The Effects of Presentation Format and Decision Aids on Decisions Under Deep Uncertainty

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Special Features of Decision Making Under Deep Uncertainty

- The “system model“ is (a) complex, and (b) not fully understood
- Actions induce a mix of short- and long-term implications
- Not all the relevant variables and outcomes are well understood
- The relevant uncertainties are not easily quantified

Three-Way Taxonomy of Sources of Imprecision in Communication of Probabilities

(Budescu & Wallsten, 1995)

(1) Nature of the event: An event is ***unambiguous (ambiguous)*** if its definition allows one to determine unequivocally if any given outcome is (is not) an exemplar of the target event.

(2) *Type of uncertainty underlying the event*: Uncertainty may be due to external, quantifiable, sources of random variation, or to internal sources (imperfect, or unreliable information about the event). ***Uncertainty is precise is it can be expressed by means of a proper probability function, and it is vague if such a function cannot be specified***.

(3) *Language of communication:* Point numerical probabilities are the language of the ***precise communication***, whereas numerical intervals (*e.g. 0.2 – 0.4*), qualified numerical values (*e.g. approximately 0.6*), and linguistic probabilities (*e.g. highly likely*) are examples of ***imprecise communication***.

Ellsberg's Paradox (for Probabilities)

- The original form: Choice between two prospects with equal outcomes, but different probability distributions. One is fully specified (precise), the other is unknown (vague).
- General pattern: Other things being equal, the more precise option is favored

Extensions

- Choice between a precise probability and a precisely specified range of values (e.g., Becker & Brownson, 1961; Curley & Yates, 1985)
- Choice between two precisely specified ranges (Kramer & Budescu, 2005)
- Choice between a precise probability and vaguely specified (linguistic) probability (e.g. Budescu & Wallsten, 1995)
- Other response formats: ratings, pricing, bidding, certainty equivalence judgments

Some Empirical Regularities

(e.g. Camerer & Weber, 1992)

- Weaker effect for losses
- Occasional reversed effect ("preference for vagueness") especially for low probabilities of gains and high probabilities of losses
- Independence between attitudes towards vagueness and towards risk

Explanations of the prototypical pattern

- Weighting by an "inferred/assumed" probability distribution (Ellsberg, 1961)
- Avoidance of vagueness (ambiguity) and preference for precision
- Competence (Heath & Tversky, 1991)
- Comparative ignorance (Fox & Tversky, 1995)
- Anchoring and adjustment (Einhorn & Hogarth, 1985)
- Avoidance of evaluation (Curley, Yates & Abrams, 1986)

Vagueness in Outcomes

- Manipulation of the certainty/reliability/agreement about the outcomes (Casey & Scholz, 1991; Kunreuther et al. 1995)
- Precisely specified ranges of outcomes (DiMauro & Maffioleti, 1996; Gonzales-Vallejo, Bonazzi & Shapiro, 1996)
- In general the more precise option is valued more and chosen more often
- People avoid taking action (favoring the default /status quo) in the absence of complete information about possible outcomes (Ritov & Baron)

Combining and Comparing the Two Types of Imprecision

- Similarity in the pattern and intensity of the two (separate) effects (Gonzales-Vallejo, et al. 1996)
- Additivity of the two effects (Casey & Scholz, 1991)
- When offered the option to “resolve the vagueness” prior to making a choice, most subjects focus on one attribute, and most seem to be primarily concerned with the probability (Schoemaker, 1989, 1991)

The simultaneous effects of vague probabilities *and* outcomes

Kuhn & Budescu (1996)

- People have common attitudes towards vagueness on both attributes
- No evidence of dominance of one type of imprecision over the other.
- Dimension prominence is the most important and consistent predictor of preferences between risky (precisely or vaguely specified) prospects. Attitude(s) towards vagueness are secondary predictors in cases where dimensional preference does not apply.

Kuhn, Budescu, Hershey, Kramer, Rantilla (1999)

- Changes in parameters (lower probabilities and higher potential losses) induced
  - (a) Higher concern with outcomes
  - (b) More sensitivity to precision of outcomes

Thus, at least in part, attitude towards vagueness is a by-product of dimensional prominence

The simultaneous effects of vague probabilities *and* outcomes

Budescu, Kuhn, Kramer, Johnson (2002)

- When judging CEs of risky vague prospects the subjects pay more attention to the precision of the outcomes, consistent with the compatibility effect (Tversky, Sattath & Slovic, 1988; Fischer & Hawkins, 1993)
- Systematic preference for vague gains and aversion to vague losses.

