A Task-based Taxonomy of Cognitive Biases for Information Visualization

Evanthia Dimara, Steven Franconeri, Catherine Plaisant, Anastasia Bezerianos, and Pierre Dragicevic

Three kinds of limitations

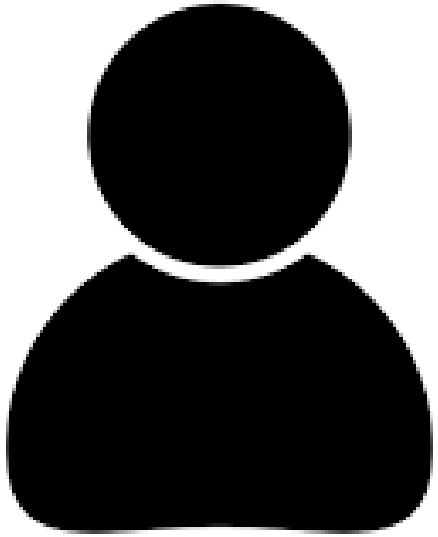
The Computer

The Display

Three kinds of limitations

The Computer

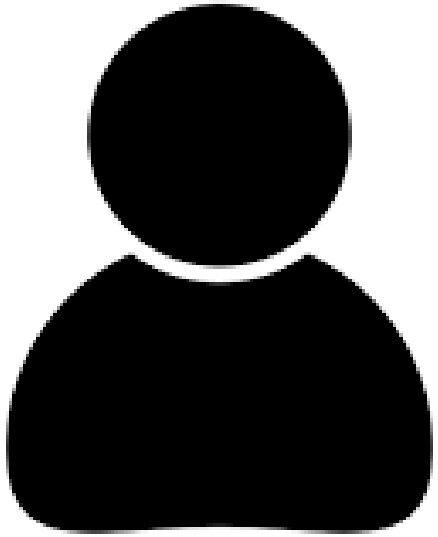
The Display



The Human

Three kinds of limitations: humans

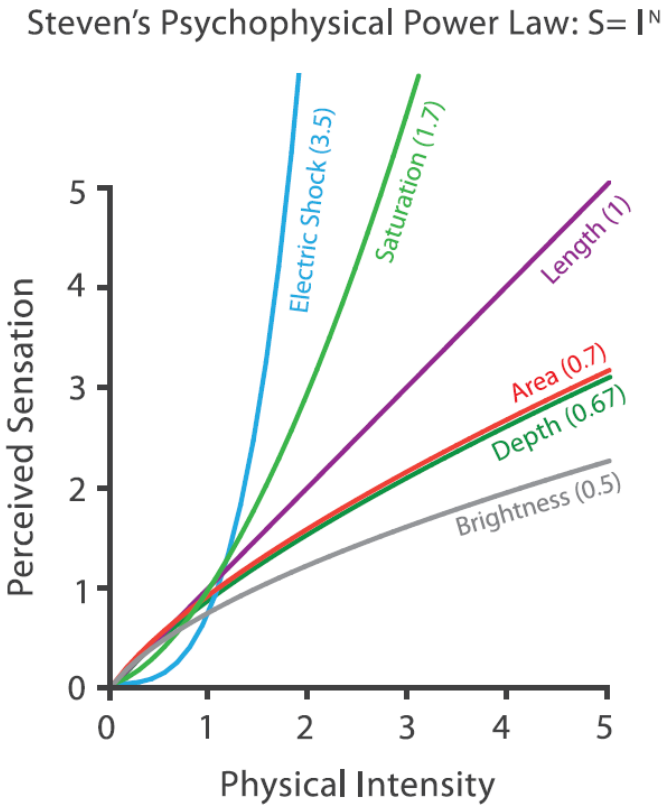
- Human vision 👁 has limitations
- Human reasoning 🧠 has limitations



The Human

Perceptual bias

Magnitude estimation



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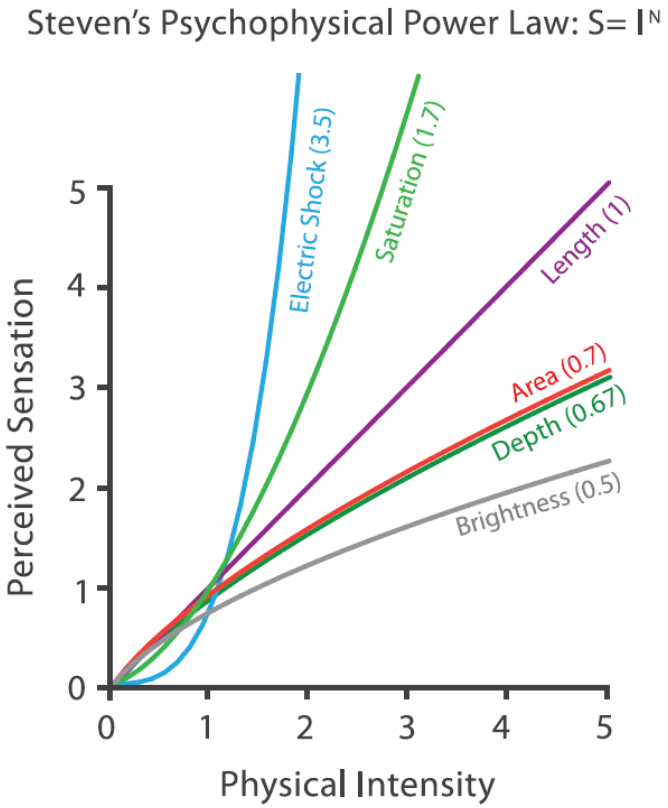


Color perception

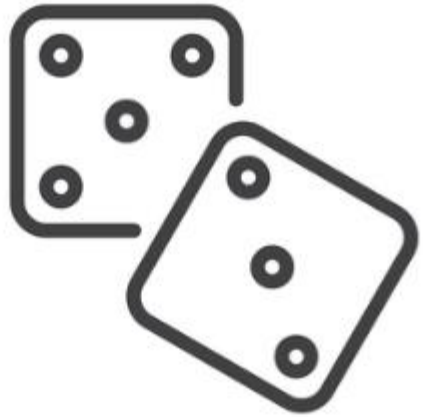
Cognitive bias

Behaviors when humans consistently behave irrationally

Pohl’s criteria distilled:

- Are predictable and consistent
- People are unaware they’re doing them
- Are not misunderstandings

