# DECISION ANALYSIS SOCIETY

# Decision Analysis Society

## 2022 Advances in Decision Analysis Conference

**informs**

UNIVERSITY of VIRGINIA

DARDEN SCHOOL of BUSINESS

## June 22–24, 2022

University of Virginia Darden School of Business
Sands Family Grounds, Rosslyn, Virginia

## The Decision Analysis Society welcomes You to ADA 2022!

The Advances in Decision Analysis conference is a two-year focal point for our society, it is the place where our members exchange ideas and shape the scientific future of the discipline. This edition is even more significant, as it is the first occasion for our community to get together in person after over two years of distance meeting due to the COVID-19 pandemic. We have a stunning scientific program, with over seventy presentations in regular sessions, a rich poster series, three impressive keynote speakers, and PhD incubators with 18 dedicated talks. We also have a special panel to honor the memory of Professor David Schmeidler.  On behalf of the DAS I would like to express my gratitude to  Yael Grushka-Cockayne and Manel Baucells for all organizational work that has made the event possible and for hosting it in the beautiful location of the Darden Business School Washington DC Campus. Also, a warm thank you goes to the several of our members who have worked at organizing this event in the organizing and scientific committee!

Welcome again and enjoy ADA 2022!

Emanuele Borgonovo

President, Decision Analysis Society, INFORMS

## Special Thanks To:

### The Organizing and Steering Committee

*Yael Grushka-Cockayne (UVa Darden), Manel Baucells (UVa Darden, Michael Albert (UVa Darden), Aurelien Baillon (Erasmus School of Economics), Emanuele Borgonovo (Bocconi), Robin Dillon-Merrill (Georgetown University), Rupert Freeman (UVa Darden), Xiaojia Guo (Maryland Smith School of Business), Ying He (University of Southern Denmark), Karen Jenni (USGS), Victor Jose (Georgetown University, McDonough School of Business), Jason Merrick (VCU), Kara Morgan (Center for Foodborne Illness Research and Prevention), Asa Palley (Indiana University, Kelley School of Business), Eva Regnier (Naval Postgraduate School), Allison Reilly (University of Maryland), Jay Simon (American University, Kogod School of Business), Canan Ulu (Georgetown University, McDonough School of Business), Jun Zhuang (University at Buffalo), Sasa Zorc (UVa Darden)*

### And Our Sponsors:

# Conference Schedule

## Wednesday, June 22nd

| Time | Room | Event |
|---|---|---|
| 8:00AM–8:45AM | Foyer | Registration |
| 8:45AM–9:00AM | Capital Classroom | Welcome speech by DAS President Professor Emanuele Borgonovo |
| 9:00AM–10:30AM | See Session Catalog | Parallel Sessions – Wednesday 1 |
| 10:30AM–10:45AM | Foyer | Break |
| 10:45AM–12:15PM | See Session Catalog | Parallel Sessions – Wednesday 2 |
| 12:15PM–1:30PM | Foyer | Lunch |
| 1:30PM–3:00PM | See Session Catalog | Ph.D. Incubator |
| 3:00PM–3:30PM | Foyer | Break |
| 3:30PM–4:30PM | Capital Classroom | Keynote 1 – Lauren Meyers |
| 4:30PM–4:45PM | Foyer | Break |
| 4:45PM–6:15PM | See Session Catalog | Parallel Sessions – Wednesday 3 |

## Thursday, June 23rd

| Time | Room | Event |
|---|---|---|
| 9:00AM–10:00AM | Capital Classroom | Panel in memory of David Schmeidler chaired by Emanuele Borgonovo |
| 10:00AM–10:30AM | Foyer | Break |
| 10:30AM–12:00PM | See Session Catalog | Parallel Sessions – Thursday 1 |
| 12:00PM–1:30PM | Foyer | Lunch |
| 1:30PM–2:30PM | Capital Classroom | Keynote 2 – Alex Imas |
| 2:30PM–3:00PM | Foyer | Break |
| 3:00PM–4:30PM | Capital Classroom | Ph.D. Incubator Blitz Session |
|  | Arlington Classroom | Parallel Sessions – Thursday 2 |
| 4:30PM–6:00PM | 30th Floor Foyer | Reception and posters |
|  | National Landing | Office hours with NSF |

## Friday, June 24th

| Time | Room | Event |
|---|---|---|
| 8:30AM–10:00AM | See Session Catalog | Parallel Sessions – Friday 1 |
| 10:00AM–10:15AM | Foyer | Break |
| 10:15AM–11:45AM | See Session Catalog | Parallel Sessions – Friday 2 |
| 11:45AM–12:00PM | Foyer | Break |
| 12:00PM–1:00PM | Capital Classroom | Keynote 3 – Ariel Procaccia |
| 1:00PM–1:30PM | Foyer | Grab-and-Go Lunch |

# Session Catalog

## Wednesday, 8:45AM–9:00AM

### Welcome Speech by DAS President Professor Emanuele Borgonovo
Capital Classroom

## Wednesday, 9:00AM–10:30AM

### Artificial Intelligence and Decision Making
National Landing

**Artificial Intelligence on Call: The Physician's Decision of Whether to Use AI in Clinical Practice**
*Tinglong Dai, Shubhranshu Singh*

Physicians are increasingly able to use artificial intelligence (AI) systems to aid their medical decision-making. This paper examines a physician's decision regarding whether to use an assistive AI system when prescribing a treatment plan for a patient. Using AI helps the physician generate an informative signal that lessens clinical uncertainty. It can also change the physician's legal liability in the event of patient harm. We analyze two patient-protection schemes that determine physician liability when using AI: the prevailing patient-protection scheme uses the AI signal to enforce the current standard of care, whereas an emerging scheme proposes using the AI signal as the new standard of care. We show that in both schemes, the physician has an incentive to use AI in low-uncertainty scenarios, even if AI provides little value. Furthermore, the physician may avoid using AI in higher-uncertainty scenarios where AI could have aided in better decision-making. As AI becomes more precise, the physician may become more hesitant to use it on certain patients. A comparison of the two schemes reveals that using the AI signal as the new standard of care may mitigate AI underuse (overuse) for certain patients but may boost AI underuse (overuse) for some other patients.

**Autonomous Decision Systems: New Technologies & Old Biases**
*Robin Dillon-Merrill, Peter Madsen, Kostas Triantis*

We explore the tradeoff decisions regarding the use (or not) of autonomous decision-making systems (ADS). An ADS, in practice, often substitutes for a human decision maker such as in the case of an autonomous vehicle, or assists humans in complex tasks that are difficult to fully automate. ADS technology is increasingly playing a critical role in many organizational processes especially for safety-critical systems, such as controlling vehicles in transportation systems. We analyze data from traffic control centers for INFRABEL, the Belgian National Railroad Company. At INFRABEL, operational service delivery decisions are made in real-time by human decision-makers, Traffic Controllers (TCs), each of whom are paired with a collaborative ADS. The TC may decide to switch off the ADS for a certain train or sections of the railroad network and make decisions manually. The research explores which system factors are meaningful predictors of the use of the ADS by a TC in the control center versus the TC making manual decisions.

**Should Advisors Signal Access to Algorithms?**
*Alessandra Cillo, Canan Ulu, Emanuele Borgonovo, Alessandro Ortis, Sebastiano Battiato*

We investigate how individuals react to advice coming from advisors who have access to algorithms. For example, if a brand manager for a new product specifies the demand model they are using, will it make it more likely that management will utilize their forecasts in decision making? We run two studies to understand advice utilization where we ask participants to forecast standardized test scores for high school students and number of views various images receive on a photo sharing website. Participants get advice from one of three sources: directly from the algorithm, from advisors who have access to an algorithm or from advisors who do not. Our results suggest that advice utilization is significantly lower if advice comes from advisors who do not have access to an algorithm.