Budescu & Templin (2005)

- The differential attitude to vague gains and losses is replicated in evaluation of mixed (gains & losses) vague prospects.

Thus, at least in part, attitude towards vagueness is a by-product of the elicitation procedure and the domain.

Decision with vague information -- Summary

- The modal pattern - Preference for precise information (outcomes and probabilities).
- The intensity of the “vagueness avoidance” tendency is a monotonic function of the level of vagueness.
- This pattern is neither universal, nor uniform (with occasional reversals).
- In most cases the level of (im)precision is secondary to the outcomes and probabilities.
- Attitudes to vagueness are malleable – they are affected by changes in the salience of the dimensions and the elicitation mode and, possibly other factors.

The Present Study

- A different (more realistic) approach to the study of individual decisions in the presence of imprecise probabilistic information
- Instead of eliciting preferences between prospects with different levels of (im)precision, we consider preferences among various actions in the presence of (the same) vague probability distributions
- This setup resembles (loosely) some decisions related to Abrupt Climate Change

The experiment

- Manipulates the degree of vagueness of the probabilities
- Compares several decision aids that correspond to distinct approaches emphasizing either Expected Values or a more Robust Decision criterion

Experimental Task

- The DM is presented with an urn with 100 (red and white) balls. The DM does not know P, the probability of drawing a red ball, but can determine its lower and upper bounds, P_l and P_u.
- DM is endowed with ***e*** and has to choose between three / four options.
  - ***Option A***: Draw two balls with replacement. If at least one ball is white, the DM keeps ***e***; if both are red the DM gives back the ***e***.
  - ***Option B***: The DM surrenders ***f*** ($0 < f < e$), and keeps the remaining (***e-f***). No actual draws from the urn take place.
  - ***Option C:*** The DM surrenders *y* ($0 < y < f$) and draws two balls with replacement. If at least one is white, the DM keeps the remaining (***e-y***). If both are red, the DM draws a third ball from the urn. If it is white, the DM keeps ***(e-y)***. If it is red, the DM loses another ***z (z < e-y)*** and keeps the remaining ***(e-y-z).***
  - ***Option D:*** Before the choice the DM can pay ***c (c < e)*** to purchase information, i.e., reduce P_u by 0.20. Then the DM must choose A, B or C.

Relating the Task to Abrupt Climate Change

- Abrupt climate change is a high consequence, low (and vague) probability threat.
- We can eliminate this threat by capping greenhouse gas emissions at very low levels immediately -- a very expensive option.
- There are a variety of near-term options which are less costly, and may prove effective against the threat, but aren't guaranteed to work.

- Option A represents continued emissions.
- Option B is the sure safe option.
- Option C represents the less costly options that eliminate some (but maybe not all) the risks.

- It is also possible to obtain more information about the likelihood of abrupt changes by deploying (costly) sensors in the atmosphere and/or oceans.

Experimental Design

The task was embedded in an experiment involving repeated decisions.

- The following were fixed: ***e=$10, f=$4, c=$2***.
- The costs of insurance, ***y***, and loss, ***z***, was manipulated. We used two combinations with fixed total: (***y=$2, z=$5***) and (***y=$3,z=$4***).
- The limits on the target probability (P_l - P_u):

	Range			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***.1 - .5***	***0 - .6***	**---**	**---**
.4	***.2 - .6***	***.1 - .7***	***0 - .8***	**---**
.5	**---**	***.2 - .8***	***.1 - .9***	***0 – 1***
.6	**---**	**---**	***.2 – 1***	**---**

Expected Payoffs of the Three Options (Principle of Insufficient Reason)

$EV(A) = e(1-p^2)$	Range			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***8.97***	***8.80***	**---**	**---**
.4	***8.27***	***8.10***	***7.87***	**---**
.5	**---**	***7.20***	6.97	6.66
.6	**---**	**---**	5.87	**---**

EV(B) = *(e-f)* = 6.00

$EV(C) = (e - y) - zp^3$				
C: y=2, z=5	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	7.80	7.73	**---**	**---**
.4	7.60	7.50	7.36	**---**
.5	**---**	7.15	***6.97***	***6.75***
.6	**---**	**---**	***6.44***	**---**