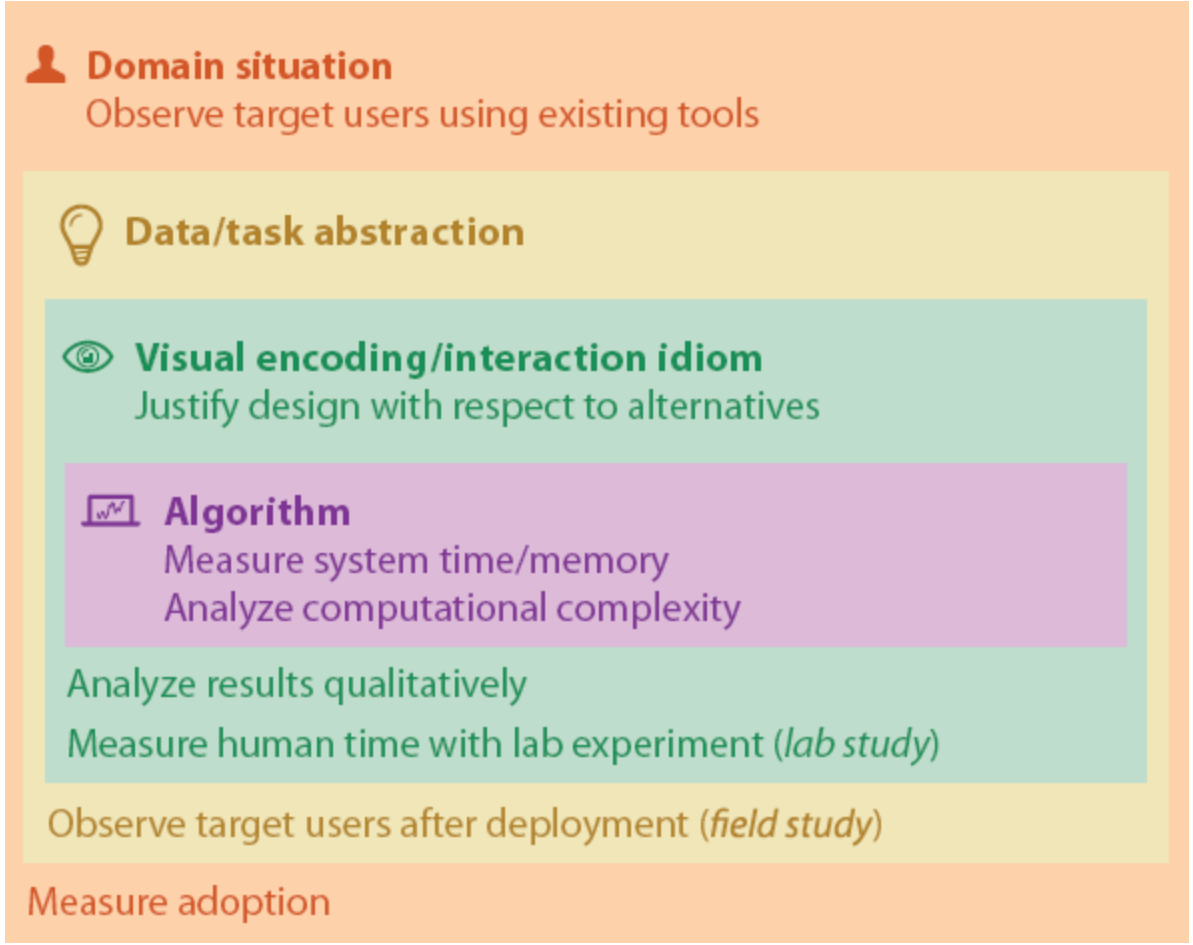
Gambler's Fallacy



Ambiguity effect, Anchoring or focalism, Anthropocentric thinking, Anthropomorphism or personification, Attentional bias, Attribute substitution, Automation bias, Availability heuristic, Availability cascade, Backfire effect, Bandwagon effect, Base rate fallacy or Base rate neglect, Belief bias, Ben Franklin effect, Berkson's paradox, Bias blind spot, Choice-supportive bias, Clustering illusion, Compassion fade, Confirmation bias, Congruence bias, Conjunction fallacy, Conservatism (belief revision), Continued influence effect, Contrast effect, Courtesy bias, Curse of knowledge, Declinism, Decoy effect, Default effect, Denomination effect, Disposition effect, Distinction bias, Dread aversion, Dunning–Kruger effect, Duration neglect, Empathy gap, End-of-history illusion, Endowment effect, Exaggerated expectation, Experimenter's or expectation bias, Focusing effect, Forer effect or Barnum effect, Form function attribution bias, Framing effect, Frequency illusion or Baader–Meinhof effect, Functional fixedness, Gambler's fallacy, Groupthink, Hard–easy effect, Hindsight bias, Hostile attribution bias, Hot-hand fallacy, Hyperbolic discounting, Identifiable victim effect, IKEA effect, Illicit transference, Illusion of control, Illusion of validity, Illusory correlation, Illusory truth effect, Impact bias, Implicit association, Information bias, Insensitivity to sample size, Interoceptive bias, Irrational escalation or Escalation of commitment, Law of the instrument, Less-is-better effect, Look-elsewhere effect, Loss aversion, Mere exposure effect, Money illusion, Moral credential effect, Negativity bias or Negativity effect, Neglect of probability, Normalcy bias, Not invented here, Observer-expectancy effect, Omission bias, Optimism bias, Ostrich effect, Outcome bias, Overconfidence effect, Pareidolia, Pygmalion effect, Pessimism bias, Planning fallacy, Present bias, Pro-innovation bias, Projection bias, Pseudocertainty effect, Reactance, Reactive devaluation, Recency illusion, Regressive bias, Restraint bias, Rhyme as reason effect, Risk compensation / Peltzman effect, Salience bias, Selection bias, Selective perception, Semmelweis reflex, Sexual overperception bias / sexual underperception bias, Singularity effect, Social comparison bias, Social desirability bias, Status quo bias, Stereotyping, Subadditivity effect, Subjective validation, Surrogation, Survivorship bias, Time-saving bias, Third-person effect, Parkinson's law of triviality, Unit bias, Weber–Fechner law, Well travelled road effect, Women are wonderful effect, Zero-risk bias, Zero-sum bias

This Paper's Goals

- Provide a broad review of cognitive biases, for visualization researchers
- Layout the problem space to guide future studies that help designers anticipate limitations of human judgement



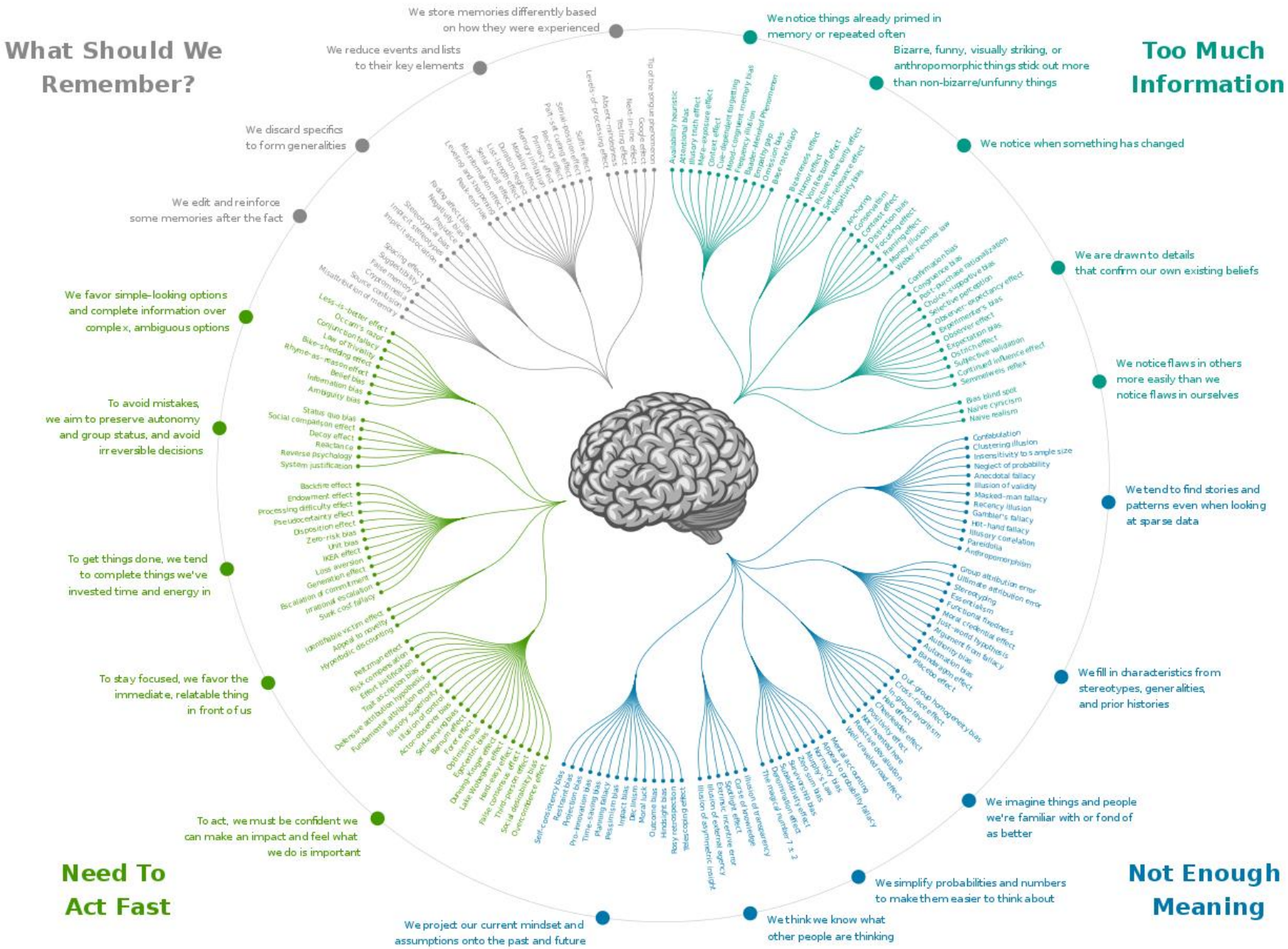
Taxonomies of Cognitive Bias

Essentially, the related work section

Taxonomies of Cognitive Biases

- **Explanatory taxonomies**
  - A. Tversky and D. Kahneman, “Judgement Under Uncertainty: Heuristics and Biases”
  - J. Baron, *Thinking and Deciding*
  - J. Evans*, Hypothetical Thinking: Dual Processes in Reasoning and Hudgement*
  - K. Stanvoich*, Rationality and the Reflective Mind*

THE COGNITIVE BIAS CODEX



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- **Taxonomies from decision-support**
  - W. E. Remus and J. E. Kottemann, “Toward Intelligent Decision Support Systems: An Artificially Intelligent Statistician.”
  - D. Arnott, “Cognitive Biases and Decision Support Systems Development: a Design Science Approach”

How they built their taxonomy

The methodology section

How they built their taxonomy

List of cognitive biases

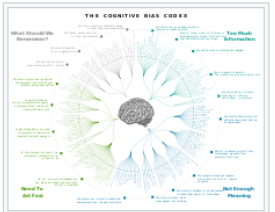
From Wikipedia, the free encyclopedia

Cognitive biases are systematic patterns of deviation from norm or rationality in judgment, and are often studied in psychology and behavioral economics.[1]

Although the reality of most of these biases is confirmed by reproducible research,[2][3] there are often controversies about how to classify these biases or how to explain them.[4] Some are effects of information-processing rules (i.e., mental shortcuts), called *heuristics*, that the brain uses to produce decisions or judgments. Biases have a variety of forms and appear as cognitive ("cold") bias, such as mental noise,[5] or motivational ("hot") bias, such as when beliefs are distorted by wishful thinking. Both effects can be present at the same time.[6][7]

There are also controversies over some of these biases as to whether they count as useless or irrational, or whether they result in useful attitudes or behavior. For example, when getting to know others, people tend to ask leading questions which seem biased towards confirming their assumptions about the person. However, this kind of confirmation bias has also been argued to be an example of social skill: a way to establish a connection with the other person.[8]

Although this research overwhelmingly involves human subjects, some findings that demonstrate bias have been found in non-human animals as well. For example, hyperbolic discounting has been observed in rats, pigeons, and monkeys.[9]



The cognitive bias codex, referencing many of the biases in this article.