**The Future of Strategic Decision-Making: What Will Human-Machine Collaboration Look Like on a Strategic Level?**
*Nina Hesel, Fabian Buder*

With growing capabilities of smart machines through advances in machine learning and natural language processing, the boundaries of artificial intelligence (AI) in decision-making shift from the operational to the strategic level in many management areas. Given the high potential of AI in marketing, this study focuses on

market-oriented strategic decisions. Previous studies indicate that managers accept to give algorithms some weight in managerial decisions, but they still want to keep a certain level of control. However, the question of how collaboration between humans and machines in strategic decision-making could look in concrete terms remains largely unanswered. Addressing this research gap, the presented study examines managers' acceptance and future preferences regarding the weight and role of AI in strategic decisions. Therefore, a model is presented to evaluate the role of AI in human-machine collaboration based on its tasks and level of autonomy. The study examines differences between specific tasks within decision-making processes and between concrete types of decisions. Results of the standardized survey study are based on a sample of 500 high-level marketing and corporate strategy executives in a B2C market context, drawn from companies on the Global Forbes 2000 list. (Study currently in field phase, results by begin of may)

## Communicating Uncertainty
Capital Classroom

### Even Experts Misunderstand Uncertainty in Scientific Results: Evidence of the Problem and an Effective Intervention
*Daniel Goldstein*

Drawing on experimental responses from medical professionals, professional data scientists, and tenure-track academic faculty, we show that the prevalent form of visualizing only inferential uncertainty can lead to significant overestimates of treatment effects, even among highly trained and knowledgeable experts. In contrast, we find that an alternative format that depicts both inferential uncertainty (by showing statistical estimates) and outcome variability (by also showing individual data points) leads to more accurate perceptions of results.

### Improving the Use of Hydrologic Probabilistic and Deterministic Information in Decision-Making
*Rachel Hogan Carr, Kathryn Semmens, Burrell Montz, Keri Maxfield*

Carr is Executive Director of Nurture Nature Center, a nonprofit organization whose research team has spent the past ten years studying how professional and lay users of probabilistic hydrologic forecasts interpret, understand and use uncertainty information. The team has used these findings to inform revised National Weather Service forecast products. Carr will share findings about how users incorporate weather-related uncertainty information into decision-making, and

lessons learned about approaches in product design that have shown to increase and decrease the utility of uncertainty data.

### Decision Analysis in Professional Golf
*Scott Fawcett*

Fawcett is a former professional golfer who has introduced a decision-analytic approach to playing golf that is quickly gaining adherents at the highest levels of the sport. At the core of Fawcett's approach is accepting variance as an unavoidable feature and adapting accordingly.

### Exploiting Uncertainty in the NFL Draft
*Jason Merrick, Zach Drapkin, Yael Grushka-Cockayne, Cade Massey*

National Football League teams spend approximately $200m each year in player costs. One of the challenges in allocating that money is selecting players in the annual college draft. When making these selections teams utilize scout assessments of players' future performance. Using historical data from one NFL team over 12 years, we evaluate 64,139 forecasts from 90 scouts regarding 13,467 players. We use historical outcomes for mapping the categorical scout assessments into complete distributions. These distributions allow combining scout grade assessments while accounting for a prospect's uncertainty. The combined distribution of expected performance enables the comparison within and across players, as well as over time.

We find that individual scouts are well-calibrated, are highly correlated with each other, and that their predictive performance cannot be reliably differentiated. We show that an equally weighted opinion pool performs better than one using performance-based weights. Using this aggregation, we can rank candidate players by comparing their means and specific quantile values. We can also compare the mechanical aggregator to the team's actual aggregation.

The proposed mechanisms extend naturally to numerous settings in which selection is based on categorical, subjective assessment of future performance, e.g. hiring, investment committees.

## Uncertainty and Learning
Arlington Classroom

### Adversarial Forecasting: An Adversarial Risk Analysis Approach
*Tahir Ekin, William Nick Caballero, Roi Naveiro, David Rios Insua*

Forecasting methods typically assume clean and

legitimate data streams. However, adversaries may attempt to influence data and alter forecasts, which in turn may impact decisions. This paper presents an adversarial risk analysis based framework that allows incomplete information and adversarial perturbations on the forecasting output. We solve the adversary's decision problem where he manipulates batch data being fed into a hidden Markov model. This research highlights the weaknesses of forecasting models under adversarial activity. It motivates the need to improve the security of existing decision frameworks.

### The Dynamics of Misspecification Fear
*Giacomo Lanzani*

We consider a Decision Maker (henceforth DM) that posits a set of structural models describing the possible probability distributions over payoff relevant states. The DM has a probabilistic belief over this set, but they still fear that the true model is not in the support, and use a generalization of the multiplier preferences introduced by Hansen and Sargent (2001) to account for this concern. The agent uses Bayesian updating to adjust their belief about the models in light of the observed evidence. At the same time, the concern for misspecification is let to depend on the observed data. If there is a model that explains well the previous observations, the DM attenuates their concern for misspecification. We show how several (single-agent) versions of equilibrium concepts arise as the limit behavior, depending on the preferences of the DM and on whether the correct model is in the support.

### Economic Behavior of Information Acquisition: Impact on Peer Grading in Massive Open Online Courses
*Onesun Steve Yoo, Dongyuan Zhan*

A critical issue in operating massive open online courses (MOOCs) is the scalability of providing feedback. Because it is infeasible for instructors to grade a large number of students' assignments, MOOCs use peer grading systems. We investigate the efficacy of that practice when student graders are rational economic agents. We characterize grading as a process of (a) acquiring information about assignment quality and (b) reporting a score. This process entails a tradeoff between the cost of acquiring information and the benefits of accurate grading. Because the true quality is unobservable, any measure of grading accuracy must reference the actions of other graders, which motivate student graders to behave strategically. We present the unique equilibrium information level and reporting strategy of a homogeneous group of student graders and examine the outcome of peer grading. We show how both the peer grading structure and the nature of

MOOC courses affect peer grading accuracy, and identify conditions under which the process fails. There is a systematic grading bias toward the mean that discourages students from learning. To improve current practice, we introduce a scale-shift grading that improves grading accuracy and adjust grading bias, and discuss how it can be implemented.

### Weighing Sample Evidence
*Karol Szwagrzak*

We study how an agent uses sample data to evaluate the optimality of her alternative actions. For each action, she observes a sample of outcomes, not the distribution from where the sample was drawn. We characterize preferences over actions determined by the average utility of the outcomes in their samples and the size of the samples, controlling for action characteristics. Actions with large enough samples are primarily evaluated using their average utility. Moreover, fixing an average utility level, increasing sample size enhances the evaluation of an action if and only if this level is above an endogenously determined threshold. The characterization describes an agent that may learn imperfectly and enables decision-theoretic definitions of important concepts in the descriptive study of probabilistic judgement.

# Wednesday, 10:45AM–12:15PM

## Auction, Bargaining, and Mechanism Design
National Landing

### The Agent-Selection Dilemma in Distributive Bargaining
*Daniel Feiler, David Hagmann*

Principals often bargain through agents, and past evidence suggests that such bargaining too often ends in costly impasse. We present experimental evidence that the agent-selection process which precedes bargaining can be a significant driver of failures to reach agreement. We find that principals select overly aggressive agents, such that those sent to the bargaining table are more polarized in their views than are potential agents in general (Study 1), as well as the principals whom they represent (Study 2). Agent-selection makes parties worse off than if they were assigned an agent at random and, conditional on engaging in agent-selection, both parties could improve their respective outcome by selecting a less aggressive agent. However, in an extension with repeated selection and information asymmetry, these less-aggressive agents fail to persist in the market and only overly aggressive agents remain (Study 3).

### The "Bad Faith" Fallacy in Intergroup Conflict: Predicted Naive Realism Is Greater than Actual
*Nadav Klein*

Although intergroup conflict is characterized by real differences in ideology and policy preferences, existing research increasingly makes clear that people exaggerate the magnitude of conflict between themselves and adversaries. The present experiments provide evidence for a pervasive psychological process that underlies exaggerated perceptions of conflict, namely that people incorrectly believe that adversaries will fail to evaluate their viewpoints fair-mindedly. Three experiments find that people exaggerate the degree to which adversaries exhibit naive realism—the phenomenon of seeing pro-attitudinal viewpoints as objective and dismissing opposing views as subjective and distorted. Three additional experiments identify faulty affective forecasting of specific emotions as a mechanism—people overestimate the extent to which adversaries feel angry when observing counter-attitudinal information and feel vindicated when observing pro-attitudinal information. Conflict resolution depends not only on mitigating biases in judging adversaries' viewpoints but also in correcting cynical expectations of how adversaries would treat one's own viewpoints.

### Minimum Revenue Socially Efficient Mechanisms Under Correlated Valuations
*Michael Albert*

In many situations of interest there is a shared resource that needs to be distributed fairly to agents that have private information about their value of that resource. Traditionally, this is distributed using an auction based mechanism requiring payments. In some situations (such as in federated server farms), there is no natural party to receive payments, and therefore, these mechanisms cannot be implemented leading to a loss in social welfare. In this work, we demonstrate how to take advantage of correlation in bidder behavior in a repeated setting to learn mechanisms with zero expected payments for all participants by learning the optimal, minimum revenue mechanism.

