

# Perception and Cognition of Uncertainty

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# Background

- Advances in quantification of uncertainty in numerical simulations
- Behavioral scientists have conducted important research on decision making under uncertainty
  - But these studies typically have not linked to quantification data
- Significant taxonomies of communication (especially visualization methods)
- But limited evaluations especially using objective measures of performance

# My Perspective

- Cognitive psychologist interested in comprehension of visual displays which might be made up of
  - Text
  - Numerical expressions
  - Static graphics (diagrams, maps, graphs)
  - Animations
  - Interactive visualizations etc.
- My talk will focus on the **communication** of uncertainty

# Ways of Communicating Uncertainty (External Representations)

## Verbal:

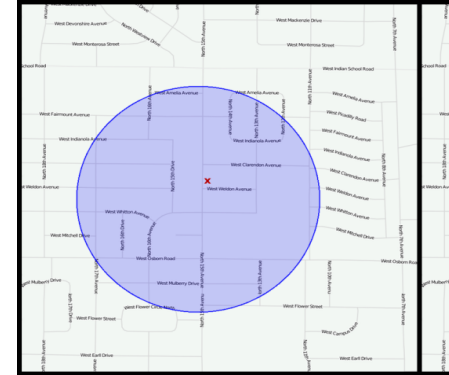
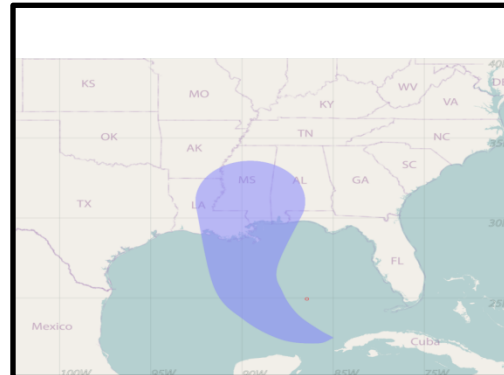
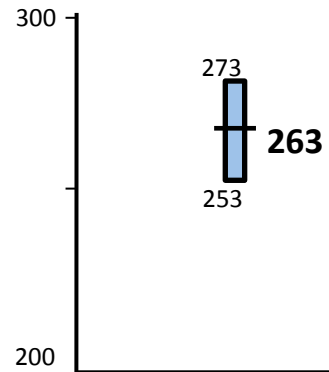
- There is a fair chance of a market upturn by the election