Decision-making, belief, and behavioral biases [edit]

Many of these biases affect belief formation, business and economic decisions, and human behavior in general.

Name	Description
Ambiguity effect	The tendency to avoid options for which the probability of a favorable outcome is unknown.[10]
Anchoring or focalism	The tendency to rely too heavily, or "anchor", on one trait or piece of information when making decisions (usually the first piece of information acquired on that subject).[11][12]
Anthropocentric thinking	The tendency to use human analogies as a basis for reasoning about other, less familiar, biological phenomena.[13]
Anthropomorphism or personification	The tendency to characterize animals, objects, and abstract concepts as possessing human-like traits, emotions, and intentions.[14]
Attentional bias	The tendency of perception to be affected by recurring thoughts.[15]

How they built their taxonomy

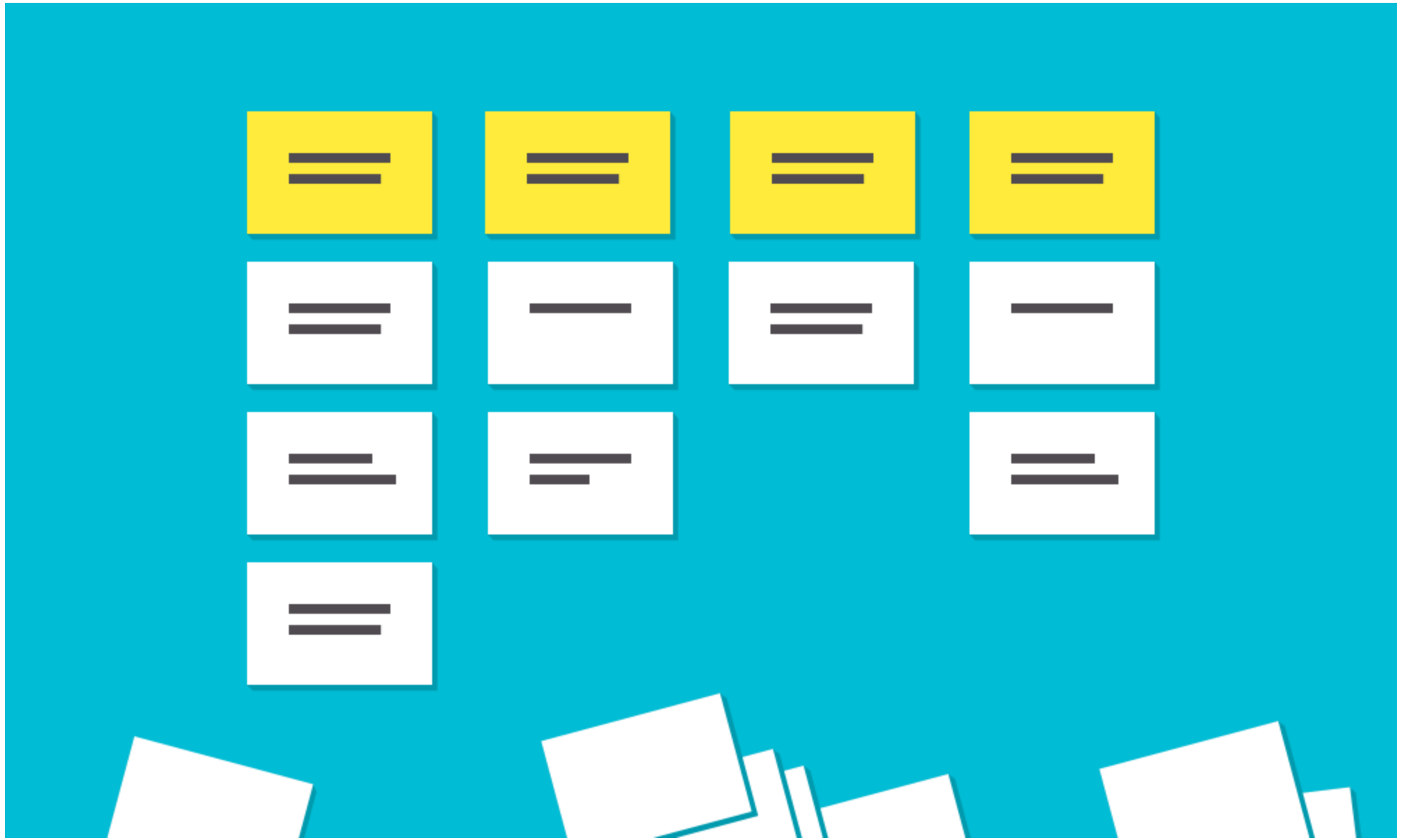
Step 1: Cross reference the biases with information visualization literature.

If vis literature exists

Step 2.a: Find the experiment study the vis paper cites for this bias

If no vis literature exists

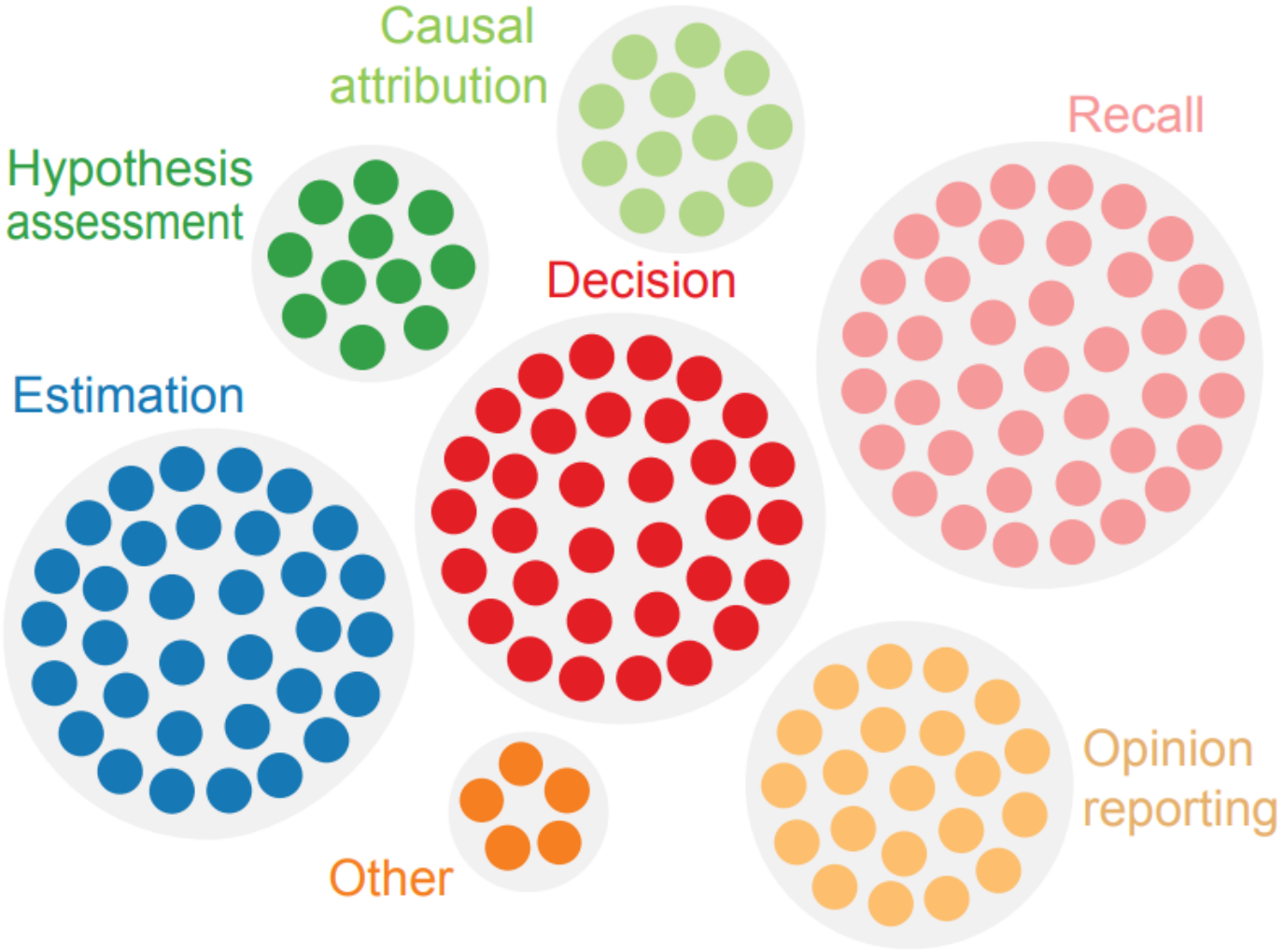
Step 2.b: Look for any literature on the bias.