### Order Symmetry: A New Fairness Criterion for Assignment Mechanisms
*Rupert Freeman, Geoffrey Pritchard, Mark C. Wilson*

We introduce a new fairness criterion, order symmetry, for assignment mechanisms that match n objects to n agents with ordinal preferences over the objects. An assignment mechanism is order symmetric with respect to some probability measure over preference profiles if every agent is equally likely to receive their favorite object, every agent is equally likely to receive their second favorite, and so on. When associated with a sufficiently symmetric probability measure, order symmetry is a relaxation of anonymity that, crucially, can be satisfied by discrete assignment mechanisms. Furthermore, it can be achieved without sacrificing other desirable axiomatic properties satisfied by existing mechanisms. In particular, we show that it can be achieved in conjunction with strategyproofness and ex post efficiency via the Top Trading Cycles mechanism (but not Serial Dictatorship). We additionally design a novel mechanism that is both order symmetric and ordinally efficient. The practical utility of order symmetry is substantiated by simulations on Impartial Culture and Mallows—distributed preferences for four common assignment mechanisms.

## Behavioral Decision Making (1)
### Capital Classroom

### Algorithms and Adaptive Risk Attitudes
*Prana Narayanan, Jeeva Somasundaram, Matthias Seifert*

We examine how risk-taking behavior in resource allocation problems changes when decision-makers (DMs) are temporarily exposed to algorithmic aids that are programmed with predetermined levels of risk aversion. We predict that DMs systematically anchor and adapt their risk preferences based on the type of algorithmic advice they observe. We further predict that the modified risk attitudes stick even after the algorithmic aid is removed and test our predictions across two randomized experiments involving a project portfolio management task (study 1) and a news-vendor task (study 2). Across both studies (N = 381), consistent with our predictions, we find that subjects who receive highly risk averse algorithmic recommendations (HRA condition) act more risk averse compared to those who receive slightly risk averse, risk neutral or no algorithmic recommendations (control condition). Strikingly, even after the algorithm is removed, subjects in the HRA condition continue to display higher levels of risk aversion compared to those in the control condition. Our findings demonstrate the mutability of human risk preferences when exposed to algorithmic aids.

### Decision Making under Impending Regime Shifts
*Sreyaa Guha, Matthias Seifert, Canan Ulu*

We study pricing decisions in dynamic environments when there is an impending regime shift. Risk attitudes as well as probability judgments regarding the occurrence of a regime shift affect such decision behavior. We develop a model that integrates prospect theory with the system neglect hypothesis and compare changes

in empirical pricing decisions to those of a Bayesian risk-neutral agent. If the decision maker's (DM) prior probability of regime shift is low, our model predicts relatively more underreaction in pricing decisions in unstable environments with precise signals and relatively more overreaction in stable environments with noisy signals. If the DM's prior probability of regime shift is high, we find do not find a significant difference between such environments. We argue that in the case of low priors, changes in risk attitude in reaction to signals indicative of regime shift amplify system neglect in probability judgments. In the case of high priors on the other hand, changes in risk attitude dampen the effect of system neglect, resulting in no significant difference between the two environments. We test our model predictions in experimental insurance markets and offer various extensions to examine the robustness of our findings.

### Does Discourse Breed an Appetite for COVID-19 Vaccination? An Experiment on Group Dynamics, Arguments and Narratives
*Huyen Nguyen, Grischa Perino, Lydia Mechtenberg, Juliane Koch*

Do discussions with vaccine supporters change the willingness to get vaccinated (WGV) of vaccine skeptics, and vice versa? How effective are narrative- vs. fact-based arguments in shifting opinions across social groups? This research presents causal evidence on the role of peer-to-peer communication on the WGV against Covid-19, in a two-wave randomized control trial of 3858 unvaccinated individuals in Germany. Using a 3x2 factorial between-subjects design, we elicit from participants their WGV, how their arguments for and against Covid-19 vaccination are influenced by text primed treatments, and whether or not these factors change after chat deliberation with others holding different WGV. We found that the narrative priming treatment induced an increase in vaccination behavior, relative to the initially stated WGV. More vaccine supporters in the group also increase the propensity of vaccine skeptics to get vaccinated. In the chat, vaccine skeptics chat more actively and use a more moderate tone in chats compared to their survey answers. Our research has external relevance for public good provision situations, where persuasion tactics and coordinated actions of individuals across social network channels matter.

### Future Incentives to Reduce Mobile Usage
*Jeeva Somasundaram, Laura Zimmermann, Pham Quang Duc*

Most people would like to reduce their smartphone usage but fail to do so due to addictive nature of many smartphone applications. Building on the theory of rational addiction, we conducted two preregistered randomized control trials that aim to reduce subject's smartphone usage by providing temporary monetary incentives and targets over a period of time. When future targets and incentives to reduce mobile usage are pre-announced, subjects conduct themselves in a forward-looking manner and reduce their mobile usage even before they are actually incentivized to do so. Subjects continue to maintain a lower usage during the incentive period and sustain that lower usage even after the incentives are removed. Our manuscript uses the theoretical framework of rational addiction to show that pre-announcing future targets and incentives could be a cost-effective intervention to kick start behavioral change.

## Practical Application of Decision Analysis (1)
### Arlington Classroom

### Arriving at Reasonable Thresholds for Risk Acceptability
*Julie Downs*

A systematic approach to incorporating risk into decisions requires explicit identification of what threshold of risk is acceptable. However, when asked to identify how much risk one would be willing to accept, a natural response is to put that threshold at floor. This zero-tolerance approach to risk pervades human judgments ranging from intuitive responses of individuals up to policy makers setting guidelines for large-scale programs. For example, sexual risk prevention programs commonly require evaluators to measure success based on reports of perfect condom use across all sexual encounters, despite the enormous risk reduction offered by a much more achievable relative increase in condom usage. Similarly, people disproportionately dismiss the relative risk reduction offered by imperfect vaccines, not seeing the benefit of a shot that will not eliminate the risk of disease. In this talk I will explore people's natural tendency toward a demand for zero risk in a variety of domains and discuss approaches to promoting appreciation of relative risk reduction in psychological judgments and policy decisions.

### Challenges of Stakeholder Engagement in Risk-Based Decision Making
*Douglas Bessette*

Morgan et. al. (2021) argues that effective risk-based decision making (RBDM) requires an active role for stakeholders, namely that they contribute to problem definition, aid in data collection to estimate the likelihood and severity of harm, or that their risk appetite be included in the RBDM process. Regulatory and resource constraints

often restrict the extent to which decision-makers can invest in such stakeholder engagement processes, however. And additional challenges exist, including difficulty in identifying which stakeholders—and how many—to engage, expanding problem definition to include social and cultural risk and objectives that are often intangible or immeasurable (at least monetarily or materially); ensuring stakeholders adequately represent and understand uncertainty in technical and value judgements; and acknowledging and overcoming stakeholders' cognitive biases. This talk will provide examples of how these challenges complicate RBDM as well as suggest methods to overcome them, many informed by the tenets of structured decision-making.

### Risk-based Decision Making: A Framework
*Kara Morgan*

Risk-based decision making (RBDM) is an aspirational goal in many fields, including health, engineering, environmental science, and food safety. The use of RBDM is gaining wide acceptance and implies a level of rigor that many decisionmakers are interested in adopting. This scoping review was conducted to develop a definition to serve as a standard and guide to ensure that using RBDM has the intended impact. The findings from this review are aligned with fundamental principles of decision analysis. Specifically, an important early step in decision analysis is defining the decision criteria that will be used to make the decision. In these findings, the most foundational definition of risk-based decision making is one that includes risk (likelihood and severity of harm) as one of the decision criteria. In addition, a risk-based decision-making approach ensures that this risk estimate is aligned with the needs of the decision maker, another core tenant of good decision analysis work. Finally, the definition includes explicit expressions of uncertainty in the estimates, which is also a key component of decision analysis work. The potential impact of this work will be discussed relative to work to develop a risk-based food safety system for low- and middle-income countries.

### Science to Support Risk-Based Prioritization
*Karen Jenni*

Morgan et. al. (2021) identify priority-setting as a significant theme in risk-based decision-making, where the fundamental decision is about resource allocation and the basis for that allocation must include consideration and comparison of risks. The U.S. Geological Survey has developed and continues to provide a variety of scientific analyses and decision-support processes to facilitate risk-based prioritization. This talk will provide examples of several of those products, with a focus on where risk assessment meets with decision-making needs in a prioritization context. Examples may include the Strategic

Hazard Identification and Risk Assessment (SHIRA) project, designed to allow DOI agencies identify and compare risks at specific facilities and across their portfolio; the use of science—and community-developed Earthquake scenarios designed to support both prioritization of both mitigation and response actions by local communities; and the risk-based approach used to identify and rank critical minerals for the U.S. Both successes of these various approaches, and the challenges of working at the boundary between risk science and decision making at a Federal science agency will be discussed.

