Dynamic Decision Making in Complex Environments
2016 City Summit

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Thanks to Adrian Camilleri, RMIT, for sharing some of the materials used in this course.
1. Pull out your laptop or smart phone.
2. Go to this website: live.voxvote.com
3. Enter PIN:
4. Click “OK next”.
5. Wait for poll to open and question to appear on screen.
6. When questions appear, press desired response and then wait for poll to close.
Choice: The essence of Decision Making

Decision tree:
- **Decision Node:**
  - Decide to do A
  - Decide to do B

- **Event Nodes:**
  - Event 1 occurs
  - Event 2 occurs

- **Outcome Nodes:**
  - Best outcome
  - Good outcome
  - Worst outcome
  - Bad outcome
Choice: The essence of Decision Making

- Rains
  - Don’t take an Umbrella
  - Take an Umbrella
- Does not Rain
  - Does not Rain
  - Rains

Outcomes:
- Worst Outcome
- Best Outcome
- Good Outcome
- Bad Outcome
Live Poll

90% chance of rain?
10% chance of rain?
50% chance of rain?

Rationality = Maximum Expected Value
Irrationality refers to behaviour that does not “maximize your expected utility”.

• Given what you know, assume, or expect about the world, you fail to make a decision that achieves the best outcome.
Two-Systems thinking

Thinking

Fast + Slow

System 1:
- Automatic
- Intuitive
- Instinctive
- Primary
- Rapid
- Blind
- “WYSIAT!”

System 2:
- Considered
- Effortful
- Focused
- Secondary
- Slower
- Lazy
Behavioral Decision Sciences

*Homo Economicus:*
- Rational.
- Perfect memory.
- Limitless computational abilities.
- No emotions.
- Selfish.
- Maximises.

*Homo sapien:*
- Boundedly rational
- Limited memory.
- Limited computational abilities.
- Emotional.
- Altruistic.
- Satisfices.
Heuristics and Biases

Mental “shortcuts” and Cognitive Illusions tha may lead to faulty beliefs and suboptimal decisions

Studies the effects of psychological, social, cognitive, and emotional factors on the decisions of individuals and institutions.
<table>
<thead>
<tr>
<th>Data Type</th>
<th>Qualitative</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitudinal</td>
<td>Focus groups, Interviews</td>
<td>Surveys</td>
</tr>
<tr>
<td>Behavioral</td>
<td>Ethnographic field studies</td>
<td>Experiments</td>
</tr>
</tbody>
</table>
Which fuel economy label leads to “better” choices?
Methods

1. Obtain a sample of respondents
2. Randomly divide the sample into different groups
3. Provide a different fuel economy label to each group and have them make choices
4. Compare the choices of individuals in the different groups
Example 1: Live poll

Imagine you are buying a new MP3 player and have narrowed down your options to the following three products:

<table>
<thead>
<tr>
<th>MP3</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>$400</td>
<td>$300</td>
<td>$450</td>
</tr>
<tr>
<td>Storage</td>
<td>30 GB</td>
<td>20 GB</td>
<td>29 GB</td>
</tr>
</tbody>
</table>

Which do you choose?

A. MP3 player A
B. MP3 player B
C. MP3 player C
The Decoy Effect

When choosing between two options, people’s preference will shift when then presented with a third option that is inferior to one of the other options.

Why does it happen?

- People prefer to make relative comparisons. It is unclear if A is better than B, but it is definitely better than C.
Example: The Decoy Effect
Example: The Decoy Effect

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Example 2: live poll

Imagine that you have just moved to a new city and are getting your driver’s license sorted out.

The forms asks about your about organ donation preference.

The default in this city is that you do not donate your organs when you die.

Do you opt out?

You are set to NOT be an organ donor  Choose to be an organ donor
Defaults

People usually go with the default.

- Increased organ donation rates:

  (Johnson & Goldstein, 2003; Smith, Johnson, & Goldstein, 2013)
Defaults

People usually go with the default.