Their Task-Based Taxonomy

Their “Results” section

Cognitive Biases by Task



ESTIMATION
DECISION
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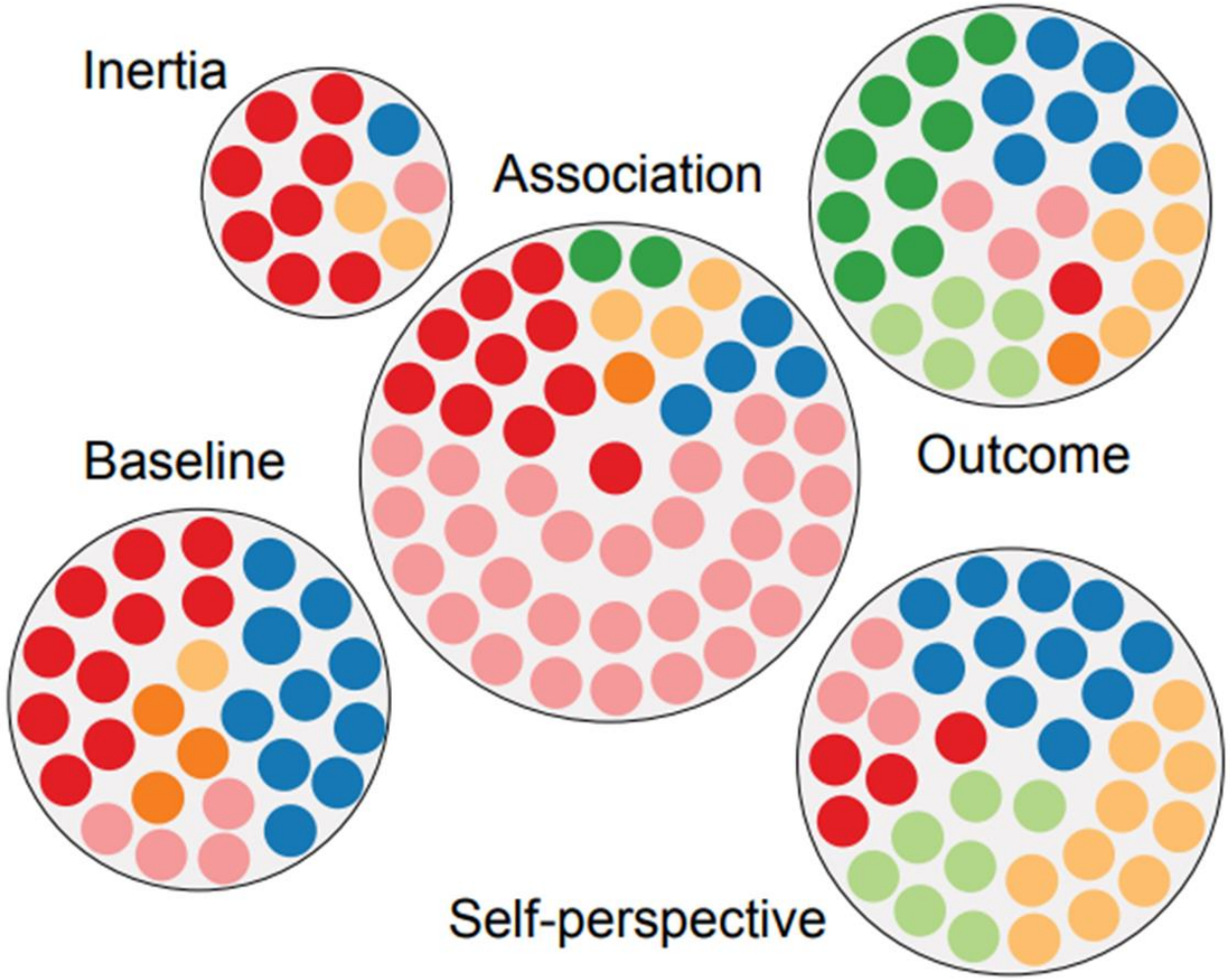
TASK: ESTIMATION

1	Association	Availability bias	[52]	#5 [26], [146]	Events more probable if easy to remember
2		Conjunction fallacy	[47]	#5 [9]	Specific outcomes more probable than general
3		Empathy gap	[147]	#1	Estimations affected by not recognizing the role of current emotional state
4		Time-saving bias	[148]	#4	Overestimate time saved when increasing speed
5	Baseline	Anchoring effect	[50]	#7 [7], [64]	Estimation affected by first piece of information
6		Base rate fallacy	[46]	#6 [59], [60]	Ignore base rate probability of general population
7		Dunning-Kruger effect	[57]	#5 [149]	Low-ability people overestimate their performance (opposite for high-ability)
8		Gambler's fallacy	[17]	#4	Current outcome that is more frequent will be less frequent in future
9		Hard-easy effect	[56]	#3	Overconfidence for hard tasks, underconfidence for easy
10		Hot-hand fallacy	[150]	#5 [146]	Current outcome that is more frequent will be more frequent in future
11		Insensitivity to sample size	[17]	#5 [9], [10]	Estimate probability ignoring sample size
12		Regressive bias	[151]	#4	Overestimate high probabilities, underestimate low ones
13		Subadditivity effect	[152]	#4	Overall probability less than the probabilities of the parts
14		Weber-Fechner law	[42]	#6 [153]	Failure to perceive small differences in large quantities
15	Inertia	Conservatism	[48]	#7 [92]	New information insufficiently updates probability estimates
16	Outcome	Exaggerated expectation	[154]	#4	Exaggerating evidence to fit a conclusion
17		Illusion of validity	[17]	#5 [9]	Overconfidence in judgment based on intuition and anecdotes
18		Impact bias	[155]	#1	Predict future emotional reactions as more intense
19		Outcome bias	[156]	#2	Evaluate decision maker only by choice outcome
20		Planning fallacy	[53]	#5 [67]	Overoptimistic task completion predictions, especially for self
21		Restraint bias	[157]	#1	Overestimate of ability to resist temptation
22		Sexual overperception bias	[158]	#1	Over or underestimate of romantic interest from others
23	Self-perspective	Curse of knowledge	[66]	#7 [65]	Experts assume that novices have same knowledge
24		Extrinsic incentives bias	[159]	#1	Others have extrinsic motivations (e.g.money), self are intrinsic (e.g.learning)
25		False consensus effect	[160]	#2	Overestimate the agreement of others with own opinions
26		Illusion of control	[161]	#3	Overestimation of one's influence on an external event
27		Illusion of transparency	[162]	#1	Overestimate insight of others into own mental state, and vice versa
28		Naive cynicism	[134]	#2	Predict that the others will be more egocentrically biased
29		Optimism bias	[51]	#4	Positive outcomes more probable for oneself than others
30		Out-group homogeneity bias	[163]	#4	Estimate out-group will be more homogenous than in-group members
31		Pessimism bias	[164]	#4	Positive outcomes less probable for oneself than others
32		Spotlight effect	[165]	#1	Overestimate probability that people notice one's appearance/behavior
33		Worse-than-average effect	[166]	#3	Underestimate own achievements relative to others in difficult tasks