# Wednesday, 1:30PM–3:00PM (PhD Incubator)

## Expert Judgment, Chair: Jay Simon
Capital Classroom

### Evaluating Forecasting Skill in Real Time Using Proxy Scores
*Author: Mark Himmelstein, David Budescu, Emily Ho*
*Discussant: Ilia Tsetlin*

A major challenge in evaluating the skill of individual forecasters is the lack of evaluation criterion prior to the resolution of any of the forecasted events. A single forecast's accuracy cannot be known until the events forecasted resolve, so forecaster's mean accuracy cannot be calculated until many events resolve. Recent work has proposed using aggregate crowdsourced judgments as a proxy criterion for the expected accuracy of forecasters. Given a sufficiently large participant pool, this allows forecasters to be evaluated in real time, prior to any event resolutions. We explore the efficacy of a new proxy metric called Expected Brier Scores (EBS) for evaluation forecasting skill in a longitudinal study in which a sample of 175 forecasters repeatedly forecasted 11 questions at fixed time points. We found that forecasters' mean EBS, which can be calculated in real time, were highly correlated with their actual mean Brier Scores (BS), calculated after all the events resolved. We also found that EBS on one sample of questions predicted BS on a separate sample nearly as well as knowing the true BS would have, and we show how one can use EBS to identify single forecasters nearly as accurate as aggregating large crowds.

### Identify Experts to Improve Wisdom of Crowds: The Revealed Expertise Algorithm
*Author: Yunhao (Jerry) Zhang*
*Discussant: Jack Soll*

Identifying the experts within a crowd may help further improve the wisdom of crowds. A new Revealed

Expertise (RE) algorithm is proposed, which uses a scaled amount of belief-updating given numerical advice (e.g., the group mean) as a measure of prior uncertainty, to better reflect the relative expertise of each agent. Empirical studies show that (1) RE is able to improve upon the existing wisdom of crowd methods by overweighting the more accurate answers in the aggregation; (2) less informed laypersons might report a narrower confidence interval than the more informed experts, yet RE is able to correctly identify the experts even so, because RE reflects the amount of information one has or has not initially taken into account. A Bayesian updating model is proposed to characterize the properties of RE and justify the algorithm's parameterization. In addition, we propose a method, in which we use subjects' departure from a (known) Bayesian benchmark, to adjust subjects' RE in the main tasks and show that the adjusted-RE further improves the algorithm's prediction accuracy.

### The Influence of Competitors on Decision-Making: Uncertainty and the Composition of Reference Groups
*Author: Eunsung Yoon*
*Discussant: John Butler*

There have been conflicting findings about whether the uncertainty increases or the social influence on decision making among competitors. Not much is known about how organizations compose reference groups depending on the level of uncertainty. This study recasts three organization theories (neo-institutionalism, network theory, and organizational ecology) to tests their premises about the choice of reference groups. This research explores the following three research questions: First, how does the composition of reference groups vary by the level of market uncertainty? Second, does the composition and influence of reference groups differ by urban neighborhood context? Third, how much impact do neighboring competitors have on price changes in the short term versus the long term? The daily gasoline price data of all gas stations in the 10 largest U.S. cities during 2019–2020 will be analyzed. The chain effect of price fluctuations will be examined to identify which neighboring actors function as the reference group for price decisions, and to what degree. Deep neural network algorithms and time series model will be used to identify reference groups based on price behavior, as well as to estimate the magnitude of the reference groups' influence on pricing decisions.

## Preferences and Decisions, Chair: Sasa Zorc
Arlington Classroom

### Additive Utility Representation under Idempotent Attention
*Author: Dayang Li*
*Discussant: Manel Baucells*

Additive utility representations indicate that the utility of a menu equals the sum of utilities of all alternatives in it, which implicitly assume that a decision maker (DM) has full attention. However, much theoretical and empirical research has argued that the DM sometimes lacks full attention. In this paper, we assume that the utility function is nonnegative-valued and mainly investigate two cases of additive utility representations under limited attention: (i) additive utility representation under idempotent attention, (ii) additive utility representation under attention filter. Given the DM's preference over the collection of menus, we provide two systems of axioms to characterize additive utility representations under idempotent attention and attention filter, respectively. Further, we provide a method of inferring whether the DM pays attention to all the alternatives in a given menu.

### Intuitive, Not Analytical Thinking, Predicts Decision Satisfaction in Real-World Choices
*Authors: Claire Gregory, Adrian Banks*
*Discussant: Aurelien Baillon*

This study investigated the relationship between the two types of decision making in dual-process models (System 1 and System 2) and post-choice satisfaction, in order to find out which of the two systems is optimal for making a real-world choice. Use of System 1 / System 2 thinking was induced using time pressure, with the System 1 group having 10 seconds to make a decision while the System 2 group had a full minute. Participants chose between two smartphone apps, then used their chosen app for a week—reporting satisfaction both immediately and 7 days after making their choice. Results showed that participants experienced significantly higher immediate post-choice satisfaction when they made their decision quickly rather than slowly. There was no difference after a week of using the app, with both System 1 and System 2 groups experiencing a decrease in satisfaction over time. Overall, intuitive, not analytical thinking, predicted immediate decision satisfaction.

### Loss Functions for Discrete Contextual Pricing with Observational Data
*Authors: Ruijiang Gao, Max Biggs, Wei Sun*
*Discussant: Spyros Zoumpoulis*

To train a contextual pricing algorithm, often the

historical pricing data is influenced by the historical sales policy which introduces difficulties in a) estimating future loss/regret for pricing policies without the possibility of conducting real experiments and b) optimizing new policies for downstream tasks such as revenue management. We study how to formulate loss functions which can be used for optimizing pricing policies directly, rather than going through an intermediate demand estimation stage, which can be biased in practice due to model misspecification, regularization or poor calibration. We adapt ideas from machine learning with corrupted labels, where we can consider each observed customer's purchase decision, as a (known) probabilistic transformation of the customer's valuation. From this transformation we derive a class of suitable unbiased loss functions and identify minimum variance estimators, and provide guidance on when the estimated demand function is useful. Furthermore, we also show that when applied to our contextual pricing setting, estimators popular in the off-policy evaluation literature fall within this class of loss functions, and also offer managerial insights on when each estimator is likely to perform well in practice.

## Wisdom of Crowds, Chair: Jun Zhuang

National Landing

### Extracting the Collective Wisdom in Probabilistic Judgments

*Author: Cem Peker*
*Discussant: Yael Grushka-Cockayne*

How should we combine disagreeing expert judgments on the likelihood of an event? A common solution is simple averaging, which allows independent individual errors to cancel out. However, judgments can be correlated due to an overlap in their information, resulting in a miscalibration in the simple average. Optimal weights for weighted averaging are typically unknown and require past data to estimate reliably. This paper proposes an algorithm to aggregate probabilistic judgments under shared information. Experts are asked to report a prediction and a meta-prediction. The latter is an estimate of the average of other individuals' predictions. In a Bayesian setup, I show that if average prediction is a consistent estimator, the percentage of predictions and meta-predictions that overshoot the average prediction should be the same. An "overshoot surprise" occurs when the two measures differ. The Surprising Overshoot (SO) algorithm uses the information revealed in an overshoot surprise to correct for miscalibration in the average prediction. Experimental evidence suggests that the algorithm performs well in moderate to large samples and in difficult aggregation

problems where there is a strong disagreement between experts.

### How Do Cognitive Processes Regulate the Wisdom and Madness of Crowds?

*Authors: Erik Kommol, Christopher Lettl*
*Discussant: Pavel Atanasov*

Understanding the conditions under which human collectives act wise or mad has been a central focus of behavioral research. While there is a common understanding that overreliance on social information can result in maladaptive herding behavior, there is strong evidence for cognitive benefits of grouping and interaction. We propose that cognitive systems involved in decision-making processes of individuals can partially explain preceding contradictory findings. We conducted a pilot experiment (n=80) using a within-subjects design and Latin-square technique with incomplete counterbalancing to test whether individuals under an intuitive processing mode (System 1) are more sensitive to social information with a low quality and if this decreases individual accuracy compared to individuals under an analytical processing mode (System 2). Results from linear mixed models including random intercepts indicate that individuals who are instructed to think intuitively and are put under time pressure are a) more likely to adapt towards social information and show a decrease in individual accuracy and that b) these relations are moderated by the quality of the social information. We discuss potential implications of our results for the design of decision environments of crowds.

