



**Transportation – A technological behemoth  
bedeviled by human behavior**

**ATTEND! CONSIDER! DECIDE!**

What Human and Machine Policy-Makers  
Must Learn to Predict Travel Behavior

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Leon Moses Distinguished Lecture in Transportation

Northwestern University Transportation Center

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# Outline – Attend! Consider! Decide!

1. Transportation Data, c. 1969
2. Behavioral Travel Demand Modelling, c. 1970's
3. Travel Behavior, Updated – Insights from Market Research, Cognitive Psychology, Behavioral Economics, and Neuroscience
4. Market, Personal, and Social Risks of Choice
5. How Attention, Consideration, and Decision-Making Influence (Travel) Choice
6. Transportation Data Today – How to Build Behavioral Structure into the Training of Human and Machine Policy-makers

# 1. Transportation Data c. 1969

O-D Table	MODE (m)		DESTINATION CBD
ORIGIN (z)	Auto	Transit	Total
Zone 1	30K	20K	50K
Zone 2	20K	20K	40K
Zone 3	40K	10K	50K
<b>Total</b>	<b>90K</b>	<b>50K</b>	<b>140K</b>



# Gravity Model

**Ernst Ravenstein (1885), George Zipf (1946)**

Travel by mode  $m$  from zone  $z$  to the CBD :

$$Trips_{zm} \propto (Population_z) \cdot (CBD\ jobs) / Cost_{zm}^r$$

$Cost_{zm}^r$  = a “generalized” dollar cost of a trip, including value of time

$r$  = a parameter (e.g., 2)

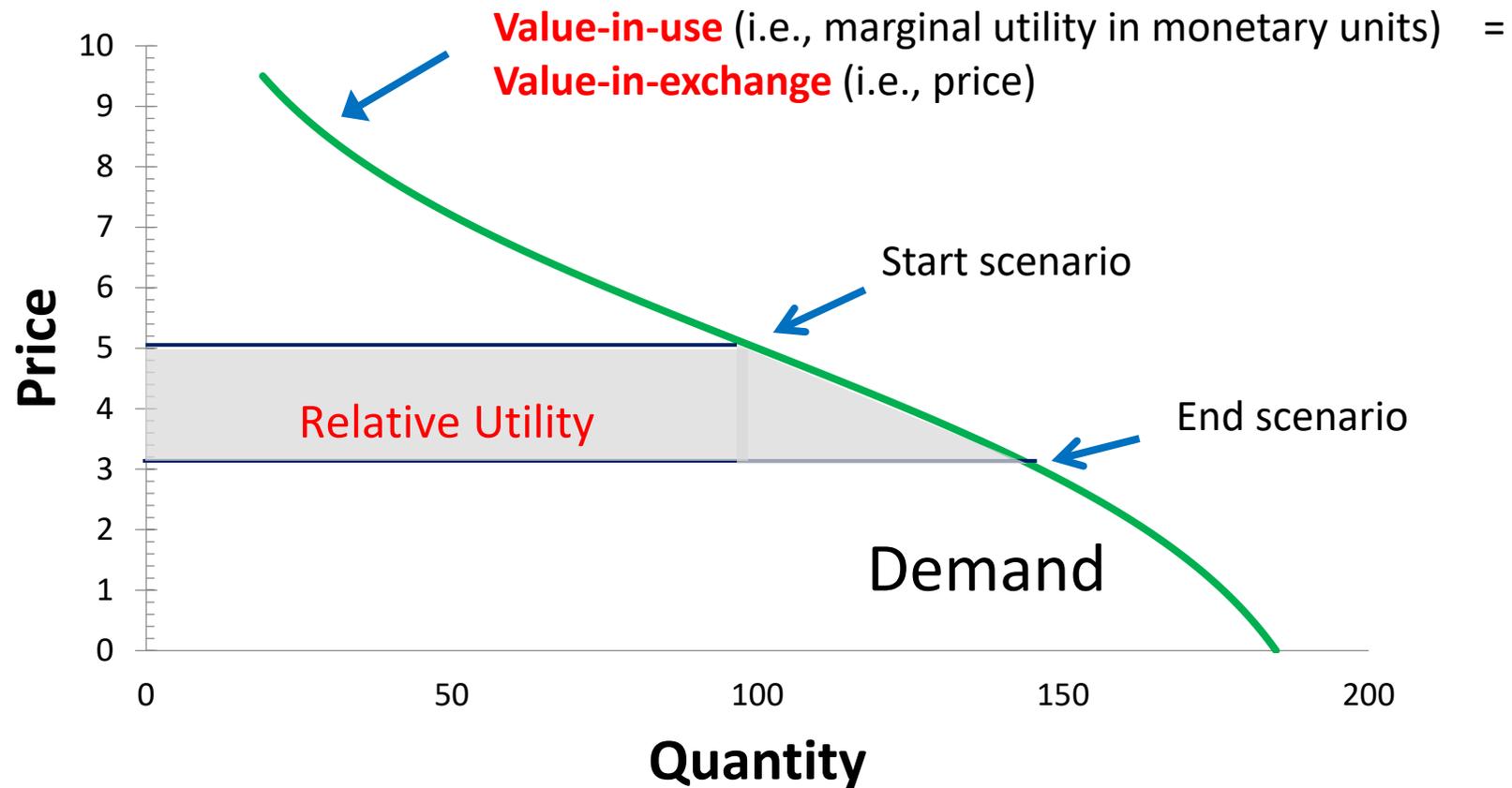


# Behavioral Travel Demand Modelling, 1969-72

- Charles River Associates undertook a project for the FHA to develop **disaggregate behavioral urban travel demand** models.
- Jerry Kraft, Bill Tye, and Tom Domencich were the project leaders, Marvin Manheim and John Kain were the academic advisors, and Peter Diamond and Robert Hall the primary academic consultants
- Diamond and Hall recruited me to provide a modeling and estimation system, and this resulted in “conditional logit” travel demand models, now called **flat** or **nested multinomial logit models** or **random utility maximization (RUM)** models
- RUM models, improved by Moshe Ben-Akiva, Kenneth Train, and many others, are a core tool for predicting choice in transportation, market research, economics, finance, and beyond

# Jules Dupuit (1844): Utility $\Leftrightarrow$ Demand

The integral of demand between two prices ( $\equiv$  values-in-exchange) is a measure of *money-metric relative utility*, a solution to the inverse problem of recovering utility from demand.