Cognitive Biases by Flavor



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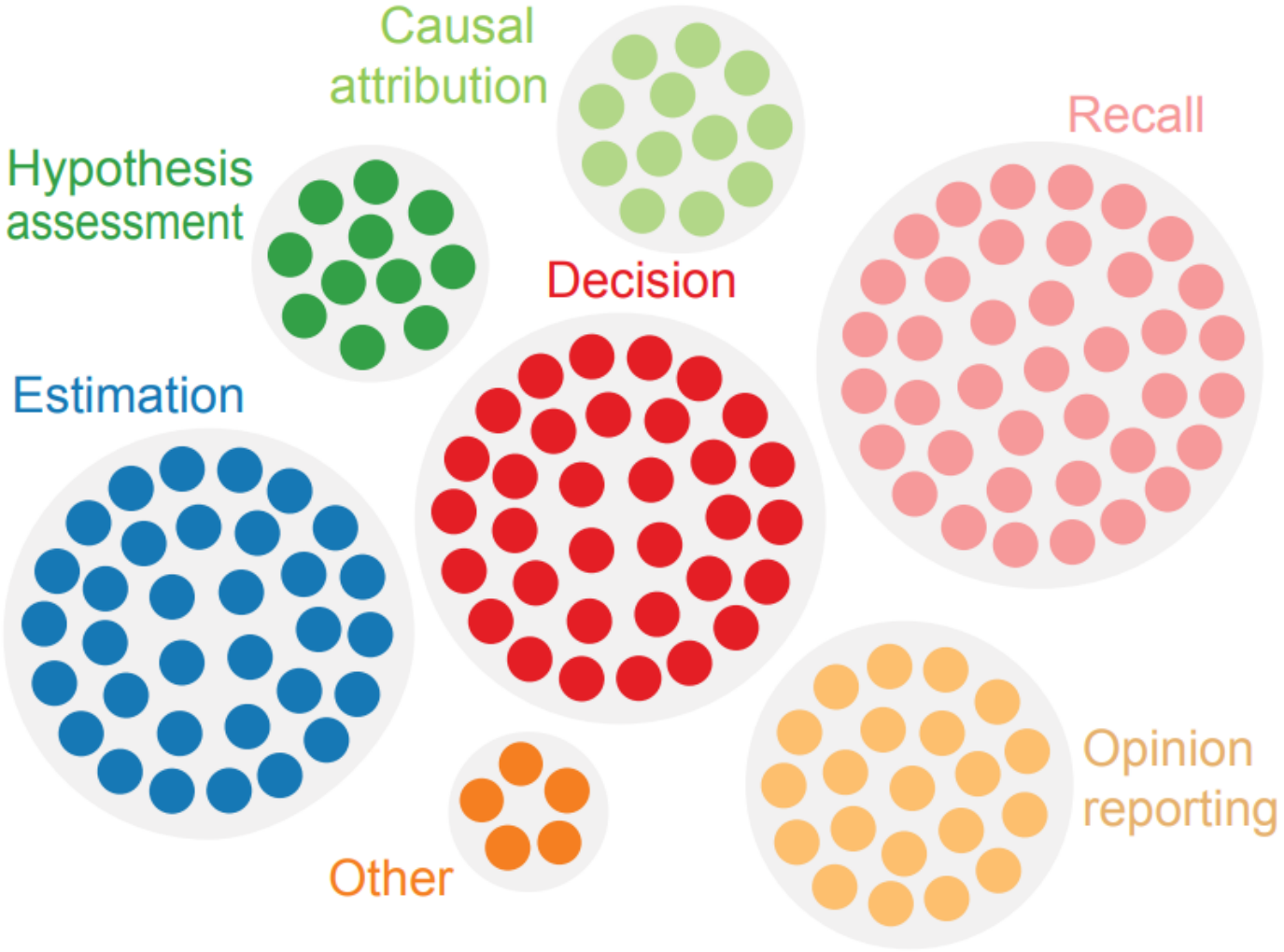
Cognitive Biases by Task



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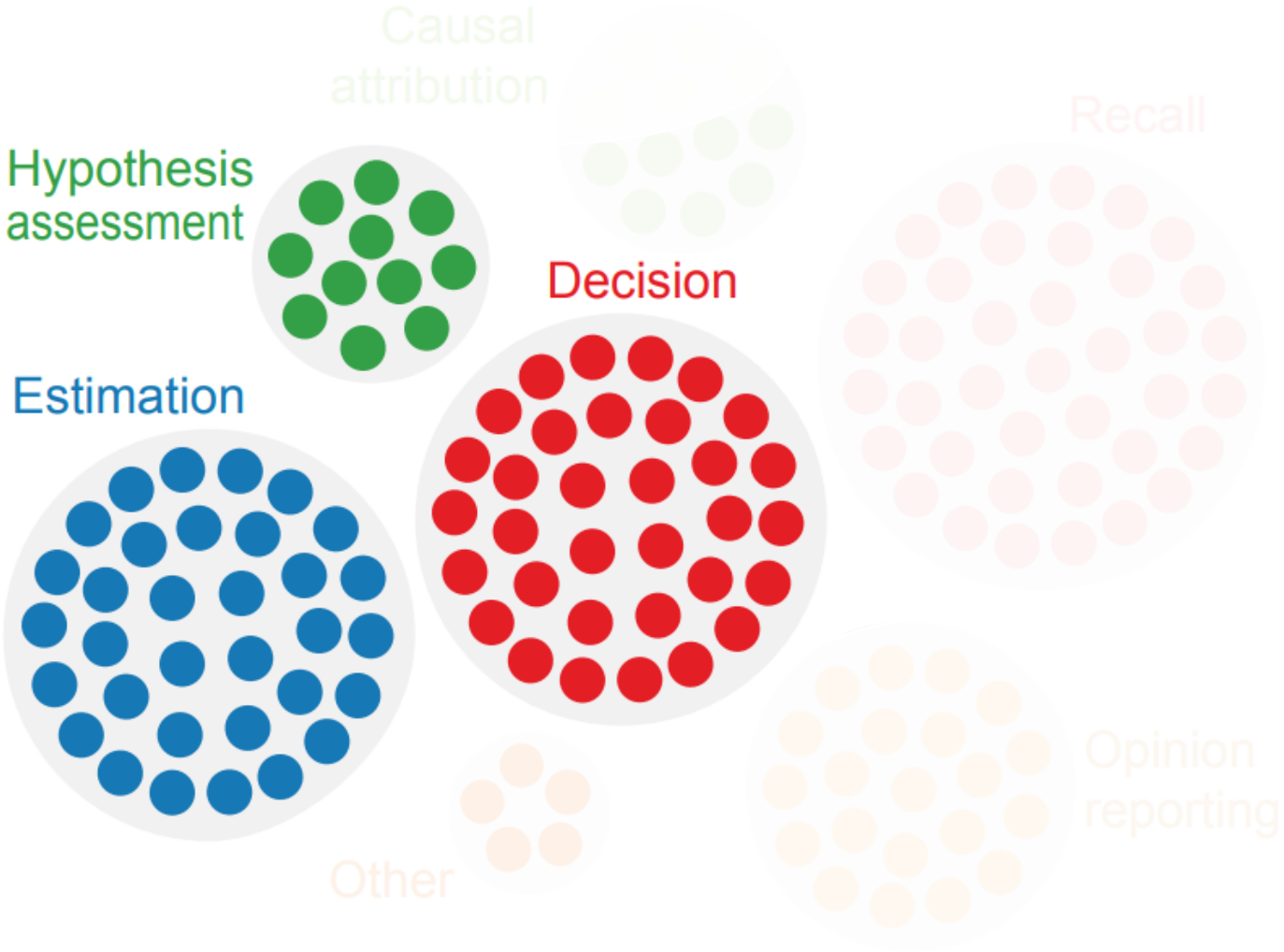

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Biases in estimation tasks: a sample

Base rate fallacy
We overestimate the likelihood of an event.

Conjunction fallacy
We believe that specific events are more probable than general ones.

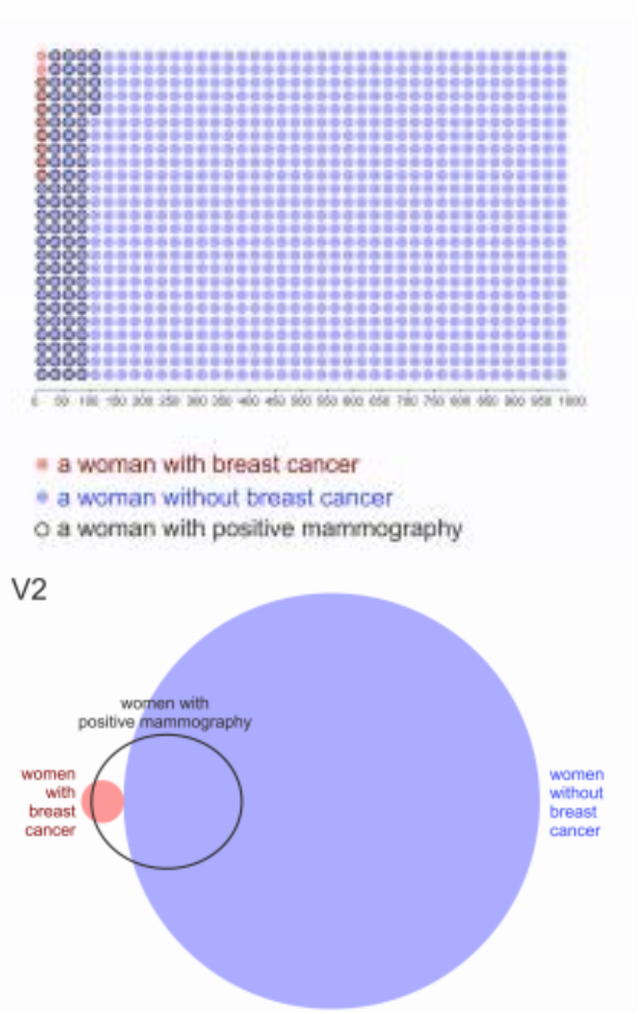
Optimism bias
We make more optimistic predictions about ourselves than other people.

Biases in estimation tasks: in vis

Base rate fallacy: We overestimate the likelihood of an event.