### When to Stop the Crowd?

*Authors: Julian Berger, Mehdi Moussaid, Stefan Herzog, Ralph Hertwig, Ralf Kurvers*
*Discussant: David Budescu*

A powerful approach to increase decision accuracy is to pool decisions of many decision makers. Studies describing the 'Wisdom of Crowds' have almost exclusively tested the performance of static crowd rules against the performance of individuals. A major drawback of such static rules is that cases are evaluated by the same number of raters, resulting in high effort. In an ideal scenario, the size of the crowd would depend on the task difficulty, using singletons or small crowds for easy and larger crowds for complex cases. We investigate such an approach using five dynamic rules based on decision trees and evidence accumulation models. We focus on binary-choice tasks and re-examine data sets from the domains of fake news detection, fingerprint analysis, replicability forecasting, geopolitical forecasting and skin and breast cancer diagnoses. We

extrapolate our empirical results with simulations to investigate environments in which dynamic stopping rules are at least as accurate as static ones, while being more efficient. Our empirical and analytic results show that under many realistic conditions, dynamic rules can match the performance of widely-used static aggregation mechanisms with fewer raters. This offers new opportunities for making wise use of the wisdom of crowds.

# Wednesday, 3:30PM–4:30PM

## Keynote 1: Lauren Meyers
Capital Classroom

# Wednesday, 4:45PM–6:15PM

## Foundations of Decision Analysis
Capital Classroom

### Additive Context-Dependent Preferences
*Stephan Jagau*

"Money equals utility" is a much criticized 'axiom' that is central across a vast range of economic experiments and theory. Subjecting this 'axiom' to experimental testing requires an empirically tractable theory of context-dependent preferences. Here, novel behavioral foundations for additive context-dependent preferences and state-dependent expected utility are presented. Crucially, these behavioral foundations do not require empirically implausible comparisons of alternatives across different states. Moreover, they can handle any state-dependent, multi-alternative decision problem. In particular, no diversity-type assumptions are used. A central application of my results is to direct utility measurement in games, enabling a causal understanding of how e.g. risk and social-preferences affect strategic choice.

### The Cost of Missing Objectives in Multiattribute Decision Modeling
*Sarah Kusumastuti*

Multiattribute decision analysis requires decision makers to identify their objectives as a critical part of sound decision making and failure to do so may result in poor decisions (Keeney & Raiffa, 1976). Research has shown that decision makers are often ill equipped to identify objectives and could not generate more than half of objectives they later recognized to be important (Bond, Carlson & Keeney, 2008;

2010). Three approaches are presented to examine the consequences of missing objectives in multiattribute models: (1) Analysis of existing multiattribute models from published applications; (2) Monte Carlo simulations evaluating the decision quality of reduced models under various model characteristics (3) Analysis of behavioral data. The results of each study provide a variety of outcomes concerning the consequences of missing objectives in multiattribute models. In general, the largest determiner of the impact of the missing objective is the attribute intercorrelation within the decision space. However, missing objectives might not necessarily be a detriment to making optimal decisions. As long as the set of objectives sufficiently captures the essential trade-offs, it is still very much possible to produce satisfactory outcomes from models with missing objectives.

### Verifiable Uncertainty
*Fan Wang, Ilia Tsetlin, Jinyuan Li*

Knightian uncertainty (aka ambiguity), where it is not easy to assign precise probabilities to different outcomes, has a long tradition in decision theory with abound theoretical and empirical work. However, this literature is rather vague on distinction between known and unknown probabilities, especially in a realistic scenario (as opposed to an artificial/laboratory setting). We suggest the notion of a verifiable lottery, which is equivalent to a classical one (based on a symmetry of the outcomes). Then we develop an axiomatic framework that yields preference representations similar to a smooth ambiguity model, but with a clear distinction between verifiable (objective) and non-verifiable (subjective) probabilities. One powerful illustration is preferences over income profiles under the veil of ignorance. We also discuss broader implications for normative and descriptive decision making.

## Statistics and DA
Arlington Classroom

### Bayesian Ensembles of Unlabeled Forecasts
*Xiaojia Guo, Kenneth C. Lichtendahl Jr., Eric Tassone*

In combining forecasts from several experts or models, the trimmed mean often offers improvement over the simple mean because it removes extreme forecasts that can severely bias the simple mean. When one concludes that an extreme forecast is severely biased, the trimmed mean represents a form of unsupervised learning—a way to draw inferences from the current forecasts alone, without any past forecasts or realizations of the quantity of interest. In this paper, we

introduce a more sophisticated unsupervised ensemble that follows from a Bayesian model of the forecasts and the experts' biases, but without exact knowledge about which expert is least biased, second-least biased, etc. This model learns only from the order statistics of the experts' point forecasts, as if the forecasts were otherwise unlabeled. In other words, the model learns anonymously, without knowing the identity of the experts and how they performed in the past. The form of our ensemble is a linear combination of the forecasts and consequently can be viewed as a robust mean. In an empirical study of time series forecasts from the M4 competition, we demonstrate that our Bayesian ensemble can outperform the simple and trimmed means and the best combination model from the competition.

### Hierarchical Forecasting for Inventory Planning
*Oliver Schaer, Nikolaos Kourentzes, Doug Thomas, Vidya Mani*

Hierarchical forecasting has been proposed to achieve coherent forecasts across different planning levels of organizations, for example, at SKU/store level and at SKU/distribution center, where coherency suggests that the more disaggregate forecasts will always sum up to the aggregate ones. Similarly, temporal hierarchies have been proposed to connect different planning horizons. The literature suggests that hierarchical forecasting have the beneficial side effect of improved forecast accuracy, with temporal hierarchies exhibiting higher gains. Arguably, coherent forecasts lead to aligned decisions that should result in better outcomes, but little work evaluates the benefits of hierarchical forecasting in decisions. We focus on inventory management and investigate how the use of hierarchies benefits inventory performance. On a dataset from a large retailer, we empirically investigate this connection between inventory and the use of cross-sectional and temporal hierarchies. We draw conclusions on the connection between accuracy and decision benefits from hierarchical forecasting, as well as investigate any benefits stemming from the qualitative benefits of hierarchical forecasting, such as enforcing coherency between forecasts.

### Limited Memory Influence Diagrams for Statistical Process Control
*Barry Cobb*

Limited memory influence diagrams (LIMIDs) are introduced for statistical process control where the number of defectives in random samples of process output are available for decision making. This presentation will describe improvements to a recent method utilizing LIMIDs for quality control that collects samples of a static size at equally spaced intervals. New procedures that employ variable and intermittent sample sizes will be discussed. The variable sample size method allows the operator to adjust the number of units in the next sample to better discern whether the process requires intervention to return to an in-control state. The intermittent LIMID model determines the time periods in which to collect pre-scheduled samples. When a sample is collected, the observed defectives determine whether the process is stopped to investigate and repair an assignable cause of variation. The process can alternatively be allowed to run without interruption until the next pre-determined sampling interval, or the results may suggest collecting a sample again in the next period. The model only requires the user to know the result of the current sample to make decisions, in contrast to Bayesian methods that require calculations based on all prior samples and a history of actions.

### On the Properties of Graphical Tools
*Emanuele Borgonovo, Manel Baucells, John Barr, Elmar Plischke, Herschel Rabitz*

The work is at the interfaces between machine learning and decision analysis. It discusses the use of machine learning indicators to answer managerial questions regarding the dependence of a quantity of interest and exogenous variables under scrutiny. We provide general theoretical results concerning mathematical properties, as well as insights for analysts working either on models for data analysis or on models developed as simulators.

# Thursday, 9:00AM–10:00PM (Panel)

## Panel: In Memory of David Schmeidler
Capital Classroom

**Moderator**
*Emanuele Borgonovo*

**David Schmeidler's Foundational Work on Aggregation of Preferences and Beliefs**
*Manel Baucells*

**David Schmeidler: The Impact of Theoretical Rigour on Our Lives**
*Itzhak Gilboa*

**David Schmelider's Fundamental Contributions to Decision Theory under Uncertainty**
*Massimo Marinacci*

**David Schmeidler: The Academic, the Teacher, the Man**
*Peter Wakker*

# Thursday, 10:30AM–12:00PM

## Forecast Aggregation
Capital Classroom

### Adjusting Machine Learning Algorithms for Risk Aversion
*Andrea Hupman*

Machine learning provides methods for decision makers to use data for better informed decisions. In the case of two-action decisions, for example, the decision maker may use information from a classification algorithm to determine which of two actions to take, where the classification algorithm provides a prediction on a key distinction relevant to the decision. However, classification algorithms are generally constructed with the assumption of a risk neutral decision maker. This talk examines how the consideration of risk aversion changes the predictions made by the classification algorithm through the adjustment of a cutoff threshold used to differentiate between the key distinctions. Parameterization of the performance measures for the classification algorithm provides a means to derive analytic results that show the optimal cutoff threshold is not reliably above or below the risk neutral cutoff threshold. Sensitivity analysis shows the misspecification of the optimal cutoff threshold results in lost value to the decision maker.

