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

External Representation of Uncertainty

Internal Representation of Display

Internal Representation of Uncertainty

Decision
External Representation of Uncertainty

Perception, Attention

Internal Representation of Display

Comprehension

Internal Representation of Uncertainty

Reasoning

Knowledge
- Domain
- Statistics
- Graphical Conventions

Decision
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

Nature of Uncertainty

Nature of the Tasks to be
Supported
Nature of the **Data** (Including Sources of Uncertainty)

**Communication of Uncertainty**

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, Visualizaiton 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?