Increased organ donation rates:

Why does this happen?

• People assume that the default has been singled out intentionally as a recommendation.
• Default is perceived as already “owned” and therefore giving it up is a loss, which people hate.
• It takes more effort to change a default.

(Johnson & Goldstein, 2003; Smith, Johnson, & Goldstein, 2013)
Example: Defaults

(Goldstein, Johnson, Herrmann & Heitmann, 2008)
Imagine that the US is preparing for the outbreak of an unusual disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume the exact scientific estimate of the consequences of the programs are as follows:

A. If Program A is adopted, 200 people will be saved.
B. If Program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved.

Which do you choose?

A. Program A
B. Program B
Imagine that the US is preparing for the outbreak of an unusual disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume the exact scientific estimate of the consequences of the programs are as follows:

A. If Program A is adopted, 400 people will die.
B. If Program B is adopted, there is a one-third probability that 0 people will die and a two-thirds probability that 600 will die.

Which do you choose?

A. Program A
B. Program B
Framing

Why does this happen?

• People’s thinking is biased by the information that is presented such that they tend not to consider information is isn’t salient.
Example 3: Framing

![Diagram of two containers labeled "Frozen Yoghurt" with different fat percentages]
Example 4-a: Live poll

Think about it for a moment: Did Mahatma Gandhi die before or after the age of 9 years?

How old was Mahatma Gandhi when he died?

A. 38  
B. 48  
C. 58  
D. 68  
E. 78  
F. 88
Example 4-b: Live poll

Think about it for a moment: Did Mahatma Gandhi die before or after the age of 100 years?

How old was Mahatma Gandhi when he died?

A. 38
B. 48
C. 58
D. 68
E. 78
F. 88
Anchoring

When making numerical estimates or judgments, people tend to stay close to their initial starting point, even if that starting point is obviously meaningless.

- “.... 9 years”: average estimated age of 50.
- “.... 100 years”: average estimated age of 67.

Why does this happen?

- The anchor influences the information that is drawn from memory to make the judgment.
- People reject the anchor and then adjust in an appropriate direction until they reach the first plausible value.
Example 4: Anchoring
Example 4: Anchoring

Bordeaux

1996  Château Lascombes, 2ème Cru Classe, Margaux  175
1996  Château Palmer, 3ème Cru Classe, Margaux  560
1990  Château Margaux, 1er Cru Classé, Margaux  2480
2000  Château Gloria, Saint Julien  170
1996  Château Gruaud-Larose 2ème C.C., Saint Julien  390
2000  Château Léoville-Poyferré, 2ème C.C., Saint Julien  420

(continued)
Example 5: Live poll

What is the weight of an empty Boeing 747 (in kgs)?

From the list below, pick the range of values for which you are 90% confidence includes the true answer.

A. 120,000 – 220,000
B. 10,000 – 150,000
C. 200,000 – 350,000
D. 80,000 – 170,000
E. 150 – 150,000
F. 460,000 - 670,000
G. 480,000 – 1,200,000
H. 310,000 – 560,000
I. 20,000 – 90,000
J. 1 - 1,000,000
Overconfidence

People believe that their judgments and decisions are better than they really are:

• Correct answer: 180,983 kg.

Why does this happen?

• People prefer to be informative than accurate.
  • Few people answer “1 - 1,000,000 kgs”.
• People’s best estimates are very poor to start.
• People remain too close to their best estimate.
Example 5: Overconfidence
Causes of overconfidence

Hindsight bias

Motivated and non-motivated confirmatory thinking
  • Confirmation bias
  • Wishful thinking

Naïve realism
Naïve realism

• You drive up to San Francisco with friends to celebrate the end of the quarter. The plans include dinner and then some entertainment afterward.
  – How much money will you personally spend on the dinner?