### Crowdsourced Prediction Systems: Markets, Polls, and Elite Forecasters
*Pavel Atanasov, Jens Witkowski, Barbara Mellers, Philip Tetlock*

We compare the aggregate performance of two distinct information systems: prediction markets, where participants trade securities corresponding to outcomes of uncertain events, and prediction polls, which directly elicit probabilistic estimates. For each, we employ two separate crowds: elite and sub-elite forecasters. Our analysis uses data from a large, multi-year forecasting competition, in which forecasters placing in the top 2% in a given year were considered elite in following years. Comparing the two crowd types, we find that small crowds of elite forecasters outperform larger, sub-elite crowds, achieving aggregate Brier score improvements of 20% in prediction markets and 23% in prediction polls. Comparing the two systems, we find that prediction markets and prediction polls produce statistically indistinguishable levels of aggregate accuracy for a given crowd type (elite or sub-elite). Moreover, while prediction polls produce more reliable sub-elite rankings, the two systems are equally effective in identifying elite forecasters. These results suggest that the recently documented accuracy benefits of "superforecasting" practices are not limited to prediction polls and forecasters working in teams, but also extend to prediction markets employing small, elite crowds.

### Developing Fair Predictive Algorithms for Optimal Resource Allocation in Healthcare
*Mehmet Ayvaci, Ozgur Araz, Asunur Cezar, Srinivasan Raghunathan*

Predictive algorithms in healthcare often use data capturing both the medical observations about a patient (i.e., medical data) and the data relating to non-medical aspects of care provision such as business processes (e.g., claims data) or the way patients live their lives (e.g., socioeconomic or behavioral data). The inclusion of non-medical data in prediction can enhance the accuracy of predictive algorithms. Yet, their inclusion can inadvertently lead to biased predictions and even racial profiling. When used for resource allocation decisions, such prediction biases may exacerbate existing healthcare disparities. Our goal in this paper is to develop equitable and fair optimal policies in the presence of algorithmic bias emanating from the use of non-medical data when developing predictive algorithms. Depending on the principles of fairness and the criteria for equality, optimal allocation policies based on algorithmic predictions can conflict with each other. A weighted approach to using medical and non-medical data when developing predictive algorithms can help mitigate such conflict.

### Inefficient Forecasts at the Sportsbook: An Analysis of Real-Time Betting Line Movement
*Jay Simon*

This analysis tests the efficiency of a set of sports betting markets using detailed betting line movement during the six-hour period preceding each of over four thousand Major League Baseball games. The reliability of the markets' forecasts are assessed at several lead times during that period. The forecasts are mostly reliable, but there are simple betting strategies that would have yielded significant profit. In addition, forecasts do not improve as the games get closer, despite more information being available; forecasts at the games' start times are significantly worse than forecasts one hour earlier. Furthermore, analysis of the sequences of forecasts within individual games reveals that these betting markets do not incorporate information optimally. There is sufficient evidence to reject weak form market efficiency; specifically, betting lines tend to overreact, exhibiting significant negatively autocorrelated changes

that could be exploited by sophisticated bettors.

## Practical Application of Decision Analysis (2)

Arlington Classroom

### Decision Analysis at FDA's Center for Drug Evaluation and Research (Part 1): Structuring Decision-Making

*Sarah Riordan, Sara Eggers, Graham Thompson, Blair Coleman, Leila Lackey*

Regulatory decision makers must integrate multiple, sometimes incomplete or conflicting, sources of information, especially when dealing with diverse data sources and multi-stakeholder input. At the Center for Drug Evaluation and Research (CDER) within the FDA, decision makers are faced with challenging pre- and post-market scenarios concerning drugs and biologics, yet still must assess the benefits, risks, and uncertainties to make informed regulatory and policy decisions. CDER is growing a Decision Support Service to offer direct support for challenging cases, and this session overviews the foundational decision science principles used within CDER to guide how decision-making is approached, structured, and communicated. The service applies qualitative tools rooted in the decision sciences, and the session will review strategies to address difficult decision-making, selecting appropriate resources, and applying principles and processes of well-structured decision-making. These strategies include the FDA Benefit-Risk Framework (BRF), and the more generally applicable PrOACT framework and graphical modeling techniques. Lastly, the session will illustrate how these approaches have been applied to benefit-risk assessment and lessons learned of the Decision Support Team. Part 2 (Lackey) will detail the role of advanced and quantitative approaches at CDER.

### Decision Analysis at FDA's Center for Drug Evaluation and Research (Part 2): Observations from Fit-For-Purpose Quantitative Methods

*Leila Lackey, Sara Eggers, Graham Thompson, Bethany Rue*

Drug regulatory decision-making at FDA rests on a judgement that the product is safe and effective or, in other words, that the expected benefits outweigh the expected risks. For many regulatory decisions at FDA's Center for Drug Evaluation and Research (CDER), the Benefit-Risk Framework, supplemented as-needed by decision-structuring tools such as PrOACT and facilitated by CDER's Decision Support Service (discussed in Part 1 by Riordan), are sufficient. However, in some cases, advanced and quantitative decision analytic approaches can add additional value; in particular

when questions about tradeoffs between outcomes arise. CDER and the Decision Support Service have recently begun to utilize fit-for-purpose quantitative decision analysis methodologies—including MCDA, preference elicitation, and others—to further support and inform the regulatory decision-making process. These techniques are also being utilized by the regulated industry and, increasingly, submitted to the Agency as part of product-specific Marketing Applications. Provision for and initial guidance on the use of these approaches has been codified in recent draft FDA Guidance for Industry. This presentation will discuss CDER's experience utilizing these methodologies and some resulting observations, lessons learned, and identified areas for future research.

### Quantifying the Benefits of Targeting for Pandemic Response

*Spyros Zoumpoulis, Sergio Camelo, Florin Ciocan, Dan Iancu, Xavier Warnes*

To respond to pandemics, policy makers have relied on interventions that target specific population groups or activities. Since targeting is potentially contentious, rigorously quantifying its benefits is critical for designing effective and equitable pandemic control policies. We propose a flexible modeling framework and algorithms that compute optimally targeted interventions that coordinate across two dimensions of heterogeneity: age of different groups and the specific activities that individuals engage in. We showcase a complete implementation focused on the Île-de-France region of France, based on commonly available public data. We find that optimized targeted policies reduce the number of deaths and the economic losses, as well as the time in confinement for each age group. Optimized dual-targeted policies have an interpretable structure, imposing less confinement on group-activity pairs that generate a relatively high economic value prorated by activity-specific social contacts. We also quantify the impact of fairness requirements that limit the differential treatment of distinct groups, and find that satisfactory trade-offs are achievable through limited targeting. Our framework highlights the benefits in explicitly and transparently optimizing targeted interventions.

### To Catch a Killer: A Data-Driven Personalized and Compliance-Aware Sepsis Alert System

*Zahra Mobini, Mehmet Ayvaci, Ozalp Ozer*

Sepsis affects more than 1.5 million people annually and contributes to as many as half of all hospital deaths in the US. Detecting and treating sepsis early can significantly reduce sepsis-related mortality. For timely detection, healthcare providers increasingly leverage automated sepsis alerts. In this study, we develop

an alert system that personalizes alerts to individual patients and accounts for caregivers' compliance behavior (i.e., caregivers' care decisions with respect to standard guidelines). Our alert system integrates predictive approaches with a prescriptive one in a Markov decision process framework to determine when a sepsis alert should be triggered. We characterize optimal alert policies that are easy to describe, follow, compute, and hence implement in the real world. Using data from a large hospital group in the U.S. with a typical alert implementation, we back-test and validate our alert policy by evaluating its performance against the hospital system's. Compared to the existing system, our alert system detects more sepsis cases and triggers earlier alerts, saving roughly 6 in 10,000 lives. Our findings shed light on how and when the personalization of alerts and incorporation of caregivers' behavior can improve sepsis-care quality.