# Travel Demand Forecasting Project (TDFP)

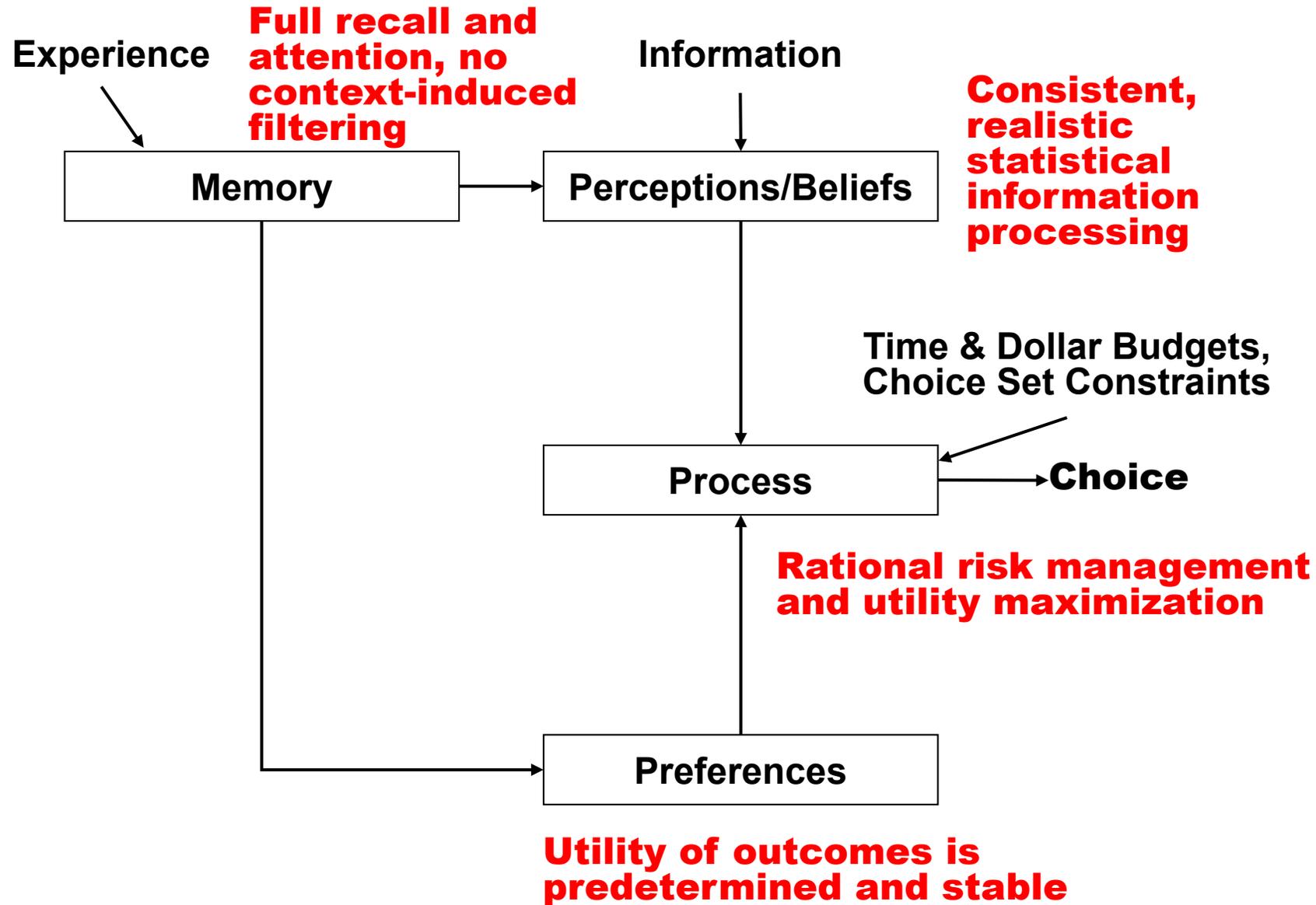
- I directed TDFP at Berkeley from 1973-77. It used the “natural experiment” of the introduction of the BART system to test whether disaggregate behavioral models estimated on data collected before BART opened could predict BART ridership after it opened three years later. The project was funded by NSF and ARPA.
- The TDFP forecasts proved substantially more accurate than those made by BART and other transportation agencies in the same time frame using more traditional forecasting methods. TDFP also developed a variety of methods for collecting and updating O-D data, implementing policy analysis, and estimation.
- Associates who went on to contribute to transportation research include Charles Manski, Kenneth Train, Ken Small, David Brownstone, Cliff Winston, and Tim Hau.

# Prediction Success Table, Work Trips

(Pre-BART Model and Post-BART Choices)

Actual Choices In 1975	Predicted Choices from 1973				
	Auto Alone	Car- pool	Bus	BART	Total
Auto Alone	255.1	79.1	28.5	15.2	378
Carpool	74.7	37.7	15.7	8.9	137
Bus	12.8	16.5	42.9	4.7	77
BART	9.8	11.1	6.9	11.2	39
<b>Total</b>	<b>352.5</b>	<b>144.5</b>	<b>94.0</b>	<b>40.0</b>	<b>631</b>
Predicted Share (%)	55.8	22.9	14.9	6.3	← 15% BART Pred.
Actual Share (%)	59.9	21.7	12.2	6.2	

# Classical Choice Theory: The Devil is in the Details





### 3. Travel Behavior, Updated

- The classical economic model of rational random-utility-maximizing choice, implemented through discrete choice models like conditional logit, has been broadly successful in predicting travel behavior under policy alternatives that can be translated into the measured attributes of alternatives facing consumers.
- **Nevertheless**, travel patterns have been observed that are hard to reconcile with the rational economic model:
  - Excessive lane-changing and delays in merging, apparently due to systematic misperceptions
  - Inertia and reluctance to trade (switch) that are strong in consumer choices such as travel mode and route, housing location, vehicle purchase, and trip route choice
- These effects are observed across a broad variety of consumer decisions, and are topics for continuing research on consumer behavior.