• You receive a telephone call from a survey firm. You initially agree to answer some questions. There is a long series of questions
  – How many minutes will you spend answering questions before you end the call?
Naïve realism

Three conditions:

- Control condition: Confidence intervals simply given a second time
- “Assumers” condition: Asked to assume that their image of the situation was, in fact, correct in all details
- Multiple construal condition: Asked to describe several alternative ways the situation they would be in could turn out

Griffin, Dunning, & Ross, 1990
Naïve realism

![Graph showing expansion of confidence interval]

How much do people change their estimates?

- Control
- Assumers
- Multiple construal

Griffin, Dunning, & Ross, 1990
Example 6: Live poll

Bill is 34 years old. He is intelligent, but unimaginative, compulsive and generally lifeless. In school, he was strong in mathematics but weak in social studies and humanities.

Which of the below is most likely?

A. Bill plays jazz for a hobby
B. Bill is a reporter
C. Bill is an accountant who plays jazz for a hobby
D. Bill climbs mountains for a hobby
Conjunction Fallacy

In many cases, people believe that a specific condition is more probable than a more general one:

- “Bill plays jazz for a hobby” is more general than “Bill is an accountant who plays jazz for a hobby”

Why does this happen?

- People are bad at thinking in terms of probabilities (use frequencies where possible).
- The more specific description is more representative and thus seems more likely.
Example 7: Live poll

Imagine you are buying a new DSL camera and have narrowed down your options to the following three products:

<table>
<thead>
<tr>
<th>Camera</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brand</td>
<td>Cannon</td>
<td>Cannon</td>
<td>Cannon</td>
</tr>
<tr>
<td>Megapixels</td>
<td>9.2</td>
<td>12.2</td>
<td>15.2</td>
</tr>
<tr>
<td>Price</td>
<td>$439</td>
<td>$489</td>
<td>$539</td>
</tr>
</tbody>
</table>

Which do you choose?

A. Camera A
B. Camera B
C. Camera C
People are more likely to choose the middle option of a selection set rather than the extreme options. Why does this happen?

- People are loss averse and so they go with the middle option to minimize future regrets about making the wrong choice.
Example 7: The Compromise Effect

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compare this car to</strong></td>
<td>i SV 4dr Sedan</td>
<td>i Touring 4dr Sedan</td>
<td>s Grand Touring 4...</td>
</tr>
<tr>
<td><strong>Compare Pricing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSRP</td>
<td>$16,945</td>
<td>$19,595</td>
<td>$25,045</td>
</tr>
<tr>
<td>Market Price</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Invoice Price</td>
<td>$16,474</td>
<td>$18,753</td>
<td>$23,961</td>
</tr>
<tr>
<td>Destination Charge</td>
<td>$795</td>
<td>$820</td>
<td>$820</td>
</tr>
<tr>
<td>Build Your Own</td>
<td>BUILD</td>
<td>BUILD</td>
<td>BUILD</td>
</tr>
<tr>
<td>Monthly Car Payment</td>
<td>$320</td>
<td>$370</td>
<td>$473</td>
</tr>
<tr>
<td><strong>Compare Purchase Options</strong></td>
<td>2014 Mazda Mazda3</td>
<td>2015 Mazda Mazda3</td>
<td>2015 Mazda Mazda3</td>
</tr>
<tr>
<td>Local Dealer Pricing</td>
<td></td>
<td>FREE Price Quotes</td>
<td>FREE Price Quotes</td>
</tr>
<tr>
<td>Find Cars For Sale</td>
<td>find in</td>
<td>GO</td>
<td>find in</td>
</tr>
</tbody>
</table>
Even More Examples: an impressive list of heuristics and biases

The endowment effect.
Affect heuristic.
Availability.
Representativeness (misperception of randomness, the hot hand, regression fallacy)

Etc.!!
Who is using this research?