Expected Payoffs of the Three Options (Principle of Insufficient Reason)

$EV(A) = e(1-p^2)$	Range			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***8.97***	***8.80***	**---**	**---**
.4	***8.27***	***8.10***	***7.87***	**---**
.5	**---**	***7.20***	6.97	6.66
.6	**---**	**---**	5.87	**---**

EV(B) = *(e-f)* = 6.00

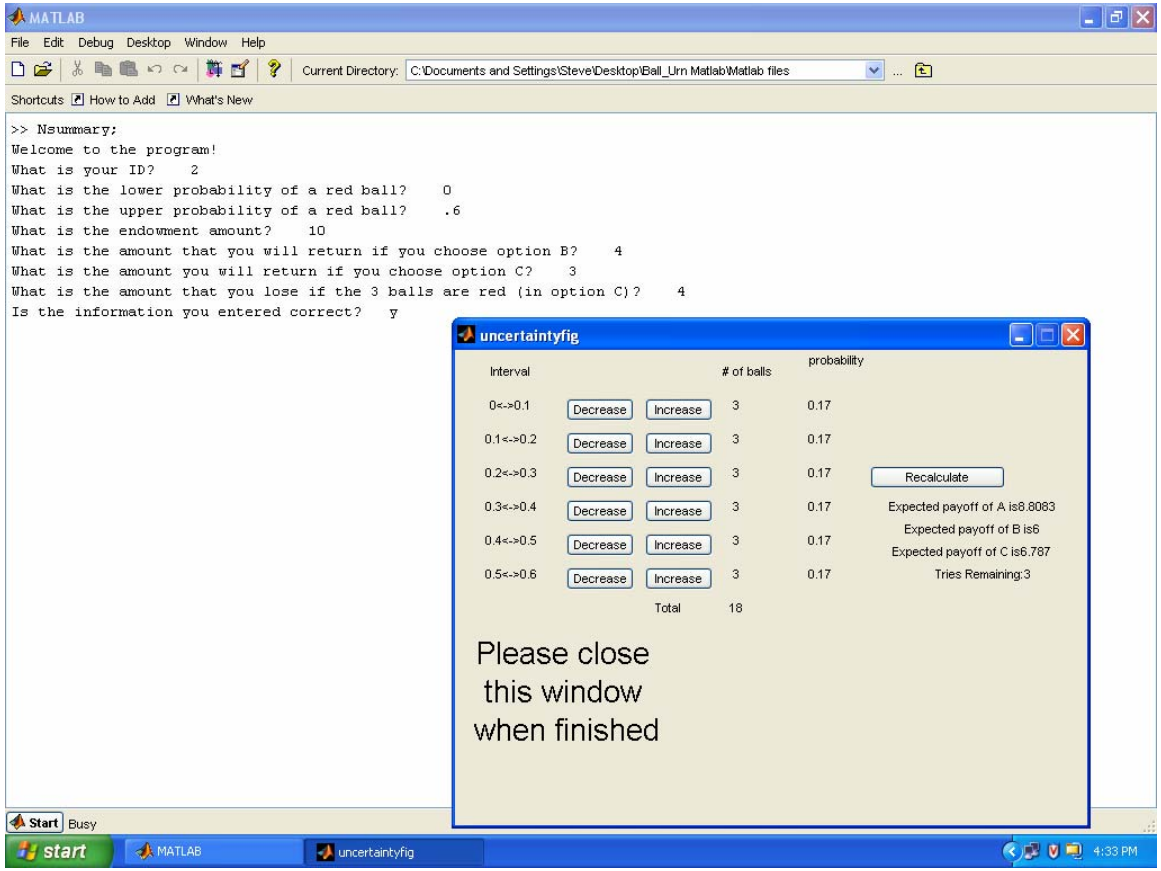
$EV(C) = (e - y) - zp^3$				
C: y=3, z=4	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	6.84	6.78	**---**	**---**
.4	6.68	6.60	6.49	**---**
.5	**---**	6.32	6.18	6.00
.6	**---**	**---**	5.75	**---**