# We are Challenged by Choice



*Dutch Proverb: He who has a choice has trouble.*

# Risks of Choice

- **Market Risk – manipulation** (e.g., shrouded product attributes), uncertain supply, undisclosed costs and volatile prices
- **Personal Risk** – memory and attention lapses, errors of perception and calculation, misreading of one's own tastes
- **Social Risk** – economic interactions between people, stress of information gathering, search, bargaining, social norms, accountability, sanctions

# Market Risk

- Market trading and switching can be risky due to manipulation (e.g., incomplete or misleading information, uncertainty about attributes of alternatives), uncertain delivery, price shocks
- Aversion to market risk is strongest when inexperienced consumers face a choice among unfamiliar alternatives with shrouded or ambiguous attributes
- Examples: Unfamiliar transit mode (e.g., ride-sharing), electric cars, automated driving, toll rings

# Markets recognize and exploit trading errors

- The sting of market punishment breeds suspicion of offered trades, distrust of traders
- Experience may make consumers cautious
  - Familiar, repeated choices, or choices with big stakes, may be nearly rational
  - Mistakes are most likely with unfamiliar choices having modest consequences, a situation similar to choice tasks in experimental laboratories
- Markets do not provide a road map to success, and some consumers are slow learners
- Protective heuristics evolve (e.g., “don’t gamble”)

# Personal Risk

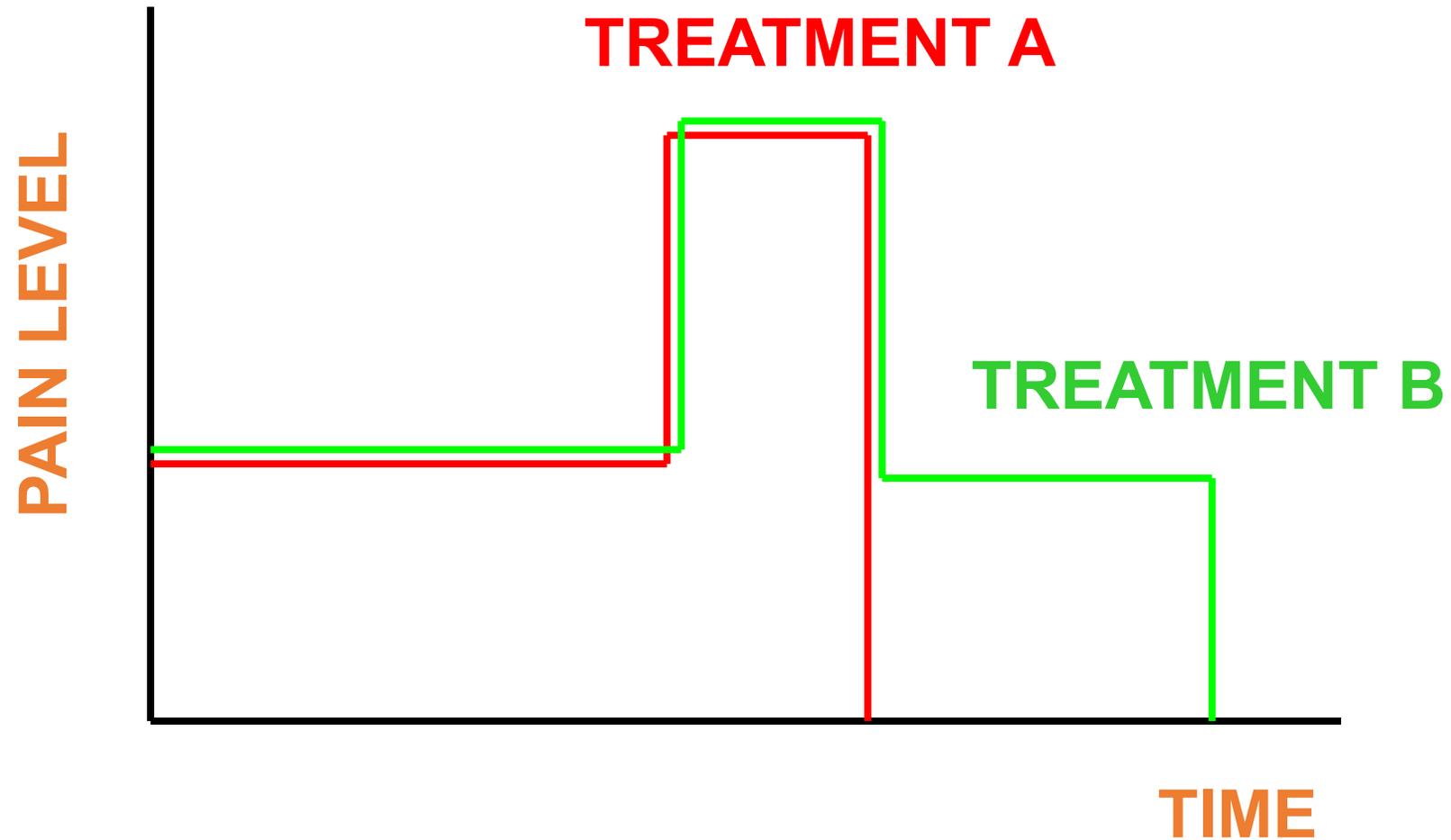
- *“A large literature from behavioral economics and psychology finds that people often make inconsistent choices, fail to learn from experience, exhibit reluctance to trade, base their own satisfaction on how their situation compares with others’, and in other ways depart from the standard model of the rational economic agent.”*