Governments:
- UK
- US
- Australia
- Canada
- Singapore

Companies:
- Google
- eBay
- Uber
- Disney
- Unilever

Consulting Firms:
- Forethought
- The Behavioural Architects
- Behavioral Science Lab, LLC

Not-for-profit organisations:
- World Bank
- UNICEF
- Red Cross
Who is using results from this research?
Linear view of decision making

Problem ➔ Action ➔ Result

Problem terminates with a choice – no feedback

Given an individual and the same decision problem, the same action will be chosen

Maximization of utility of each decision
"... static decision theories have only a limited future. Human beings learn, and probabilities and values change; these facts mean that the really applicable kinds of decision theories will be dynamic, not static" Edwards (1961, page 485).

Ward Edwards (1927-2005)
Stock Market
Loop view of decision making: a Learning Process

Decision Making is a Learning process - a continuous judgment-action-outcome feedback loop
Decision Making is about controlling a system
Decision Making is affected by dynamic complexity, real-time responses
Decision making includes information seeking, foraging, search for cues
It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is MOST ADAPTABLE TO CHANGE

Charles Darwin, 1809 -1882
How do we adapt to changing conditions of the environment?

How do we contribute to change through decisions we make?
Dynamic Decision Making

1. Series of Decisions under various degrees of uncertainty
2. Decisions are sequentially interdependent: the output of one becomes the input of the future ones
3. Environment changes: either independently or dependently as a result of previous decisions
4. Utility of decisions is time-dependent (according to *when* they are made)
5. Resources (e.g., Time) are limited
Dynamic Decision Making: Consequential Choice
Dynamic Decision Making: Choice from Sampling
Dynamic Decision Making: Control
Complex dynamic environments: Microworld research

- Dynamic Visual Detection
- Real-time resource allocation
- Climate Change
- Supply Chain Management
- Conflict Resolution
- Military Command and Control
- Medical Diagnosis
- Fire Fighting
- Threat Sensors
- Weapon System Sensors
- Radar Grid
- Quiet Airspace Report
- Target Set (Memory Set)
- Total Block Score
- Guns Ignore Missiles
- F D G J
- Dynamic Visual Detection
- Climate Change
- Fire Fighting
Water Purification Plant (WPP)
Learning and adapting to Time Pressure

1. More practice is better
2. Same speed is better

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Total Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fast (N=14)</strong></td>
<td>6 trials of 8 minutes</td>
<td>6 trials of 8 minutes</td>
<td>6 trials of 8 minutes</td>
<td>144 minutes</td>
</tr>
<tr>
<td><strong>Slow</strong></td>
<td>2 trials of 24 minutes</td>
<td>2 trials of 24 minutes</td>
<td>Fast</td>
<td></td>
</tr>
<tr>
<td><strong>Total (N=33)</strong></td>
<td>48 minutes</td>
<td>48 minutes</td>
<td>48 minutes</td>
<td>48 minutes</td>
</tr>
</tbody>
</table>

Gonzalez, 2004
Raven Progressive Matrices Test: Fluid Intelligence test

Complete the matrix by selecting the appropriate missing symbol from the group of symbols.
Example 2
Slow is fast – Adaptation to time pressure
Better pattern matching ability helps

Mean Performance For High and Low Raven participants

Day
Performance
High
Low
1 2 3
What was learned?: Heuristic fit

Average Fit to heuristic

Fit

Fast

Slow

Day

1
2
3
Pattern matching ability and heuristic fit

Low Raven

Fit

Day

Fast

Slow

High Raven

Fit

Day

Fast

Slow
How do we adapt to changing conditions of the environment?