Experimental Design

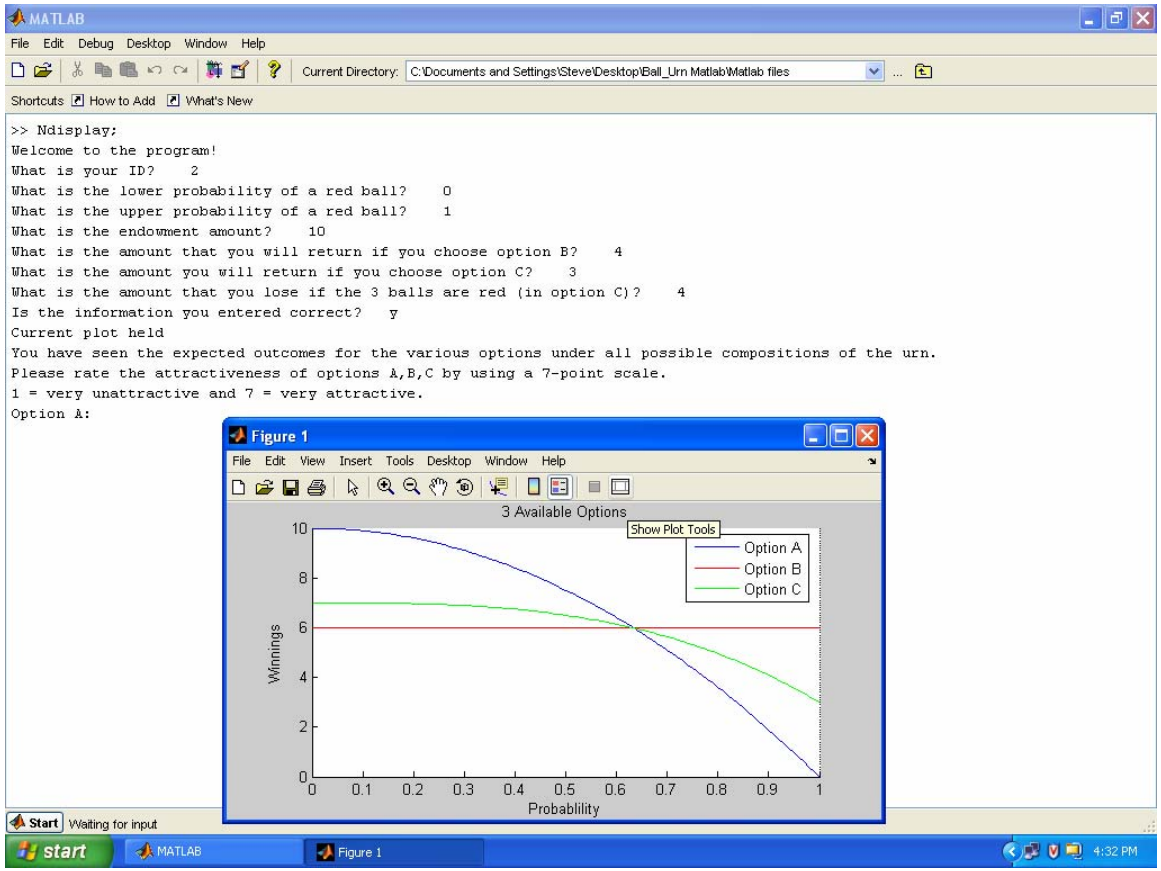
- Subjects were assigned randomly to one of 3 groups:
  - *Control* – without any decision aids.
  - *Display* – saw the expected value of A,B,C over the (P_l, P_u) range.
  - *Summary* – saw the EVs of the 3 options assuming a uniform prior over the (P_l, P_u) range, and (as many as 3) other distributions of the subjects' choice.

- About half of the subjects (randomly selected) were offered the possibility of purchasing vagueness reducing information.