## Prospect Theory
National Landing

### A Certainty Effect for Preference Reversals Under Risk: Experiment and Theory
*Paul Feldman, Paul Ferraro*

Under the expected utility paradigm, two behavioral anomalies are prominent. First, individuals tolerate risk when the odds are unfavorable but become averse to risk as the odds approach certainty. Second, risk attitudes can be context-dependent and exhibit reversals. Although new theories predict a relationship between these two anomalies, most empirical research examines them in isolation. Understanding how they interact is critical for adjudicating among competing behavioral theories. To address this gap, we conduct a lab-in-the-field experiment with high stakes and expert subjects. We observe a certainty effect for reversals and find that reversals persist at higher stakes and among experts. Although these novel findings cannot be explained by leading theories from economics and psychology, they can be explained by a theory that combines insights from both disciplines.

### Inverse S-Shaped Probability Weights and Lognormal Utility
*Robert Bordley*

Expected utility weights utilities with subjective probability while prospect theory weights value functions with probability weights (which are an Inverse S-shaped function of probability.) The Laplace approximation of an S-shaped utility defined over wealth will be a cumulative Gaussian function of some variable transformation of wealth (or value function). The gamble's certain value equivalent is an inverse-Gaussian function of the gamble's expected utility. As a result, probability weights are an inverse S-shaped function of subjective probabilities (consistent with prospect theory).

### On Risk Seeking and Risk Aversion for Qualitative Losses
*Johannes Müller-Trede, Shlomi Sher, Craig R.M. McKenzie*

In previous work, we found that the shape of prospect theory's value function strongly depends on the numerical representations used to describe gains and losses. This raises the question whether prospect theory's behavioral predictions generalize to choice problems in which—as is commonly the case outside the laboratory—outcomes are described qualitatively rather than numerically. We seek to answer this question in a series of experiments involving choices between gains and losses without numerical quantifiers. For instance, we report a simple hypothetical choice problem in which participants in one condition had to choose between "a small probability you will gain a lot" and "gain[ing] a little for sure." Participants in another condition saw the same problem, but with "gain" changed to "lose" throughout. In contrast to the "reflection effect," we found clear majority risk aversion for both gains (63.4%) and losses (65.4%). In more involved follow-up studies, we formulate and test conditions for the diminishing sensitivity by which—unlike traditional economic theory—prospect theory predicts risk-seeking for losses. These studies did not yield consistent support for risk-seeking, either. Our findings raise important questions about the empirical scope of prospect theory.

### Price Setting and Price Stickiness: A Behavioral Foundation of Inaction Bands
*Georgios Angelis*

This paper puts forward a model of price setting based on three elements of Prospect Theory introduced by Kahneman and Tversky (1979) and refined by subsequent work: i) people evaluate different aspects of their choices separately (narrow bracketing); ii) people evaluate prospective outcomes relative to a reference point (reference dependence); iii) prospective losses loom larger than prospective gains (loss aversion). The model predicts a pricing rule that involves an inaction region. Firms underreact compared to the canonical neoclassical model when updating their prices upwards or downwards. The model replicates two empirical patterns of the microdata that standard menu cost models have difficulty accounting for: i) The distribution of price changes has both small and large price changes, and ii) the hazard function of price changes is downward sloping initially, that is, firms that have just

recently changed their price have a higher probability of changing it again, while this probability becomes constant thereafter.

# Thursday, 1:30PM–2:30PM

## Keynote 2: Alex Imas
Capital Classroom

# Thursday, 3:00PM–4:30PM (PhD Incubator)

## Blitz Session, Chairs: Jay Simon, Jun Zhuang, Sasa Zorc
Capital Classroom
*Discussants: Max Biggs, Vicki Bier, Victor Jose, Jason Merrick, Michael Albert, Kirsten Rohde, Rick Larrick*

### Actual Events vs. Actual Reporting: Modeling Firm Performance Under Environmental Uncertainty Using Machine Learning
*Minh Nguyen*

Not all companies respond the same to natural disaster events. This study investigates two ways that natural disasters affect firm performance: actual events vs. actual reporting. In this study, I consider the billion-dollar weather and climate disasters in the US as the actual events and the number of words related to natural disasters in the Management Discussion and Analysis section in Form 10-Ks filing by the U.S. public companies as the actual reporting. This study also aims at comparing the performances of classification and regression trees (CART) and neural networks with linear regression model in predicting the performance of the U.S. public companies under environmental uncertainty. I find that both actual events and actual reporting of natural disasters in year t negatively affects firm performance in year t+1. Even though environmental uncertainty has some effects on firm performance, it is much less important than the traditional financial statement variables in predicting firm performance with the CART model. Comparing among CART, neural networks, and linear regression models, I discover that CART and neural networks outperform linear regression models in predicting firm performance in any given criteria, any given split ratios, and any given error measures.

### A Game Theory Model of Public-Private Partnerships

### Confidence vs. Confidence
*Joseph Rilling, Ken McAlinn, Junpei Komiyama*

Decision makers typically consult experts before making large decisions. Expert inputs are often forecast densities. The decision maker uses these individual predictions to capture the agents' private informations and synthesize an improved final forecast. If the decision maker has past predictions from each agent, she can use advanced methods to leverage agent biases and codependencies. However, in a one-off game, there are no historical predictions from the experts.

In one-off games, a traditional approach is weighting by confidence. Given a density, an agent's confidence is often considered inversely proportional to the variance. I argue that an agent's confidence in their prediction should be separated from their forecast variance. Many agents get their forecasts from models, and do not alter these predictions once they get the output. At the same time, the agent can see potential obstacles on the horizon, such as a regional conflict, that their model, which trains on past data, cannot access. Therefore, by asking experts to rate their confidence in their predictions, and not just inferring confidence from forecast variance, the decision maker will gain access to information that cannot easily be quantified, and she will be able to synthesize an improved final forecast.

### Models for Technology Adoption and Information Disclosure in Homeland Security
*Kyle Hunt, Jun Zhuang*

Homeland security agencies throughout the world play a vital role in safeguarding against terrorist attacks. As a result of the evolving and adaptive behaviors of terrorists, it is critical that security agencies continue to adopt new technologies in order to expose and deter threats. To this end, these agencies need to decide (i) whether or not to adopt new security-enhancing technology, and (ii) whether or not to announce this adoption to the public. In this work, we develop three novel game-theoretic models to explore this complex decision environment. In the first model, we study the problem of whether or not to disclose information related to new counterterrorism technologies. In the second model, we formulate a technology adoption game with a discrete-choice defender and a continuous-choice attacker, while studying the risk preferences of both players. In the third model, we study a multi-target game where the defender decides which target(s) should be announced in the information release.

### Portfolio Optimization with f-Divergence induced

## Risk and f-Betas
*Rui Ding*

In this paper, we build on using the class of f-divergence induced coherent risk measures for portfolio optimization and derive its necessary optimality conditions formulated in CAPM format. We have derived a new f-Beta similar to the Standard Betas and previous works in Drawdown Betas. The f-Beta evaluates portfolio performance under an optimally perturbed market probability measure and this family of Beta metrics gives various degrees of flexibility and interpretability. We conducted numerical experiments using DOW 30 stocks returns data to demonstrate the new perspectives provided by Hellinger-Beta as compared with Standard Beta and Drawdown Betas, based on choosing square Hellinger distance to be the particular choice of f-divergence function in the general f-divergence induced risk measures and f-Betas. Furthermore, we calculated Hellinger-Beta metrics based on deviation measures and drawdown measures respectively (resulting in another new metric which we termed Hellinger-Drawdown Beta), and compared the resulting Hellinger-Beta values under various choices of the risk aversion parameter to study their sensitivity to increasing stress levels.

## Resilience in Financial Portfolio Decisions
*Xiaochen Zhu, Jeffrey Keisler*

In recent years, the concept of resilience has been applied in numerous domains, but not much to investment decision making. Traditional asset allocation problems in finance derive from modern portfolio theory based on a consistent expectation of the tradeoff between return and risk. Resilience, if considered, is usually equated with low volatility (beta). But this misses reasons decision makers may desire resilience. Personal or institutional investors with plans for future use of funds may experience disutility during shortfalls below their target trajectory.

We model portfolio performance where there may be an uncertain shock to the market which not only changes asset prices but can also change estimates of their future risk and return. We develop a portfolio resilience measure which depends on the portfolio's potential shortfall from its target and recovery speed and its potential deviation from its target. The measure includes a parameter capturing the decision maker's attitudes toward shortfall vs. speed. The measure alone can be useful information in comparing portfolios. We also illustrate its use in initial portfolio allocation decisions, and in a two-stage portfolio allocation process where the second stage involves costly rebalancing.