*Danny Kahneman and Alan Krueger, 2005*

# Personal Risk -- Memory

Effect	Description
Affective attenuation	Affective memories are recalled/anticipated with diminished intensity
Availability	Memory reconstruction uses the most available and salient information
Primacy/Recency	Initial and recent experiences are the most readily retrieved
Reconstructed memory	Imperfect memories rebuilt using current cues and context, historical exemplars, customary search protocols
Selective memory	Coincidences are more available than non-coincidences
Subjective time	Compression and attenuation of history, duration neglect

# Memory of Integrated Experience



# Personal Risk -- Perception

Effect	Description
Anchoring	Judgments are influenced by quantitative cues contained in the decision task
Context/Framing	History and framing of the decision task influence perception and motivation
Endowment/ Reference Point	Status quo is a “safe” known alternative. “The devil you know is better than the devil you don’t”
Extension	Representative/extreme/recent rates code integrated experience.
Prominence/Order	Format or order of decision tasks influences weight given to different aspects
Prospect/Ambiguity	Inconsistent probability calculus, asymmetry in gains and losses, aversion to ambiguity
Regression	Attribution of causal structure; failure to anticipate regression to mean
Representative	Frequency neglect in exemplars

# Framing – 600 people at risk

Experiment 1		Experiment 2	
A: 200 people saved		C: 400 people die	
B: 600 saved with prob. $1/3$ 0 saved with prob. $2/3$		D: 0 die with prob. $1/3$ 600 die with prob. $2/3$	

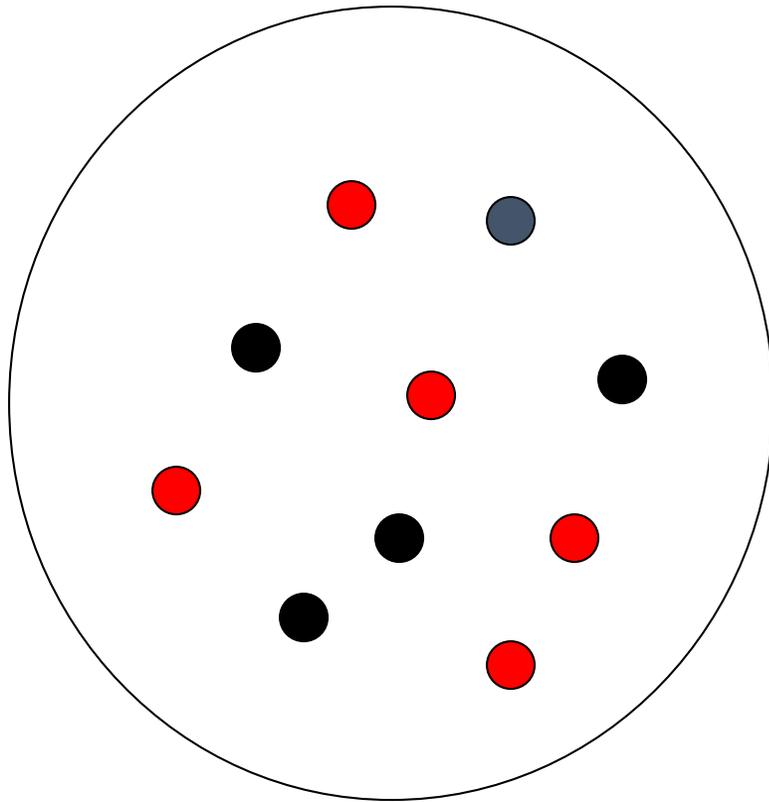
# Framing – 600 people at risk

Experiment 1 N = 152		Experiment 2 N = 155	
A: 200 people saved	72%	C: 400 people die	22%
B: 600 saved with prob. 1/3 0 saved with prob. 2/3	28%	D: 0 die with prob. 1/3 600 die with prob. 2/3	78%

Asymmetry of perceptions for gains and losses, risk-aversion for gains, not for losses