Can visualization help?

- Muddled results



Micallef, et al. Assessing the Effect of Visualizations on Bayesian Reasoning Through Crowdsourcing

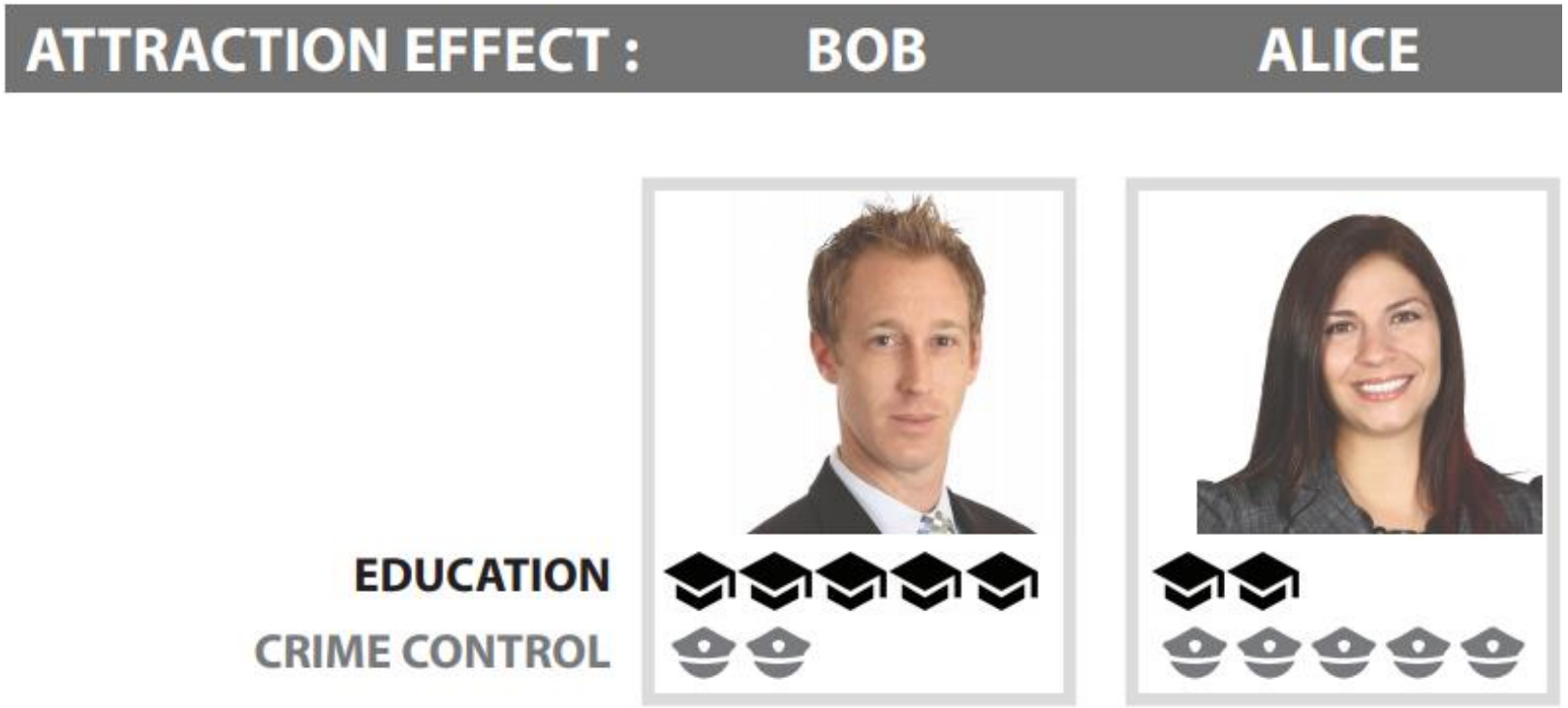
Decision tasks biases: a sample

Attraction effect
Our decision between two alternatives is influenced by the presence of inferior alternatives.

Ambiguity effect
We avoid decisions associated with ambiguous outcomes

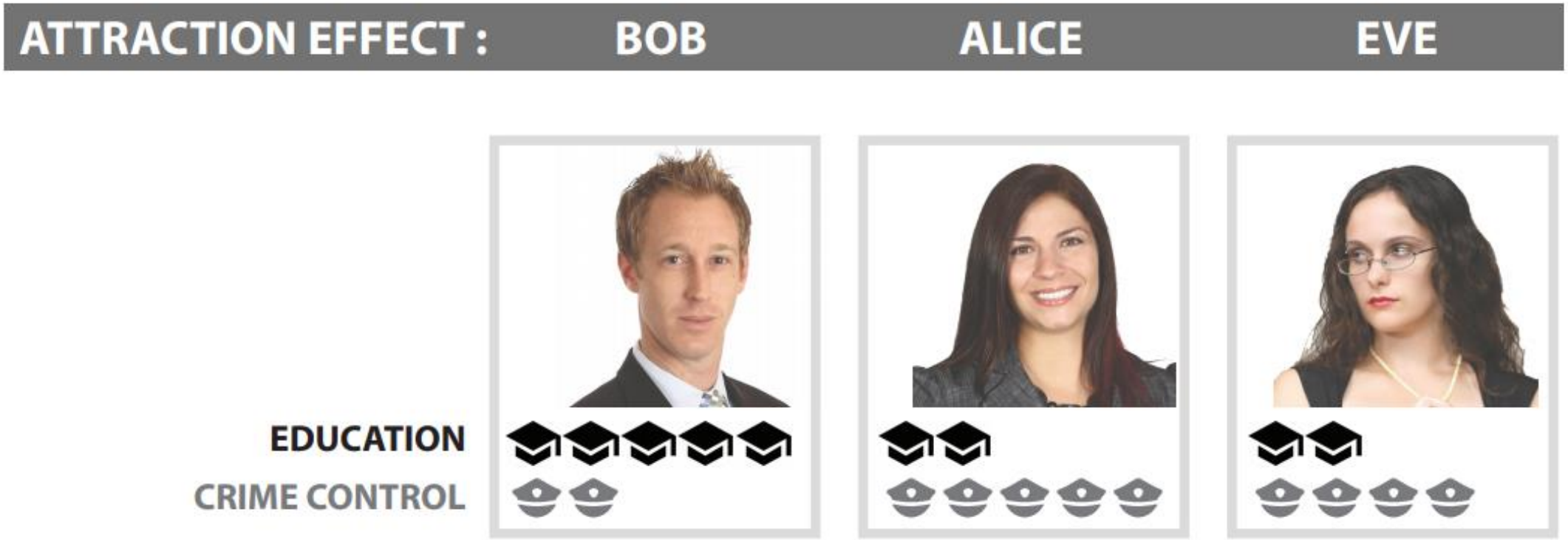
IKEA effect
We like things we invest self-effort into more

Decision tasks biases: attraction effect



Dimara, E. (2017). *Information Visualization for Decision Making: Identifying Biases and Moving Beyond the Visual Analysis Paradigm*.

