

# A Task-based Taxonomy of Cognitive Biases for Information Visualization

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## 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

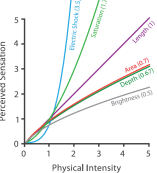


The Human

## Perceptual bias

### Magnitude estimation

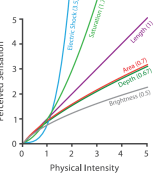
Steven's Psychophysical Power Law:  $S = I^a$



## Perceptual bias

### Magnitude estimation

Steven's Psychophysical Power Law:  $S = I^a$



### 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

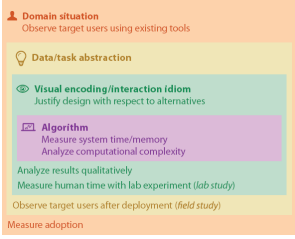
## Gambler's Fallacy



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, Ostich 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, Restrained bias, Rhyme as reason effect, Risk compensation / Peltzman effect, Saliency 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

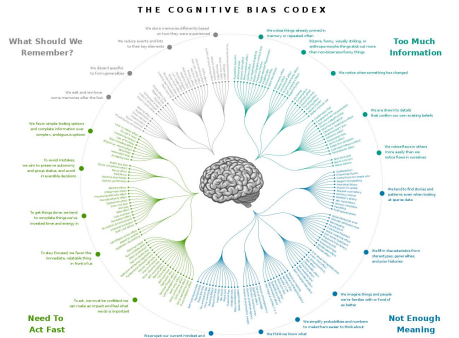


## Taxonomies of Cognitive Bias

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 Judgement*
  - K. Stanovich, *Rationality and the Reflective Mind*



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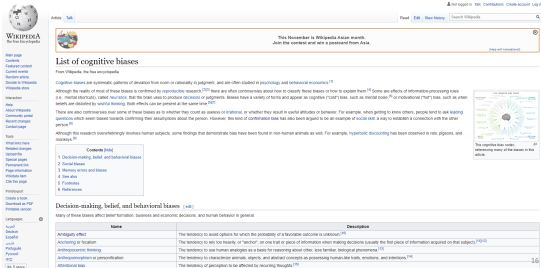
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- Taxonomies from decision-support**
  - W. E. Remus and J. E. Kottemann, "Toward Intelligent Decision Support Systems: An Artificially Intelligent Statistician."
  - D. Arnott, "Cognitive Biases and Decision Support Systems Development: a Design Science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

## How they built their taxonomy

The methodology section

## How they built their taxonomy



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

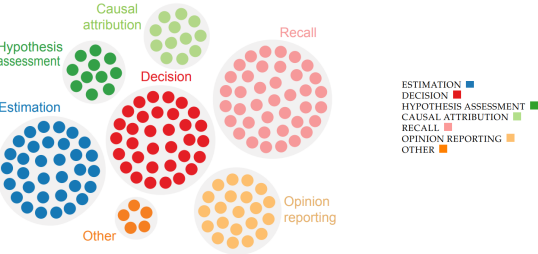
**Step 2.b:** Look for any literature on the bias.



Their Task-Based Taxonomy

Their "Results" section

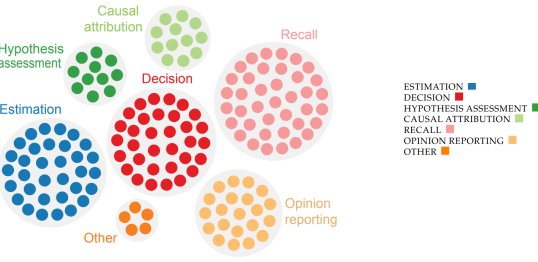
Cognitive Biases by Task



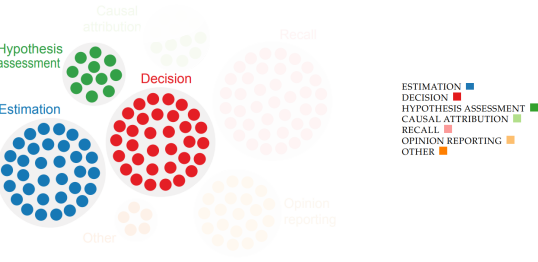
Cognitive Biases by Flavor



Cognitive Biases by Task



Cognitive Biases by Task



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

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

**Attraction Effect:** BOB ALICE

EDUCATION CRIME CONTROL

Decision tasks biases: Attraction effect

**Attraction Effect:** BOB ALICE EVE

EDUCATION CRIME CONTROL

Decision tasks biases: Attraction effect

**The Gym Experiment**

**The Bet Experiment**

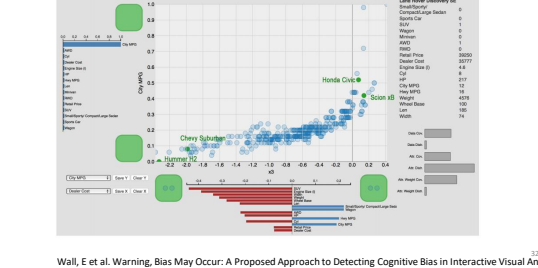
Hypothesis assessment tasks: a sample

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

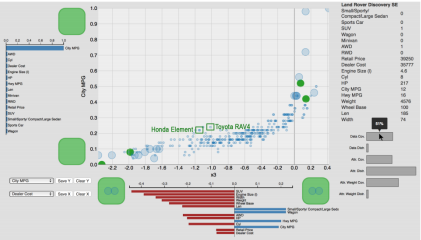
**Illusory Truth Effect**  
We think propositions are true if repeatedly exposed to it

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

Hypothesis assessment tasks: Confirmation Bias



Hypothesis assessment tasks:  
Confirmation Bias



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

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.

My opinion

👉 Survey of cognitive biases that are relevant to visualization research

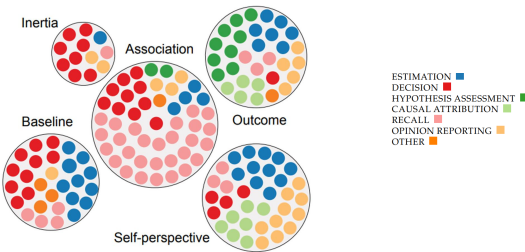
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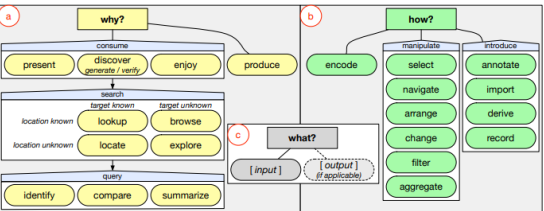
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👉 Survey of cognitive biases that are relevant to visualization research

👉 Their taxonomy good but not great  
What’s the point of flavors?  
It’s another task taxonomy

A Multi-Level Typology of Abstract Visualization Tasks



Questions