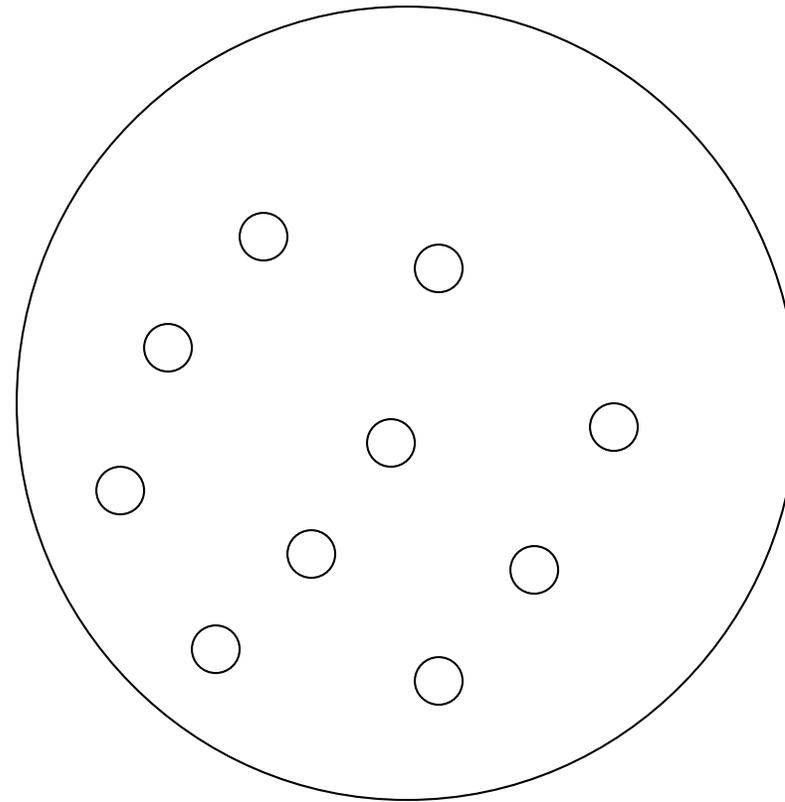
# Ambiguity Aversion – win if draw Red

**BOWL A**



$N = 10, R = 5, B = 5$

**BOWL B**



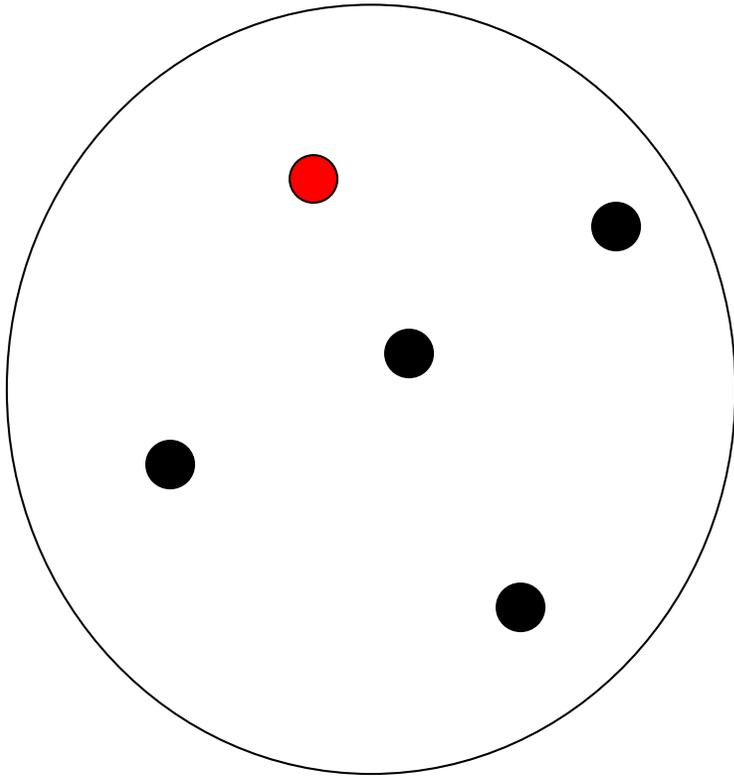
$N = 10, R = ?, B = 10 - R$

# Personal Risk -- Processing

Effect	Description
Awareness/Attention/ Consideration	Recognition of choices, subjective definition of choice set Filtering and Limited attention to alternatives, attributes, risks
Confidence/Optimism	Overconfidence in perceptions and abilities, optimism about ability to control outcomes
Construal/ Constructive	Cognitive task misconstrued, preferences constructed endogenously
Disjunction	Failure to reason through or accept the logical consequences of choices
Engagement	Limited attention to and engagement in the cognitive task
Innumeracy	Limited capacity to "run the numbers"
Suspicion/Superstition	Mistrust offers and question motives, avoid choices that "tempt fate"

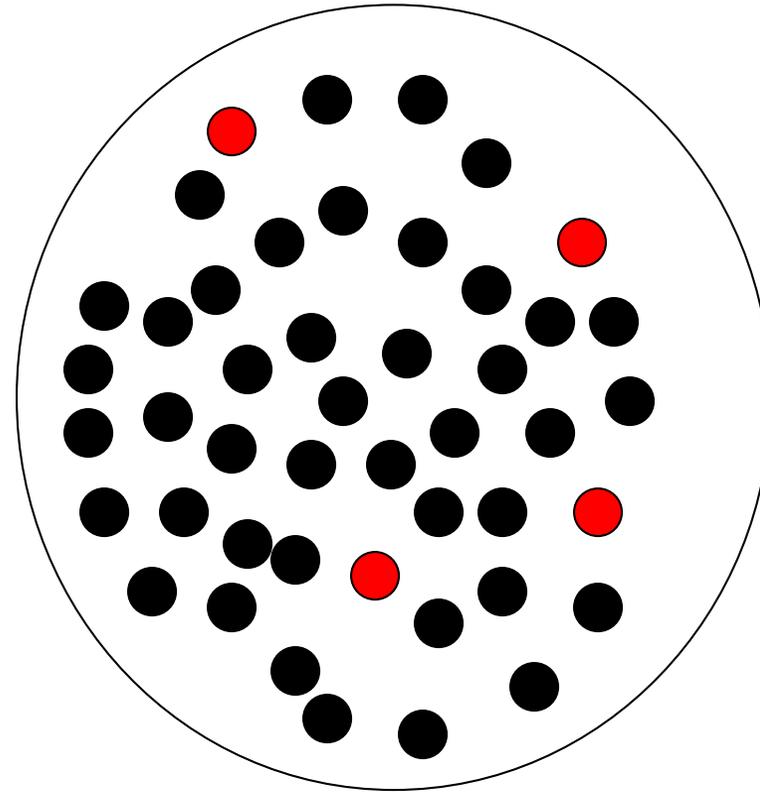
# Innumeracy

**BOWL A – 10%  
probability of winning**



**$N = 5, R = 1, B = 4$**

**BOWL B – 8%  
probability of winning**



**$N = 50, R = 4, B = 41$**

# Social Risk

- *In risk perception, humans act less as individuals and more as social beings who have internalized social pressures and delegated their decision-making processes to [social networks]. They manage as well as they do, without knowing the risks they face, by following social rules on what to ignore ...*

*Mary Douglas and Aaron Wildavsky, 1982*

# Social Networks and Information

- People make interpersonal comparisons, judging the desirability of options from the apparent satisfaction and advice of others
- While personal experience is the proximate determinant of the utility of familiar objects, primary sources of information on novel objects come from others, through observation and advice
- People join and migrate to social networks that match their attitudes and tastes

# Accountability, Approval, Sanctions

- Affiliation with social networks, limiting choice by accountability to network norms, is an efficient decision-making strategy that saves attention, energy
- The bicycle peloton – a model of voluntary choice-limiting, energy-saving affiliation with a “network”



# The Peloton – a voluntary social network

- Competitors in bicycle racing form a voluntary group (social network) that provides a energy-saving, choice-limiting environment
  - The peloton limits choice by accountability to network norms – e.g., take your turn as leader, stay in line, leave effort of planning and strategy to leader
  - When peloton behavior diverges from goals of some individuals, they may break away to form a new peloton
  - The old peloton sanctions breakaways, pursuing and eliminating them when it can
- The peloton exemplifies the operation of voluntary social networks to facilitate and limit choice