Decision tasks biases: Attraction effect



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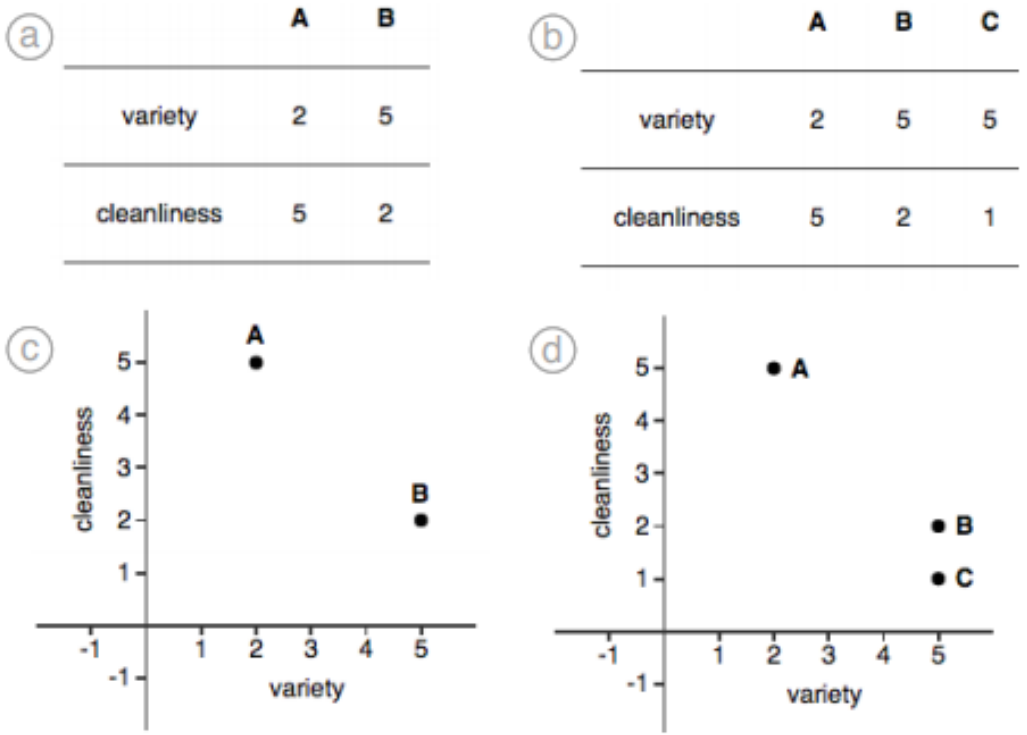
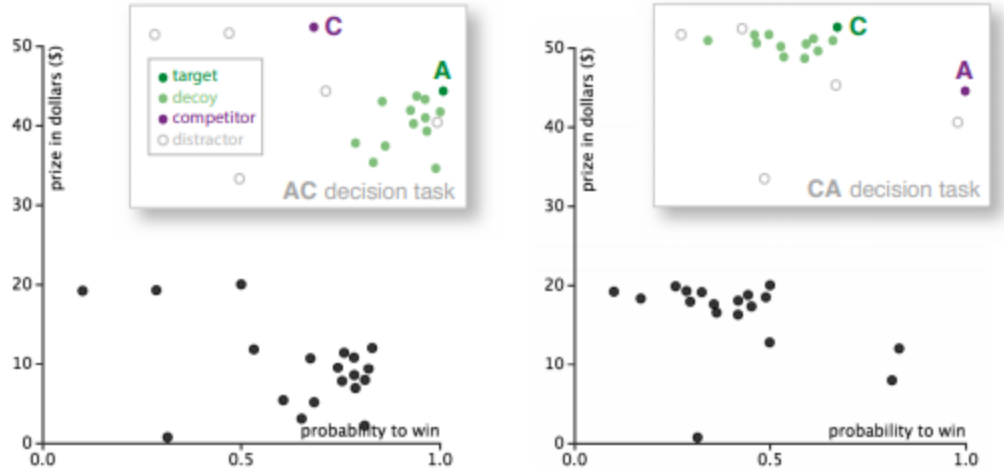
Decision tasks biases: Attraction effect

The Gym Experiment

The Bet Experiment





Dimara, et al. The Attraction Effect in Information Visualization

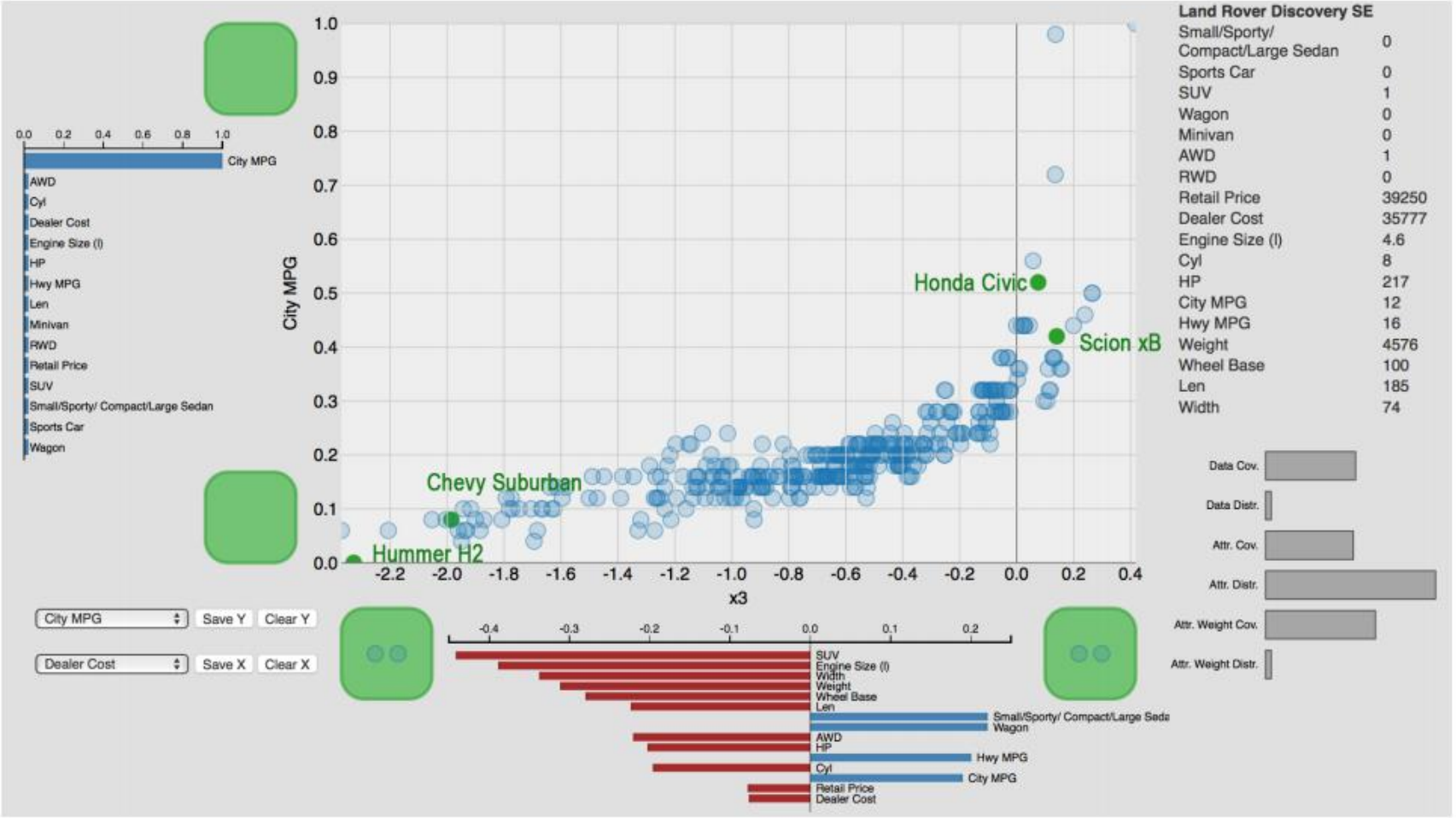
Hypothesis assessment tasks: a sample

Confirmation Bias
We favor evidence that confirm our initial hypotheses with ignoring disconfirming evidence

Illusory Truth Effect
We think propositions are true if repeatedly exposed to it

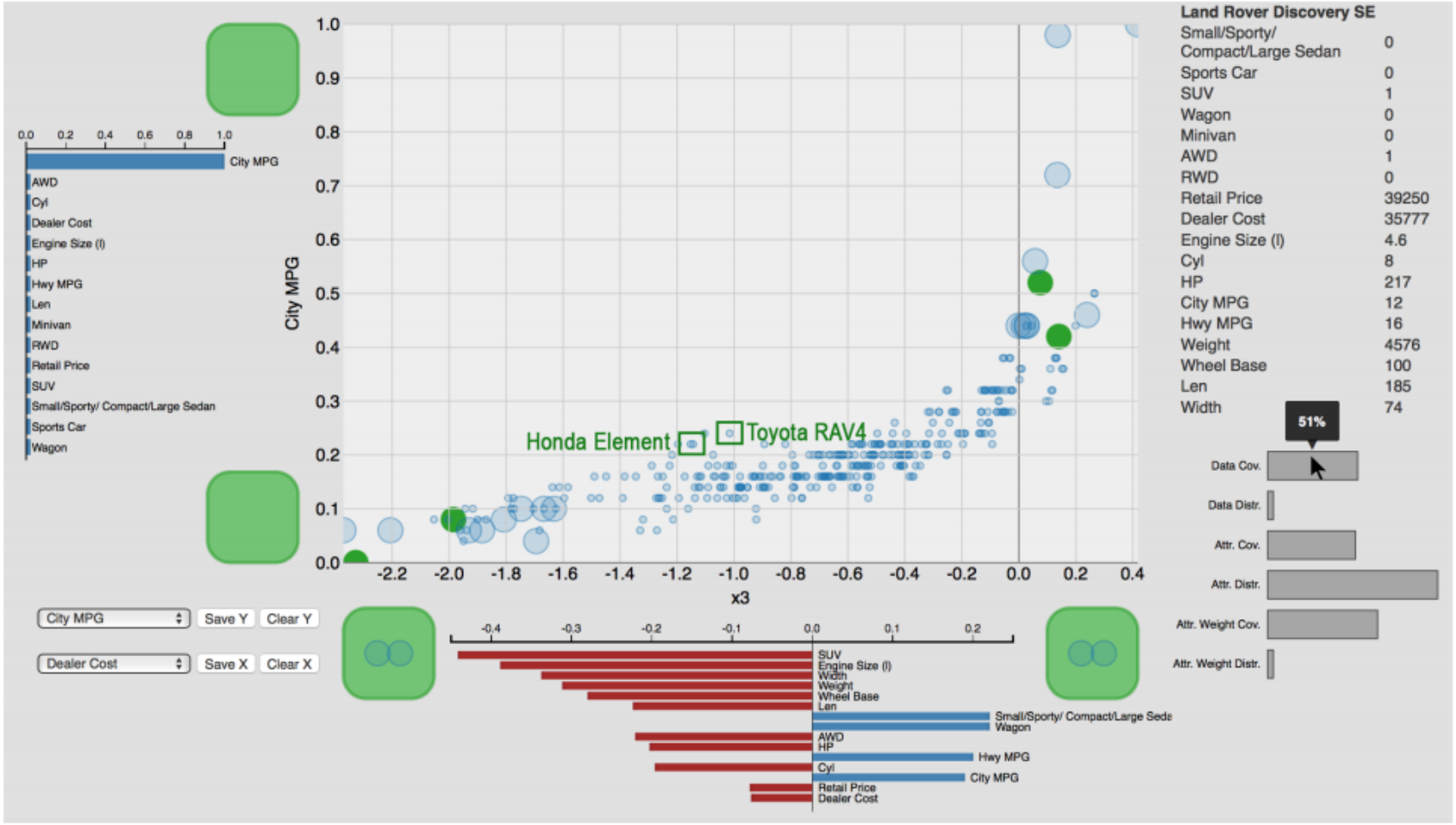
Illusory Correlation Bias
We consider relationships between variables that do not exists