Screen for the Summary Condition



Screen for the Display Condition



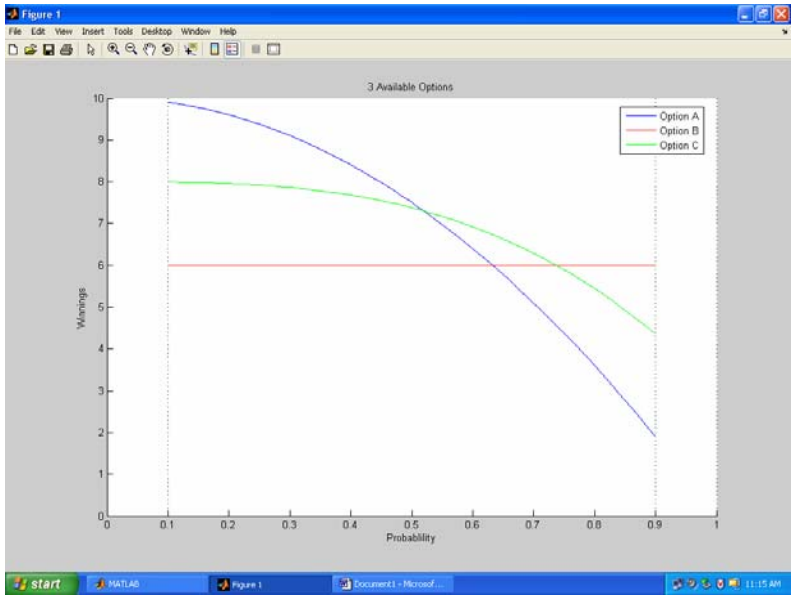


Figure 1
File Edit View Insert Tools Desktop Window Help
3 Available Options
Option A
Option B
Option C
Winnings
Probability
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
0 1 2 3 4 5 6 7 8 9 10
start
MATLAB
Figure 1
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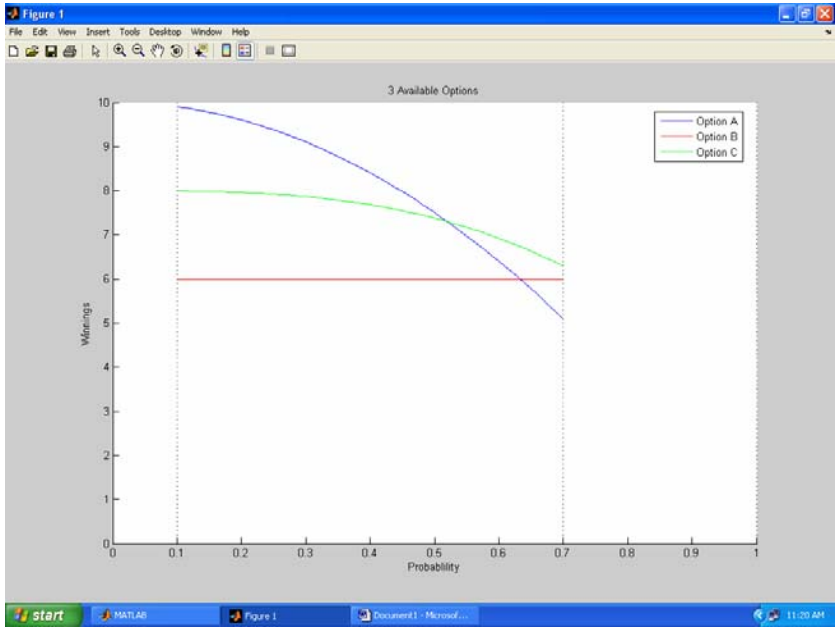
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Experimental Design and Procedure

- Each subject (in each of the 6 groups) made 18 decisions (in randomized order).
- For each decision the urns were (partially) filled in the presence of the DM to allow him/her to figure the lower and upper bounds of P.
- After entering the parameters of the decision problem (and accessing the decision aids) each DM was asked to:
  - Rate the attractiveness of Options A,B,C (1-7 scale);
  - Choose one option;
  - Rate confidence in the choice (1-7 scale).
- At the conclusion of the experiment, subjects were paid according to 3 of their decisions (the first one + 2 selected randomly from the other urns).

Predictions / Hypotheses for the Present Study

- Aversion to imprecision reflected by preference for risk minimizing options
- This pattern should hold primarily for (a) high levels of vagueness and (b) high probabilities of undesirable outcomes

Attitude to vagueness (and the pattern of revealed preferences) is sensitive to the mode of presentation underlying the decision aids

- Access to alternative presentation modes (decisions aids) should reduce the level of vagueness aversion and favor more risky actions
- Presentations emphasizing expected values / total pattern of outcomes would cause DMs to favor the actions with the higher expected values / relative superiority
- Access to alternative presentation modes (decisions aids) should increase the level of confidence in one's decisions

Experimental Details

Subjects: 67 students (57% women) at UIUC.