# Insights from Neuroeconomics

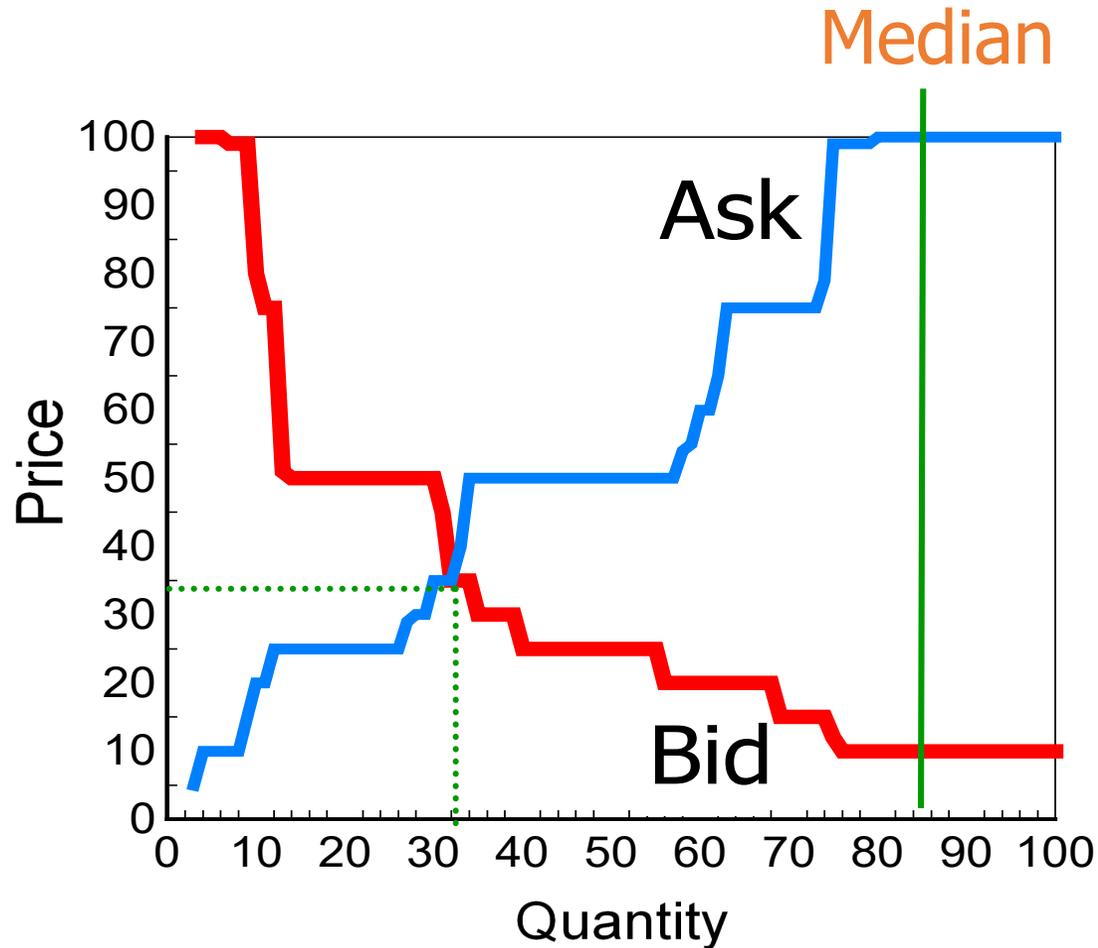
- Trade is a contest, and contests involve emotions, stress, and their own pleasures and pains
- The trust relationships required by trade are primitive brain functions that seem to have an evolutionary foundation – D2 dopamine and oxytocin receptors activated by trade are the same as those that reward social interaction, sharing, and reproduction in humans and other animals
- Humans are on a *hedonic treadmill*, quickly habituating to the status quo, and experiencing pleasure from gains and pain from losses *relative* to their reference point
- Asymmetric loss aversion and hyperbolic discounting correspond to brain structure, processing location, and incomplete coordination

# Trade-Suppressing Status-Quo Effect

- Pencils embossed with the course name were allocated randomly to 172 of 345 students in my introductory micro class in Berkeley
- A market for pencils was then operated using a Vickery sealed-bid uniform price double auction
  - Buyers pay highest losing bid, sellers receive lowest winning bid. The dominant strategy is to bid one's true value even if others do not.
- If students have stable pre-formed tastes for pencils, then about  $86 = 172/2$  of the winners should have values below the class median value, and offer to trade at this value.

# Endowment Effect -- Pencils

Rational: 86.25 trades (Std. Dev. 6.56) at the class median offer of 55 cents



- The market actually cleared with 32 trades at a price of 35 cents.
- The median ask was 100 cents, the median bid was 10 cents.