**RECOGNITION**
- Identifying typical situations and responses
- Determining the similarity (pattern matching) between a situation and past experience

**EXPERIENCE**
- Acquiring context-based knowledge with practice in the task
- Reducing the use of heuristics over time and relying more on memory
DDM Control tasks: Abstract and simple experimental paradigms

Graphical representations
(Cronin & Gonzalez, 2007; Cronin, Gonzalez & Sterman, 2009)

Dynamic Stocks and Flows (DSF)
(Gonzalez & Dutt, 2011)

Beer Game
(Fu & Gonzalez 2006; Martin, Gonzalez & Lebiere, 2004)
How many are in the store?

\[ P_t = \int_{t_0}^{t} (\text{Entering}_t - \text{Leaving}_t) \, ds + P_{t_0} \]

\[ \frac{dP}{dt} = \text{Entering} - \text{Leaving} \]
Department Store Task
(N=173)

The graph below shows the number of people entering and leaving a department store over a 30 minute period.
Please answer the following questions. Check the box if the answer cannot be determined from the information provided.

3. During which minute were the most people in the store?

   Minute ________  □  Can’t be determined

4. During which minute were the fewest people in the store?

   Minute ________  □  Can’t be determined
Why? What are people thinking? What mental models are in play?

**Common Explanations:**

1. Complexity of the graph
2. Type of information representation
3. Context familiarity
4. Motivation
1. Complexity of the graph

Perhaps people understand stocks and flows… but are overwhelmed by the complexity of the task

- Too many data points, too much information

Performance should improve if the tasks are simplified
## Results (N=63)

<table>
<thead>
<tr>
<th></th>
<th>Q1: Most Entering</th>
<th>Q2: Most Leaving</th>
<th>Q3: Most in Store</th>
<th>Q4: Fewest in Store</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Original</strong></td>
<td>96%</td>
<td>95%</td>
<td>44%</td>
<td>31%</td>
</tr>
<tr>
<td>(n = 173)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Simple</strong></td>
<td>94%</td>
<td>87%</td>
<td>52%</td>
<td>41%</td>
</tr>
<tr>
<td>(n = 63)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>p(Simple = Complex)</strong></td>
<td>.490</td>
<td>.083</td>
<td>.320</td>
<td>.166</td>
</tr>
</tbody>
</table>
2. Data Display

Perhaps people understand stocks and flows... but are unable to read/construct graphs.
Performance should improve if the data are presented in tabular or textual form.
Simplified Visual Isomorphs

A. Line graph

B. Bar Graph

C. Table

<table>
<thead>
<tr>
<th>Minute</th>
<th>People Entering</th>
<th>People Leaving</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>11</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>12</td>
</tr>
</tbody>
</table>

D. Text

In the first minute, 9 people enter and 8 leave. In the second minute, 10 people enter and 5 leave. In the third minute, 9 people enter and 8 leave. In the fourth minute, 14 people enter and 12 leave. In the fifth minute, 9 people enter and 8 leave. In the sixth minute, 9 people enter and 7 leave. In the seventh minute, 8 people enter and 8 leave. In the eighth minute, 7 people enter and 9 leave. In the ninth minute, 4 people enter and 13 leave. In the tenth minute, 7 people enter and 11 leave. In the eleventh minute, 10 people enter and 15 leave. In the twelfth minute, 8 people enter and 12 leave.
### Results (N=264)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>89%</td>
<td>83%</td>
<td>56%</td>
<td>46%</td>
</tr>
<tr>
<td>A Graph (both line and bar, N = 127)</td>
<td>94%</td>
<td>91%</td>
<td>61%</td>
<td>48%</td>
</tr>
<tr>
<td>No graph (both text and table, N = 137)</td>
<td>85%</td>
<td>76%</td>
<td>51%</td>
<td>44%</td>
</tr>
<tr>
<td><em>Exact test p =</em></td>
<td>0.015</td>
<td>0.001</td>
<td>0.137</td>
<td>0.537</td>
</tr>
<tr>
<td>B Line graph (N = 63)</td>
<td>94%</td>
<td>87%</td>
<td>52%</td>
<td>41%</td>
</tr>
<tr>
<td>Bar graph (N = 64)</td>
<td>95%</td>
<td>95%</td>
<td>69%</td>
<td>55%</td>
</tr>
<tr>
<td><em>Exact test p =</em></td>
<td>0.718</td>
<td>0.127</td>
<td>0.071</td>
<td>0.157</td>
</tr>
<tr>
<td>C Text (N = 59)</td>
<td>86%</td>
<td>75%</td>
<td>47%</td>
<td>42%</td>
</tr>
<tr>
<td>Table (N = 78)</td>
<td>83%</td>
<td>77%</td>
<td>54%</td>
<td>45%</td>
</tr>
<tr>
<td><em>Exact test p =</em></td>
<td>0.811</td>
<td>0.841</td>
<td>0.493</td>
<td>0.862</td>
</tr>
<tr>
<td>D Baseline (N = 173)</td>
<td>96%</td>
<td>95%</td>
<td>44%</td>
<td>31%</td>
</tr>
<tr>
<td>Line graph (N = 63)</td>
<td>94%</td>
<td>87%</td>
<td>52%</td>
<td>41%</td>
</tr>
<tr>
<td><em>Exact test p =</em></td>
<td>0.490</td>
<td>0.083</td>
<td>0.302</td>
<td>0.166</td>
</tr>
</tbody>
</table>
3. Context familiarity

