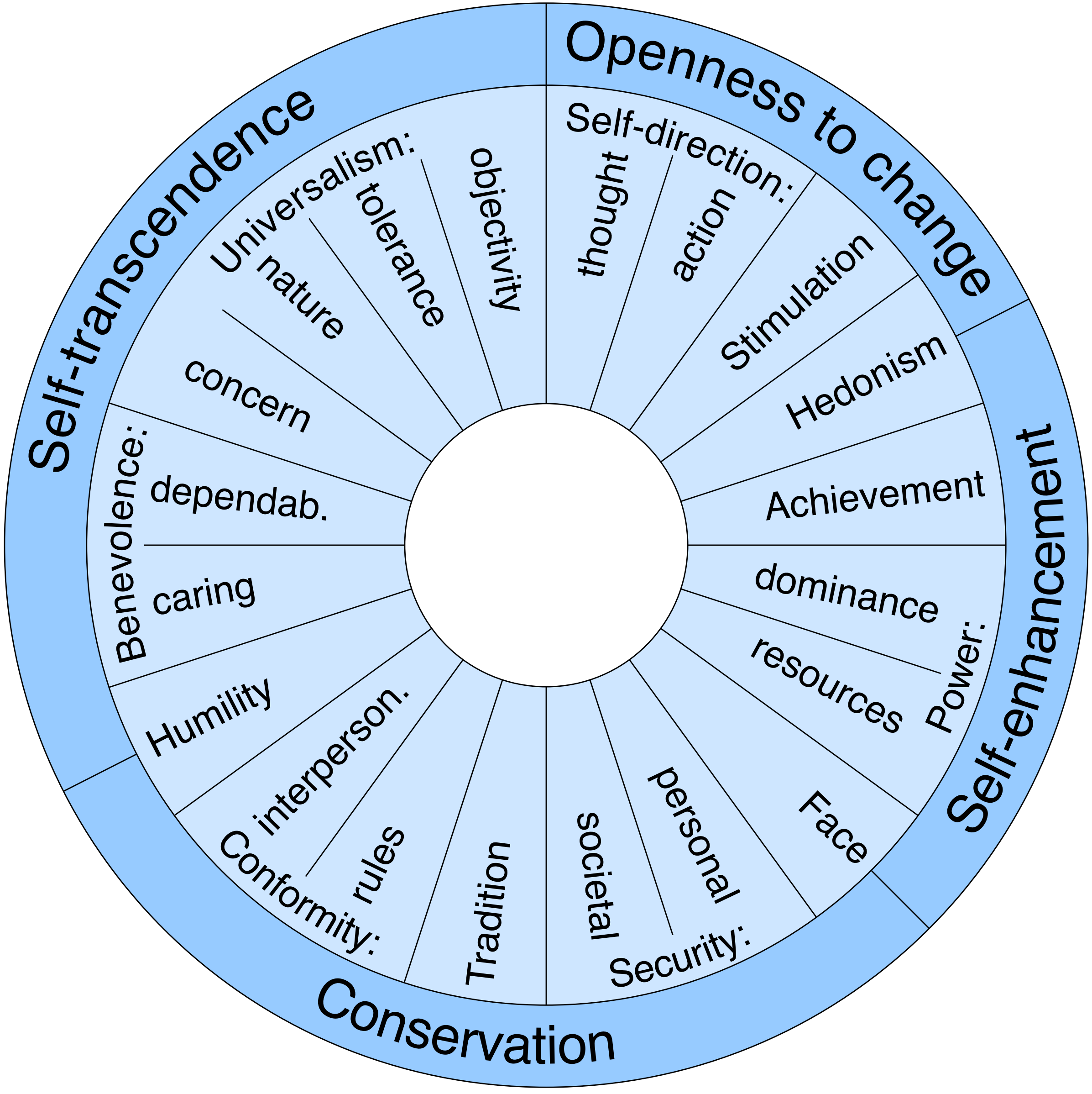
Keywords: Heuristics; Decision-making;

As far as we can know, animals h
lems, and so have humans. To measu
a rock, an ant has no yardstick but a
fixed period while laying down a phe
different irregular path, and estimate
the old trail. This heuristic is remark
counter frequencies 1.96 times grea
mate, a peahen similarly uses a heuri
displaying in a lek eager to get her
calculate the one with the highest ex

Correspondence should be sent to Gerd Gi
lee 94, 14195 Berlin, Germany. E-mail: giger

are computationally intractable, and this is why engineers and artificial intelligence (AI) researchers often rely on heuristics to make computers smart.

In the 1970s, the term *heuristic* acquired a different connotation, undergoing a shift from being regarded as a method that makes computers smart to one that explains why people are not smart. Daniel Kahneman, Amos Tversky, and their collaborators published a series of experiments in which people's reasoning was interpreted as exhibiting fallacies. ''Heuristics and biases'' became one phrase. It was repeatedly emphasized that heuristics are sometimes good and sometimes bad, but virtually every experiment was designed to show that people violate a law of logic, probability, or some other standard of rationality. On the positive side, this influential research drew psychologists' attention to cognitive heuristics and helped to create two new fields: behavioral economics, and behavioral law and economics. On the negative side, heuristics became seen as something best to avoid, and consequently, this research was disconnected from the study of heuristics in AI and behavioral biology. Another negative and substantial consequence was that computational models of heuristics, such as lexicographic rules (Fishburn, 1974) and elimination-by-aspects (Tversky, 1972), became replaced by one-word labels: availability, representativeness, and anchoring. These


Openness to change
Self-enhancement
Conservation
Self-transcendence
Self-direction:
thought
action
Stimulation
Hedonism
Achievement
Power:
dominance
resources
Face
Security:
personal
societal
Tradition
Conformity:
rules
interperson.
Humility
Benevolence:
caring
dependab.
Universalism:
concern
nature
tolerance
objectivity