## Numerical

- There is a 20% chance of rain tomorrow;  $p < .05$

## Graphical:

- Static
- Dynamic
- Interactive

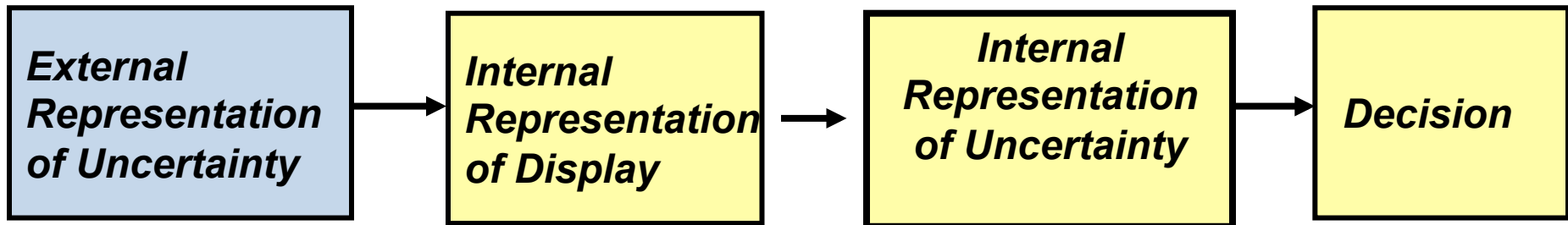


**Combinations** of these (multimedia & multimodal displays)

# A Simplistic Cognitive Model

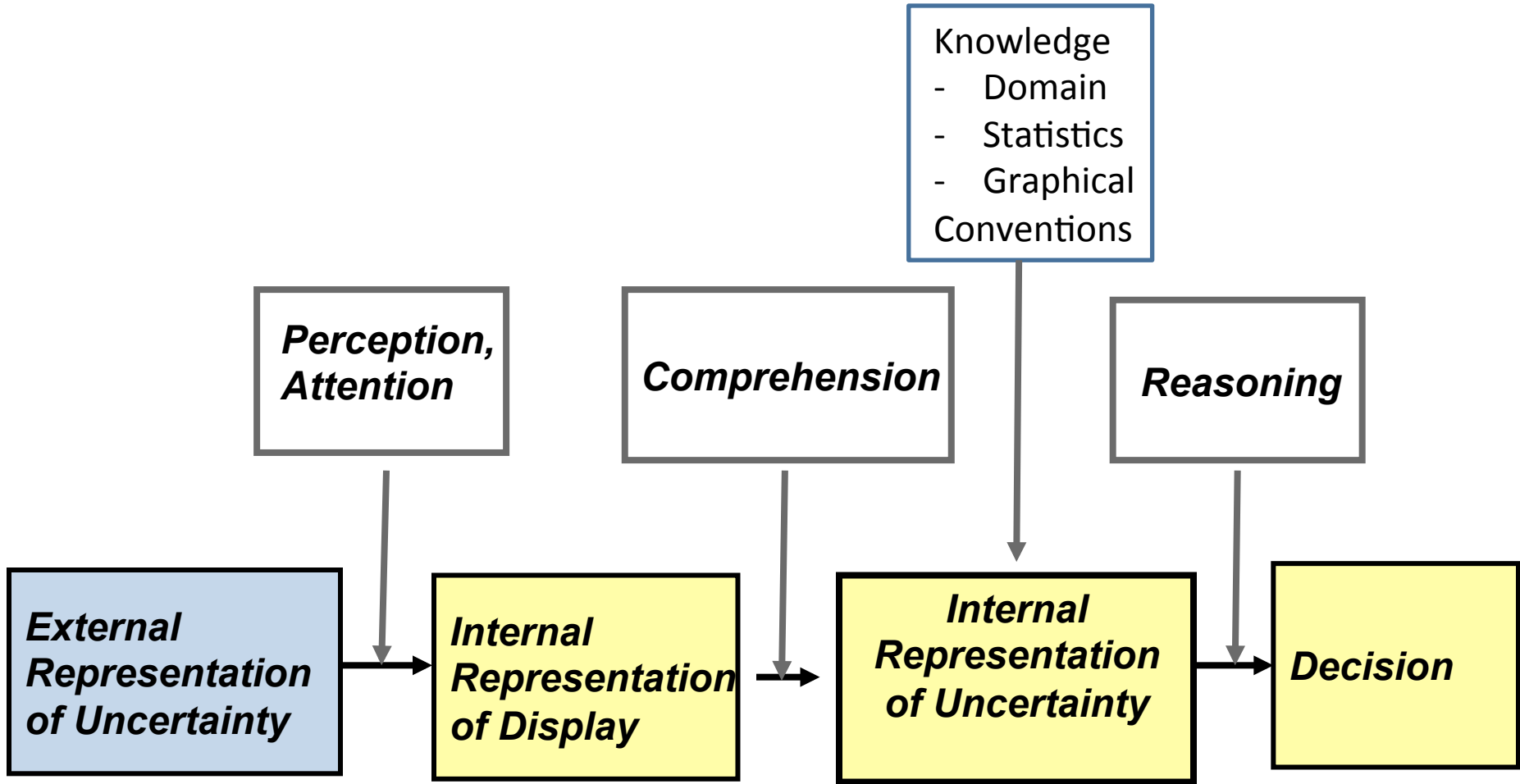
External  
Representation  
(in the world)