Perhaps people understand stocks and flows… but are unable to apply their knowledge in unfamiliar contexts.

Performance should improve as context familiarity improves.

Treatment: Department store task + isomorphs with different contexts
  • Distance between two cars on a straight road
  • Water level of a tub

If familiarity matters, then performance should be ordered as: tub, cars > store.
## Results (N=47)

<table>
<thead>
<tr>
<th>Overall success rates (N = 47)</th>
<th>Question 1: Largest inflow</th>
<th>Question 2: Largest outflow</th>
<th>Question 3: Stock most full</th>
<th>Question 4: Stock most empty</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>96%</td>
<td>94%</td>
<td>28%</td>
<td>26%</td>
</tr>
<tr>
<td>A</td>
<td>Store (N = 18)</td>
<td>100%</td>
<td>100%</td>
<td>22%</td>
</tr>
<tr>
<td></td>
<td>Cars (N = 16)</td>
<td>100%</td>
<td>100%</td>
<td>38%</td>
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<tr>
<td></td>
<td>Exact test p =</td>
<td>1.000</td>
<td>1.000</td>
<td>.457</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Store (N = 18)</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Tub (N = 13)</td>
<td>85%</td>
<td>77%</td>
<td>23%</td>
</tr>
<tr>
<td></td>
<td>Exact test p =</td>
<td>.168</td>
<td>.064</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Tub + cars (N = 29)</td>
<td>93%</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>Store (N = 18)</td>
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<td>100%</td>
<td>22%</td>
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<tr>
<td></td>
<td>Exact test p =</td>
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<td>.276</td>
<td>.739</td>
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<td>D</td>
<td>Tub (N = 13)</td>
<td>85%</td>
<td>77%</td>
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<td></td>
<td>Cars (N = 16)</td>
<td>100%</td>
<td>100%</td>
<td>38%</td>
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<tr>
<td></td>
<td>Exact test p =</td>
<td>.192</td>
<td>.078</td>
<td>.454</td>
</tr>
</tbody>
</table>
4. Motivation and Feedback

Perhaps people understand stocks and flows...but:
• weren’t sufficiently motivated
• and didn’t get feedback pointing out errors

Treatment:
• Simplified Department Store task
• Subjects were told they can leave as soon as they answer all 4 questions correctly, else after 1 hour
• Subjects bring their answers to instructor, who marks each question, then try again
# Results (N=69)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>No motivation/no feedback</strong></td>
<td>100%</td>
<td>86.5%</td>
<td>18.9%</td>
<td>21.6%</td>
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<tr>
<td>condition (n = 37)</td>
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<tr>
<td><strong>Motivation/feedback</strong></td>
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<tr>
<td>condition (n = 32):</td>
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<tr>
<td>Attempt 1</td>
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<td>96.9%</td>
<td>15.6%</td>
<td>12.5%</td>
</tr>
<tr>
<td><strong>Exact test, p =</strong></td>
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<td>25.0%</td>
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<td>Attempt 4</td>
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<tr>
<td>Attempt 9</td>
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</table>
Linear Thinking: Cause-Effect are thought to be linearly related

The graph below shows the number of people entering and leaving a department store over a 30-minute period.