# **The Decision-Making Process**

## **– Attention, Consideration, Choice**

*“A wealth of information creates a poverty of attention.”*

*Herb Simon, 1971*



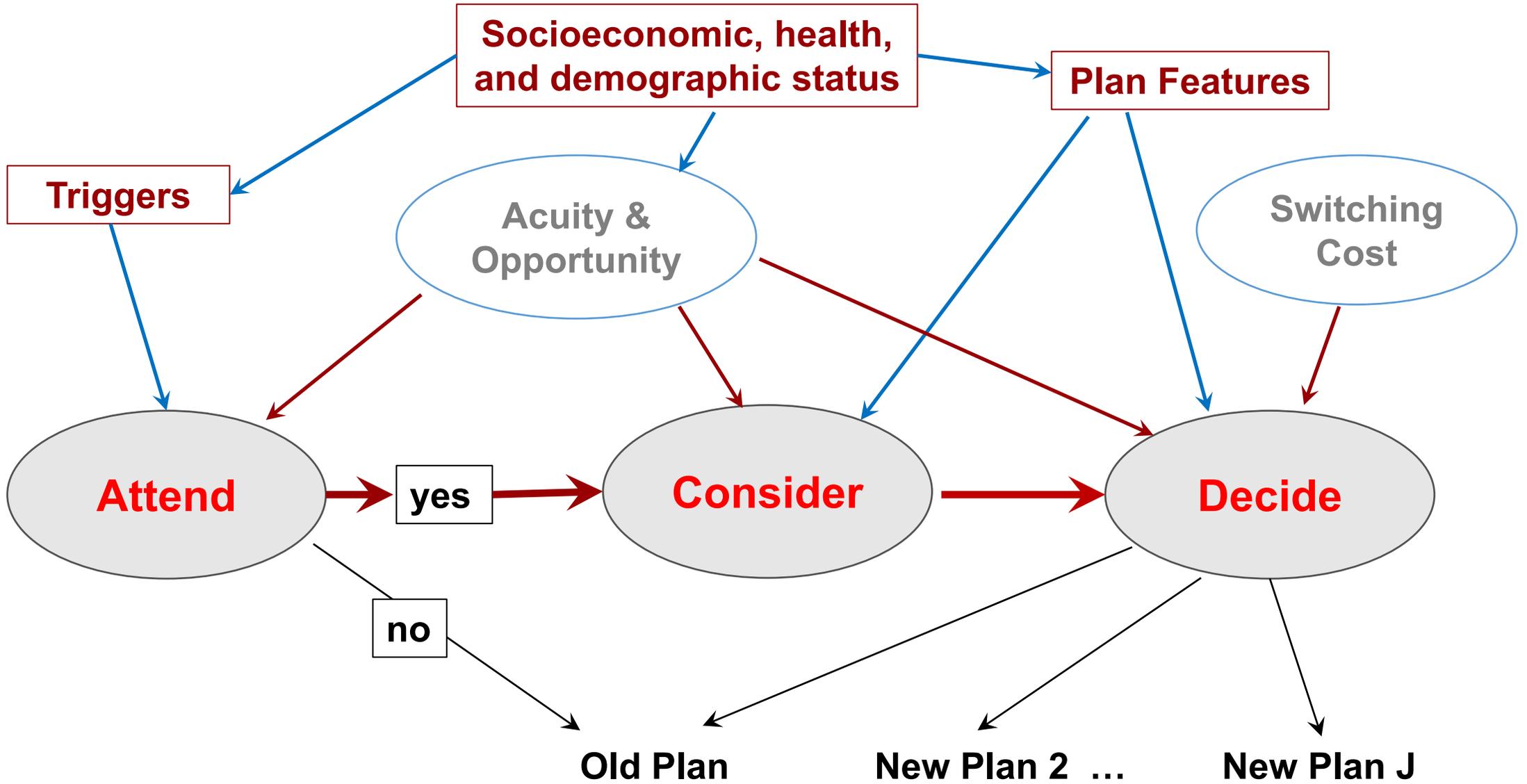
# Attention, Consideration, Choice

- Does the consumer think about having a choice, or simply stumble into a choice through habit or default? **Attention!**
- Does the consumer consider and investigate diligently the attributes of all available alternatives? **OR**, does the consumer use **search with a stopping rule, editing, and filtering** on observed gross attributes to form a **consideration set**, and after this engage in some level of due diligence to acquire information on the attributes of alternatives in the consideration set? **Consideration!**
- Some decision protocol is used to select an alternative from the consideration set (e.g., maximize utility, stop search when an “acceptable” alternative is found, follow the choices of friends)? **Decision!**

# Example: Health Insurance Plan Choice

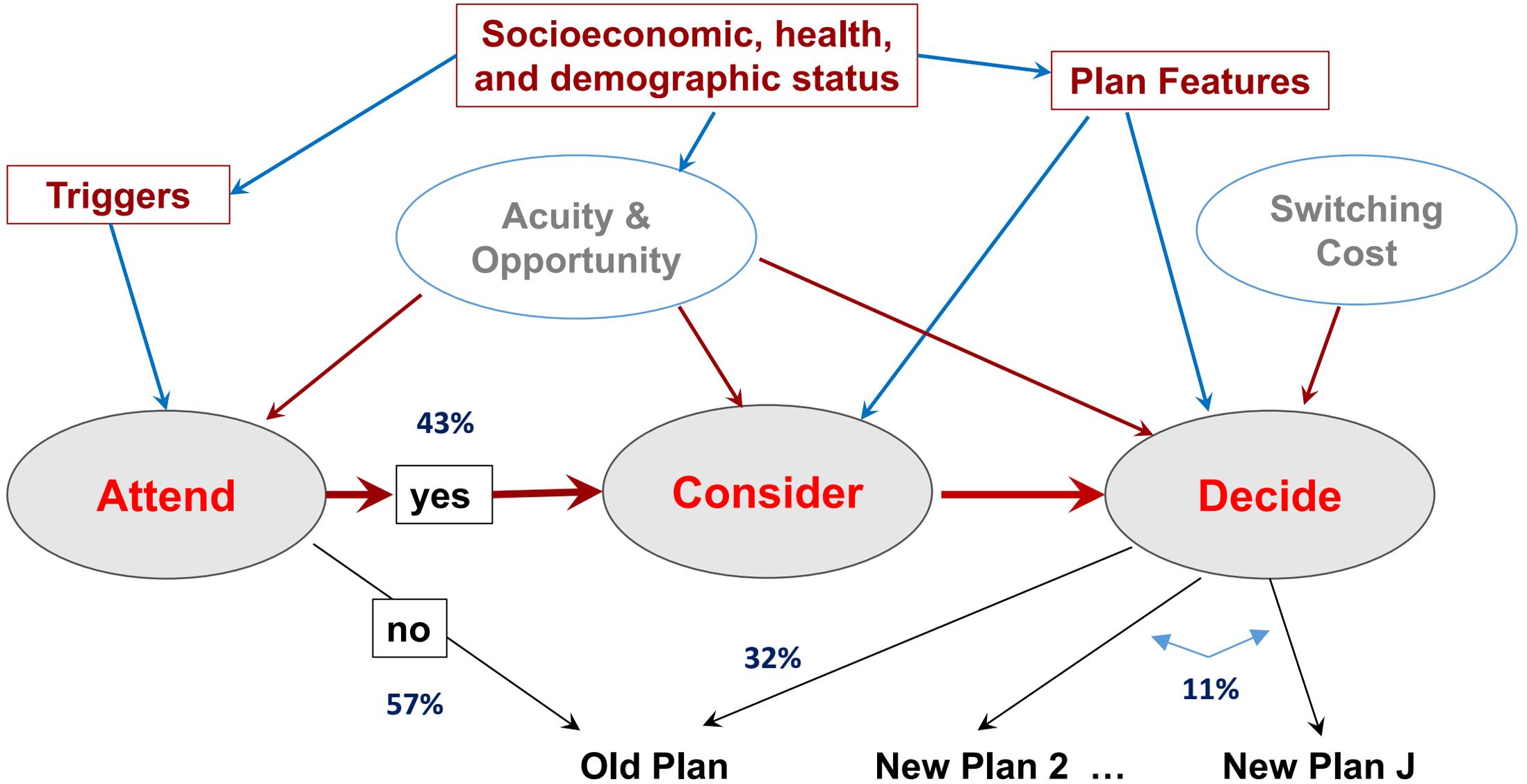
Source: F. Heiss, D. McFadden, J. Winter, A. Wupperman, B. Zhou (2019) “Inattention and switching costs as sources of inertia in Medicare Part D”, USC working paper