Internal Representations  
(in the mind)



Visual Elements  
No Meaning

Meaningful

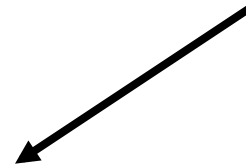
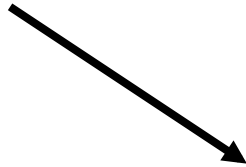


# Designing Displays of Uncertainty

- When to use graphics/visualizations and when to use verbal or numerical representations?
- When to use static vs. animated displays?
- Not either-or, might use a combination of representations or media
- If we decide on a visualization, many different visualizations we might use
- Some might be more intuitive, but others might be more effective with supporting documents explaining the conventions

Nature of the **Data**  
(Including Sources of  
Uncertainty)

Nature of  
**Consumers** of  
the Data



Communication of Uncertainty



Nature of the  
**Tasks** to be  
Supported



## Nature of the Data

Dimensionality: (1d, 2d, 3d)

Precision

Source of Data:

(simulation, data analytics  
etc.)

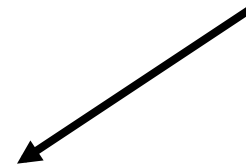
Source of Uncertainty:

(sparse data, simulation error,  
measurement error)

Type of Uncertainty:

attribute, (geo)spatial,  
temporal)

Nature of  
**Consumers of**  
the Data

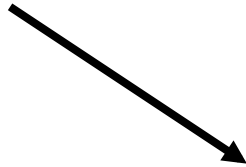


**Characterization of Uncertainty**



Nature of the  
**Tasks to be**  
Supported

Nature of the **Data**  
(Including Sources of  
Uncertainty)



Communication of U



Nature of the  
**Tasks** to be  
Supported

**Nature of Consumers  
Of the information**

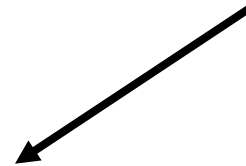
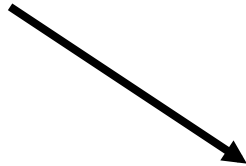
Domain Experts?  
Statisticians?  
Visualization experts?  
Members of the general  
Public?

Differ in:

- Domain Knowledge
- Literacy
- Numeracy
- Graphical Literacy

Nature of the **Data**  
(Including Sources of  
Uncertainty)

Nature of  
**Consumers** of  
the Data



**Communication of Uncertainty**

**Nature of the Task & Situation:**



General understanding of a data set  
Prediction of a specific value  
Persuasion vs. Decision making  
Urgency of the Situation (wildfire vs. ebola vs. climate change)

# Status Quo of Evaluation of Uncertainty Displays

(Kinkeldy, MacEachren & Schwiewe, 2014, Visualization of Geospatial Uncertainty)

- “User Studies”: Experiments with undergraduates or Amazon Turk workers, surveys, focus groups
- Measure
  - Display preferences (not always related to performance)
  - Intuitions about displays
  - Objective measures of accuracy and response times
- Ad hoc, no systematic choice of task, participants
- Playing 20 Questions (Newell, 1973)
  - Text vs. graphic, extrinsic vs. intrinsic, hue vs. saturation
  - Each study is with a specific task, specific population, specific scenario etc.

# Beyond the Status Quo

- We need a **broad** and **systematic** research program to examine the effectiveness of communications of uncertainty
- Needs to consider the full range of tasks, stakeholders, data types etc.
- Need to get beyond ad-hoc studies to the development of theories of when and why different types of communication will be effective
- Need to develop systematic methods for studying the effectiveness of visualizations and apply them across the full range of tasks etc.

# Beyond the Status Quo

- We also need an educational agenda
- We should not assume that what people can understand about uncertainty now is the upper limit
- How can educate people to be better consumers of uncertain data?