	Condition			
Information Purchase?	**Control**	**Display**	**Summary**	**Total**
Yes	12	10	13	35
No	11	9	12	32
Total	23	19	25	67

Information Purchase

Group	No of subjects*	Overall rate
Control	9/12	22%
Display	6/10	19%
Summary	7/13	15%
Total	22/35	18%

* Purchased information more than once

Analysis of Ratings / Choices

- In 90% of the cases (equal across conditions) the chosen option is the one with (or tied for) the highest rating.

- The analysis focuses on the “normalized” ratings that are obtained by dividing the raw ratings by the sum of the three (A, B, C) ratings, and add to 100 for each urn.

- When information was purchased the choices and ratings were analyzed as pertaining to the case with reduced vagueness. Thus, 21 urns (1.7%) are not included in the analysis

Analysis of Ratings / Choices
Modal Choices Across Presentation Modes

C: y=2, z=5	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	A (77)	A (57)	---	---
.4	A (55)	A (46)	C (38)	---
.5	---	C (41)	B (40)	B(45)
.6	---	---	B (63)	---
C: y=3, z=4	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	A (83)	A (73)	---	---
.4	A (62)	A (47)	A (36)	---
.5	---	B (37)	B (39)	B (54)
.6	---	---	B (69)	---

Analysis of Ratings: Mean Normalized Ratings (Y=2 and Z=5)

Option A	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***42***	***40***	---	---
.4	***36***	***36***	34	---
.5	---	30	28	28
.6	---	---	24	---
Option B	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	24	25	---	---
.4	28	29	31	---
.5	---	33	***37***	***36***
.6	---	---	***41***	---
Option C	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	33	35	---	---
.4	36	35	***35***	---
.5	---	***36***	35	35
.6	---	---	35	---

Analysis of Ratings: Mean Normalized Ratings (Y=3 and Z=4)

Option A	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***43***	***40***	---	---
.4	***40***	***36***	***34***	---
.5	---	33	32	28
.6	---	---	24	---
Option B	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	26	27	---	---
.4	28	31	34	---
.5	---	***34***	***36***	***41***
.6	---	---	***44***	---
Option C	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	31	33	---	---
.4	33	33	32	---
.5	---	33	32	31
.6	---	---	32	---

Ratings and Choices as a Function of the Probabilities Across all Presentation Conditions

- As the range increases, Option A becomes less attractive and Option B becomes more attractive.
- As the mid-range increases, Option A becomes less attractive and Option B becomes more attractive.
- As the cost of insurance (***y***) increases Option C becomes less attractive.

Attractiveness of Options as a Function of the Presentation Conditions Across all Probabilities

Choices

Condition	Option A	Option B	Option C
Control	37%	34%	29%
Display	43%	27%	30%
Summary	50%	22%	28%

Mean Normalized Ratings

Condition	Option A	Option B	Option C
Control	30	35	34
Display	35	32	33
Summary	38	29	34

Modal Individual Choices (At least half cases)

Condition	Option A	Option B	Option C
Control	8/23	7/23	4/23
Display	8/19	3/19	5/19
Summary	11/25	3/25	4/25

Analysis of Ratings / Choices
Attractiveness of Options as a Function of the Presentation Conditions Across all Probabilities

- The attractiveness of Option A is lowest under the Control presentation and it is highest under the Summary presentation.

- The attractiveness of Option B is highest under the Control presentation and it is lowest under the Summary presentation.

- The availability of decision aids (especially the EV calculator) make the riskier options (especially A) more attractive, at the expense of the riskless (safe) Option B.

Highest Rated Option (Y=2 and Z=5) as a Function of the Presentation Condition and Probabilities

Control	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***A***	***A***	---	---
.4	***C***	***C***	***B***	---
.5	---	***B***	***B***	***B***
.6	---	---	***B***	---
Display	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***A***	***A***	---	---
.4	***A***	***A***	***C***	---
.5	---	***C***	***B***	***B***
.6	---	---	***B***	---
Summary	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***A***	***A***	---	---
.4	***A***	***A***	***A***	---
.5	---	***C***	***C***	***C***
.6	---	---	***C***	---

Highest Rated Option (Y=3 and Z=4) as a Function of the Presentation Condition and Probabilities