Hypothesis assessment tasks: Confirmation Bias



Wall, E et al. Warning, Bias May Occur: A Proposed Approach to Detecting Cognitive Bias in Interactive Visual Analytics.

Hypothesis assessment tasks: Confirmation Bias



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Discussion

My opinion

👍 Survey of cognitive biases that are relevant to visualization research

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👌 Their taxonomy good but not great.

Acknowledged Limitations

- Each bias was assigned a single category
  - One bias could exist in more than one task category.

- Only one person did the initial coding and sorting
  - But all authors reviewed the process

- “Deviations from reality” is a complex and controversial notion.
  - We haven’t proved that cognitive biases actually reflect irrationality.

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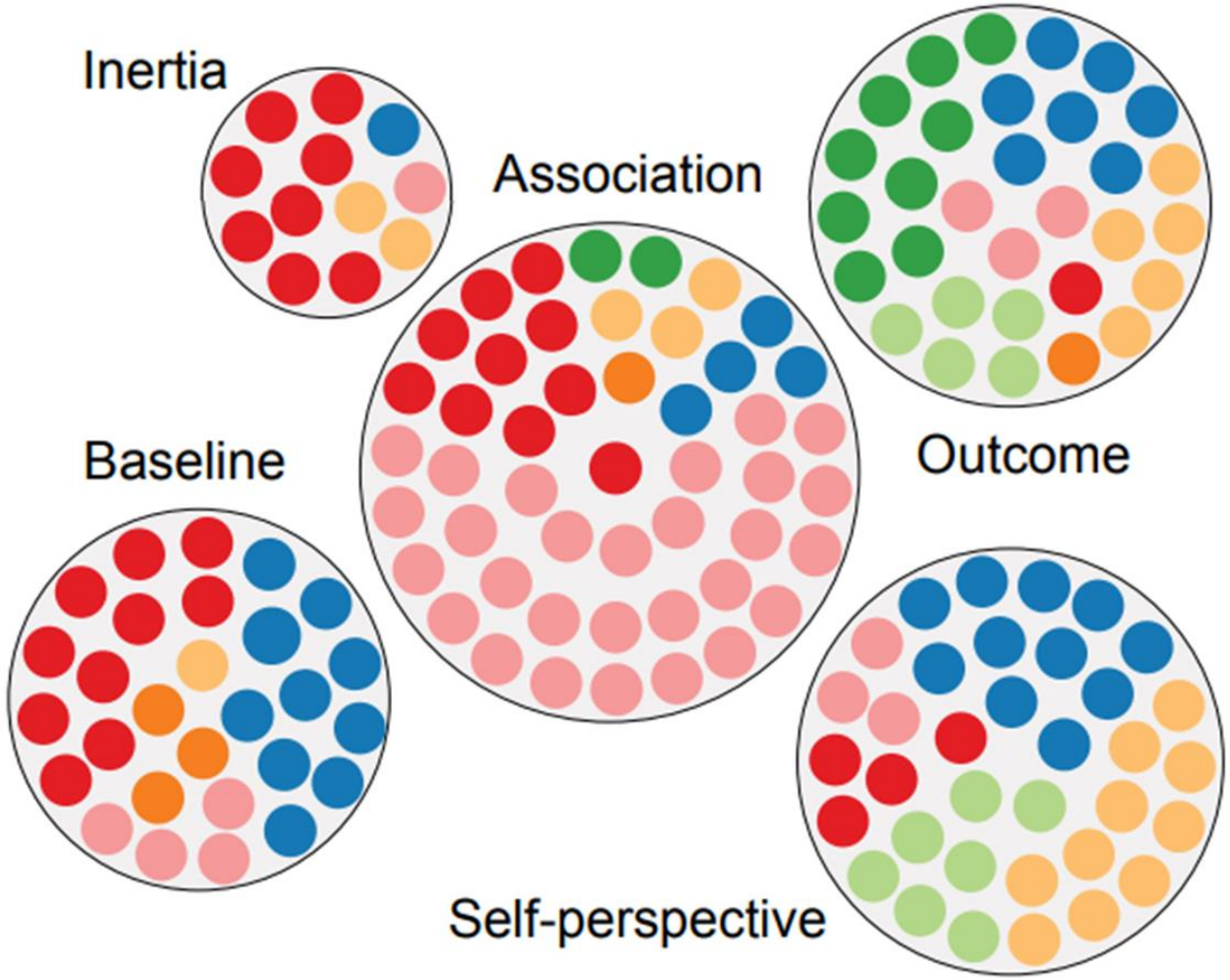
What's the point of flavors?

Cognitive Biases by Flavor



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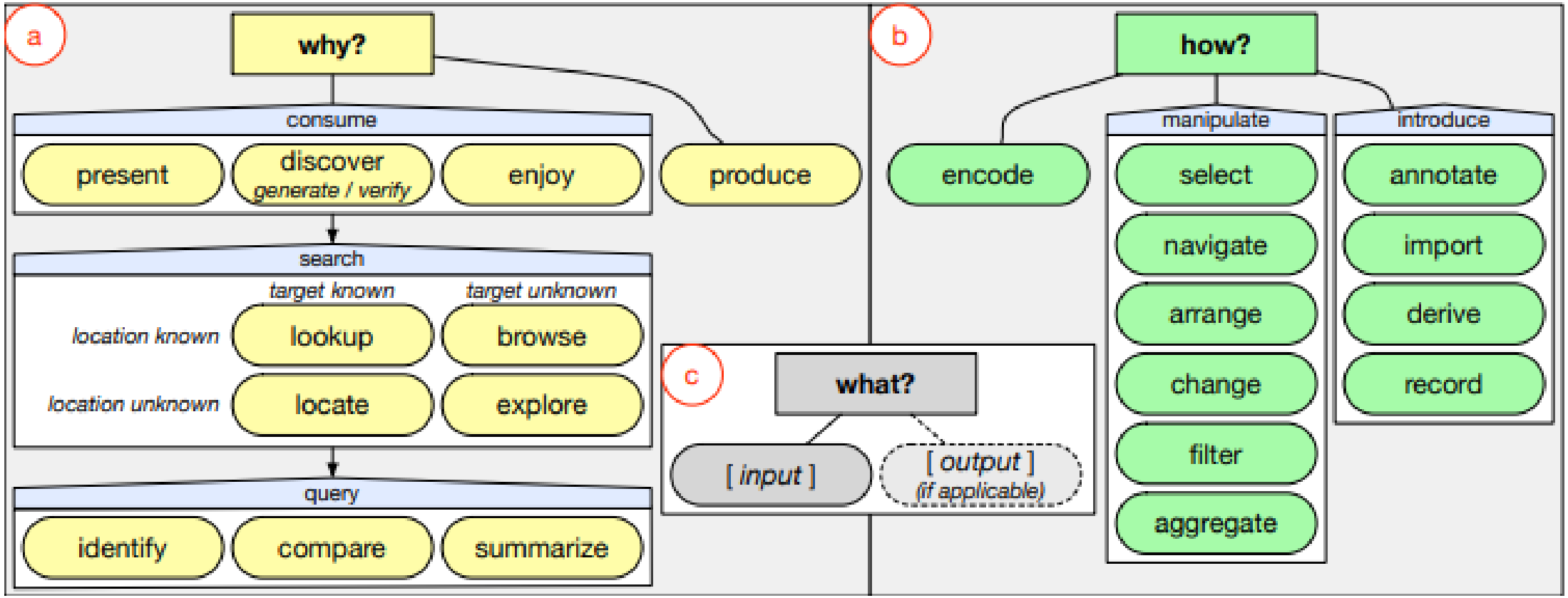
It's another task taxonomy

A Multi-Level Typology of Abstract Visualization Tasks



Questions