In the space below, graph the number of people in the store over the 30-minute interval. You do not need to specify numerical values. The dot at time zero shows the initial number of people in the store.
1. Constant Flows; $I < O$

Net flow is constant and $< 0$. Stock falls linearly.

2. Linear decline in both $I$ and $O$, Constant Net Flow, $I > O$

Net flow is constant and $< 0$. Stock falls linearly.

3. Constant Outflow, Linear increase in Inflow; $I \leq O$

Net flow $< 0$, rises linearly to 0 by time 30. Stock falls at decreasing rate, is constant at $t=30$

4. Constant Outflow, Linear increase in inflow; $I \geq O$

Net flow $> 0$, rises linearly throughout. Stock rises at increasing rate from initial equilibrium.
5. Constant Flows; \( I \leq O \)

Net flow > 0, falls linearly to 0 by \( t = 30 \). Stock rises at decreasing rate, reaches equilibrium at \( t = 30 \).

6. Linear decline in both \( I \) and \( O \), Constant Net Flow, \( I \geq O \)

Net flow \( \leq 0 \), rises to 0 at midpoint, then falls. Stock falls at decreasing rate, is flat at midpoint, then falls at increasing rate.

7. Constant Outflow, Linear increase in Inflow; \( I \leq O \)

Initially zero, net flow rises to max, then falls. Stock follows s-shape with inflection point at midpoint and equilibrium at start and end.

8. Constant Outflow, Linear increase in inflow; \( I \geq O \)

Net flow \( \geq 0 \), follows S-shape. Stock starts in equilibrium, rises at increasing rate until last few minutes, where growth is linear.
Problems to adapt in dynamic environments:

**Linear thinking**
- Make choices expecting that the effect will be linearly related to the cause

**Misperceptions of feedback**
- Most humans select actions through reinforcing cause-effect patterns over time
In static environments longer lasting memory (low recency) may be a good predictor of future outcomes, but in dynamic environments recent outcomes (high recency) may be more representative of future outcomes than are older ones.
Groups better than individuals?
• Groups have higher information-processing capacity; make fewer mistakes and are more consistent than individuals.
• Coordination within groups can be costly and often detrimental to performance.

➔ Groups would do worse than individuals in adapting to change
Gradual and sudden changes
Groups are better than individuals before the change point but individuals adapt to the change more successfully
Individuals explored more than groups
Patterns of memory

**Static environments**

Recency: Best estimate of future behavior is obtained from a large history of outcomes (less recency)

Noise: A good strategy is to learn which option gives the best outcomes more often and sticking to it, is a good strategy

**Dynamic Environments**

Recency: Recent outcomes might be a better estimate of recent changes than are outcomes in the distant past – It is better to forget.

Noise: people *ought* to search for patterns that might indicate that a change has occurred
Conclusions:

Engage “System 2”
- Learn the common errors that people make in our uncertain world
  - They rely too much on affect, availability and representativeness
  - They’re overconfident in their decisions
- Take a skeptical mindset even when you like an initial judgment
  - Don’t be an “assumer”
- Invoke an audience to which you need to justify your thinking

Learning to adapt to a dynamic world is essential for survival

Research questions:
- Most decisions are made from a combination of experiential and symbolic information – Theory integration
- Scaling-up models of decisions from experience – Towards group and society decision making
- Investigate relevance of context and task complexity – A unified theory of environments
- Explore effects of environmental change: Number of options, information, feedback delays, etc.
NATIONAL LEAGUE OF CITIES
CITIES STRONG TOGETHER