Control	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***A***	***A***	---	---
.4	***A***	***C***	***B***	---
.5	---	***B***	***B***	***B***
.6	---	---	***B***	---
Display	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***A***	***A***	---	---
.4	***A***	***A***	***A***	---
.5	---	***B***	***B***	***B***
.6	---	---	***B***	---
Summary	**Range**			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***A***	***A***	---	---
.4	***A***	***A***	***A***	---
.5	---	***A***	***A***	***B***
.6	---	---	***B***	---

Rating of the Options as a Function of the Presentation Condition and Probabilities

- For the highest levels of vagueness the safe option (B) is the highest rated under all presentation modes.
- Under the Summary presentation ratings are consistent with EVs in most cases (favoring mostly A).
- The ratings under the Display condition are in between the other two conditions (a slower move away from B) and include a higher number of cases favoring C.

Confidence in Decisions as a Function of the Probabilities Across Presentation Conditions

- Confidence is highest when vagueness is reduced

	Range			
Mid-Range	**.4**	**.6**	**.8**	**1.0**
.3	***5.34***	***4.95***	**---**	**---**
.4	***4.89***	4.64	4.86	**---**
.5	**---**	4.41	4.61	4.66
.6	**---**	**---**	4.77	**---**

- No significant differences in the overall confidence under the various presentation modes
- In the Control condition confidence is highest when Option B is chosen (5.0) and lowest for choices of Option A (4.4)
- In the Display and Summary conditions confidence is highest when Option A is chosen (5.0) and lowest for choices of Option C (4.6)

Exploring Alternative Distributions

In the Summary condition subjects could examine up to 3 alternative distributions over the relevant range.

- On the average, DM examined 2.15 distributions (between 1.9 and 2.4 for various urns).
- In 67% of the urns DMs examined 3 distributions
- On average, the distributions examined have (a) higher means and (b) smaller variance than the (baseline) uniform distribution
- Systematic patterns of search

Summary and Conclusions

Confirming previous results and our hypotheses we found in the Control presentation:

- Preference for the risk minimizing option, reflecting aversion to imprecision
- This pattern is especially salient for (a) high levels of vagueness and (b) high probabilities of undesirable outcomes
- Its intensity decreases monotonically as (a) vagueness is reduced and (b) the range of probabilities shifts downwards

Summary and Conclusions

As predicted, the pattern of preferences is sensitive to the mode of presentation underlying the decision aids

- Alternative presentation modes using various decisions aids reduced the level of vagueness aversion and caused DMs to favor more risky actions
- Presentations using the expected value calculator shifted DMs to favor (almost always) the action with the highest expected value
- Presentations tracing the pattern of values across all probabilities in the range had a weaker effect, leading to decisions riskier than in the Control group but less risky than in the Summary condition. This mode did not necessarily favor the "insurance" option.
- Surprisingly, the effect of presentation mode on the DMs' confidence was modest.
- Surprisingly low rates of vagueness reducing information.

Lessons from J/DM for Abrupt Climate Change

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Two Problems

- Detecting systematic patterns in the presence of noisy measures.
- Predicting future values based on (a) past noisy values and / or (b) other predictor(s).

The Problem – Detection

Judgment by representativeness (the degree to which A is representative of, resembles to, or is typical of B):

- Misperception of randomness (generation, judgment, local representativeness). Example: “hot hand”

- Underestimation of “natural variability” (local representativeness, downplaying effects of extreme values). Example: Cyril Burt

The Problem – Detection

- "Positivity Bias" (Overweighting positive instances).
  Example: Judgment of co-variation driven by the (+,+) cases.

- "Confirmation Bias" (Overweighting evidence confirming one's hypotheses and expectations).
  Example: Wason's detection task, studies of information search.

- "Motivated Reasoning" Skewed evaluation of information that coheres with one's expectations.

The Problem – Prediction

Judgment by invoking / using “mental anchors” and “insufficient adjustment” away from the anchors.

- Predictions of trends anchored on the most recently observed values (recency effects) and too regressive.
- Under (Over) estimating the probability of conjunctive (disjunctive) events.
- Overconfidence due to insufficient adjustment from the central values (Alternative explanation – Bounds are “representative” of the information available)

Puzzle

Over reliance on global, intuitive, judgments – “Why do we trust our heads more than our formulas?”

Example: Clinical vs. Statistical judgment.