- Medicare recipients purchase drug insurance coverage from private firms in an organized exchange. Each year they have to make a choice to continue on their old plan (the default), or switch to a new one.
- Switching rates are low, about 10%, even though most consumers have more than 50 alternative plans available, and plan features, prices, and consumer needs shift substantially over time.
- This behavior is qualitatively similar to that observed for many consumer durables and services (e.g., cell phones)
- For markets to work efficiently, consumers need to be prepared to switch readily to more desirable products
- Policy interventions to promote market efficiency will depend on how inattention, limited consideration, high switching costs, and bad decision protocols contribute to inertia and limit choice



# Identifying the “Attend! Consider! Decide!” Process

- The process of attention, consideration, and decision is a “black box” in which all one observes directly are measured attributes of alternatives, some consumer history, and actual choice.
- Attempts to introduce a consideration set stage in travel choice (e.g., Swait) encounter the problem that an alternative may not be chosen because it was not considered, or was considered but determined to be undesirable.
- However, there are identifying exclusion restrictions that allow policy interventions to focus on the most effective places for behavior modification:
  - Attention is triggered by past shocks, cannot depend on choice set and attribute information unavailable to the inattentive
  - Consideration is a search process that filters based on information at hand, cannot depend on information available only upon further search
  - Decisions can depend only on attributes of alternatives under consideration, not on information filtered out or on past shocks



# Results:

- Of the 89% of people who do not switch plans, 57% do so because they default without paying attention, 32% do not because they consider switching, but don't either because their current plan is best or because it is not inferior enough to offset the switching cost
- Average overspending is about \$360, about 23% of annual average OOP cost of about \$1400 per year
- An unobserved factor, which we call “acuity”, but also reflects opportunity cost, has an important positive effect on both attention and choice efficiency. Acuity rises with (noisily measured) income. Attention rises with acuity, but peaks below the highest income levels, presumably due to opportunity cost. If choice mistakes are attributed to “switching cost”, this is quite high for low acuity levels, and falls sharply with rising acuity.
- Consideration as a separate stage has not yet been studied empirically.

# Summary: Insights from Market Research, Cognitive Psychology, Behavioral Economics, and Neuroscience

- ACUITY is heterogeneous, and affects memory, perceptions, effort, and decision protocols
- ATTENTION is scarce, triggered by events that demand diligence
- EXPERIENCE, CONTEXT, and OPPORTUNITY COST induce FILTERING that limits CONSIDERATION of attributes and alternatives
- People are not natural statisticians, and motivation, attitudes, emotions color perceptions
- Utility is local, situational, myopic, and focused on gains and losses from status quo (hedonic treadmill)
- The DECISION process relies on exemplars and heuristics, and utility maximization is myopic
- SOCIALITY: People look to others for information and approval

# Implications for Transportation?

- Behavioral choice models in transportation applications should consider adopting the “Attend! Consider! Decide” approach to sharpen the focus of policy interventions to improve transportation efficiency and environmental performance.
- The combination of strong endowment effects and strong sociality in transportation decisions suggests further study of how to incentivize peloton leaders to adopt early, and how to encourage social networks that promote desirable travel behavior
- To the extent that deviations from the classical model of individual rationality are systematic, they can be added into RUM choice models and their effect on travel can be successfully predicted

# Transportation Big Data and Learning by Human and Machine Policy-Makers

- Contemporary transportation data, particularly from roadway sensors and GPS tracking, provide vast real-time monitoring of transportation network performance. Can these data be combined with machine learning algorithms to detect and predict travel patterns more successfully than “batch process” behavioral modelling?
- For short-term forecasting, the answer is yes
- For longer-term policy analysis, machines must learn to recognize causal paths and separate them from ecological correlations. Like humans, machines tend to attribute causal structure to correlations and “overfit” their “model” of system outcomes.

# Can Machines Learn Wisdom?

- In health applications, epidemiological datasets from administrative records are combined with Randomized Clinical Trials (RCTs) and biology experiments that isolate causal paths. For example, the training of Deep Blue to do medical diagnosis recognizes that medical reports vary in quality, and RCT's that establish unambiguous causal paths are core elements in the learning experience
- Naïve approaches to machine learning risk repeating the history of O-D data analysis in transportation and epidemiological studies in medicine
- Behavioral travel demand studies, updated to be truly behavioral, should have the same role in transportation machine learning as RCT's do in health systems. To accomplish this, use simulated population behavior generated by behavioral studies as core elements in learning.