## Self-Other Discrepancies and Risky Choice
*Arslan Javed, Ayse Onculer*

Making decisions on behalf of others is common in practice but past findings on self-other discrepancies in decision-making are not conclusive. There is some evidence for lower risk-aversion when making decisions for others (e.g., Chakravarty et al., 2011), whereas other findings are in the opposite direction (e.g., Lu et al., 2018). Several factors have been proposed to explain this discrepancy, such as social expectation (Stone and Allgaier, 2008), accountability (Pollmann et al., 2014), perspective taking (Tunney and Zieglar, 2015), and psychological distance (e.g., Batteux et al., 2017). In this paper, we distinguish between making a decision for oneself, familiar others (e.g., family, friends), and unfamiliar others (e.g., public, emergency patients) and investigate the role of social distance in decision-making. Our findings from three online experiments show that, when their identity is revealed, individuals are more risk-averse when deciding for themselves than for strangers but not for their own social circle. However, when their identity is kept anonymous, they make more risk-seeking choices for familiar and unfamiliar others, compared to deciding for themselves. We discuss the role of accountability and anticipated shame in making decisions for others.

## Unlocking Algorithm Potential: Overcoming Naive Advice Weighting with Feature Transparency
*Maya Balakrishnan, Kris Ferreira, Jordan Tong*

Although algorithms typically make better forecasts than human decision-makers (HDMs), occasionally HDMs have private information which the algorithm does not have access to -such as social media buzz- that can be used to improve algorithmic forecasts. We propose a mathematical model that captures how an HDM combines information she directly observes (some of which is private) with an algorithmic prediction to make a final demand forecast. We hypothesize HDMs take a weighted average between their own forecast and the algorithm's, where the weights depend only on the aggregate relative historical performances. This leads to HDMs overadjusting the algorithm's predictions when it performs well and underadjusting the algorithm's predictions when it performs poorly. We confirm our hypothesis using a lab experiment where 359 participants make demand forecasts for 20 products while having access to an algorithm's recommendations. In a followup experiment we show that providing transparency into the algorithm's input features can help HDMs use private information to differentially adjust the algorithm's forecasts. Our result shows that feature transparency –even when the underlying algorithm is a black box– helps users better incorporate algorithmic

recommendations in their decisions.

# Thursday, 3:00PM–4:30PM

## Risk Preferences and Ambiguity
### Arlington Classroom

### Judicial Decision under Ambiguity and Predictive Justice
*Sébastien Massoni, Vincent Teixeira*

Going to court is always a tough decision to take. Indeed, you never know your probabilities to win, the time it will require and how much you will win or spend. Predictive justice is an AI tool that uses big data to bring information to lawyers and litigants about their probabilities to win and the potential rewards. This objective information should reduce the difficulty to make the ambiguous decision of going to court or not. Seeing judicial decision as a decision under natural ambiguity, we test the effect of three types of information on attitudes: partial ambiguity, risk and similarity. In a complement study we elicit the willingness to pay to access this information. Results first show that behaviors differ between situations of natural and artificial ambiguity. Then information shapes the attitudes but with no significant differences between the three types of information. This common impact of information might be inconsistent with the different valuations of information that we expect to observe.

### Motivated Ambiguity Perception
*Aurelien Baillon, Romain Espinosa, Jan Stoop*

Situations in which risks are unknown or lacking proper probability estimates are referred to as ambiguous. When facing difficult decisions that could require major lifestyle changes (such as adapting one's behavior to climate change or animal suffering), people may want to think that the situation is more ambiguous than it really is, or that there are no conclusive probability estimates even when there actually are. Drawing from the motivated reasoning literature, we call such behavior "motivated ambiguity perception" and introduce a dual-self model to account for it. The model predicts that ambiguity perception will depend on the costs to adapt to adverse events, being maximum when adaptation is impossible. Furthermore, ambiguity perception is not monotonic with respect to the likelihood of adverse events, with no ambiguity being perceived when the worse is quite unlikely or almost certain. The latter prediction leads agents to act as if they overweight small probabilities of good outcomes or underweight large probabilities of bad outcomes, as often empirically documented.

### Research Protocol to Study Attitude to Ambiguity in Entrepreneurship
*Jacqueline Csonka-Peeren*

Entrepreneurs must routinely decide whether to pursue consequential opportunities despite having far from perfect information about expected outcomes, reward or loss. Much remains unknown and unknowable at the time of such an entrepreneurial decision, creating a condition of ambiguity for the decision-maker. This presentation describes the theoretical development and validation of a research protocol to study attitude to ambiguity in an entrepreneurial context. The work draws from both ambiguity research and behavioral decision making. Methodical analysis of attitude to ambiguity leads to a proposed prescriptive policy for entrepreneurs as they cope with ambiguity. This research protocol represents an advance in decision analysis because it provides a practical means to help answer research questions in entrepreneurship, specifically in entrepreneurial action research and entrepreneurship education.

### Responsible Investing under Ambiguity Induced by Climate Risk
*Francesco Rocciolo, Monica Billio, Massimo Guidolin*

We propose a theory of responsible investing under conditions of ambiguity induced by climate risk by studying the portfolio allocation problem solved a smoothly ambiguity averse representative agent. Within this setting, we find that the ambiguity risk premium is a strictly decreasing function of the environmental scores of the assets. Ambiguity-averse investors behave as environmentally motivated agents who allocate their wealth according to a mean-variance-ambiguity efficient frontier and their attitude towards risk and ambiguity. The agents rationally choose green portfolios in order to diminish their exposition towards ambiguity and maximize their ambiguity Sharpe ratio. Our theoretical predictions are consistent with the empirical literature on the rewards-to-risks trade-off of responsible investment.

# Thursday, 4:30PM–6:00PM (Posters)
### 30th Floor Foyer

**Comparing Data Quality From One Online Decision Study Across mTurk, CloudResearch, Prolific, and Undergraduates**

*Nick Byrd, Simon Cullen, Phillip Chapkovski, Danny Oppenheimer, Neil Thomason*

Philosophers and cognitive scientists have found that reflective reasoning is linked to certain decisions and philosophical preferences. However, correlational and experimental experiments sometimes produce seemingly contradictory evidence about the links between reflection and decision-making. Further, some have called into question the trustworthiness of certain participant samples—e.g., crowd work platforms such as Amazon Mechanical Turk (mTurk). We conducted one pre-registered experiment with four samples: mTurk, CloudResearch, Prolific, and undergraduates. Findings reproduced the divergence between correlation and experimental findings as well as differences between the four samples—in both data quality and results. In the end, responses to some philosophical thought did not correlate with reflection test performance as expected and mTurk data quality was remarkably worse than the other platforms (even though HITs completed and acceptance rates were identical for all crowd work platforms). Together, these data suggest that there may be more reflective responses to some thought experiments, but such results for other thought experiments may vary depending on the study design and the participant pool.

## Consumption Categories: Complexity and Risk Attitude
*Kfir Tshuva*

We offer a model that adapts the classic consumer choice model by assuming consumption categories with minimal expenditure thresholds. The model also seems plausible with reference to real life (e.g., consumption related to car ownership or home ownership). We show that is np-hard to find the optimal set of categories to consume from but easy to optimally allocate money for a given set. We also show that the complexity of the consumer problem is non-monotonic increasing in wealth. This result suggests that people of moderate wealth may deviate from utility maximization (due to complexity costs) more than either poor or rich people. Our model provides novel explanations for two puzzles of risk attitude: (1) why people buy both insurance and lottery tickets and (2) why probability range affects risk attitude and, in particular, why it does so in opposite directions for gain and loss. We show that investing in a lottery with high gain and small loss can be worthwhile for agents with low wealth whereas, for agents with medium wealth, the added value of the lottery decreases as wealth increases

## Course Decision Systems: The Case of Fairness
*Christian Gilde, Tyler Seacrest*

Deciding on college courses is tied to an elaborate decision-process. In this respect, the consumer aspects of course decision systems are different from traditional market dynamics. This exploratory research takes a closer look at college course decision systems in the context of mathematical fairness as compared to consumer fairness. The prevalent literature in this area points to concepts such as optimization and fair distribution. An exploratory experimental design tests the fairness properties of different course decision algorithms to improve fairness. Upon closer examination it can be discovered that mathematical fairness and consumer fairness have quite distinct attributes in the context of college course decision systems, which could have some wider implications for general consumer decision-making.

## Decision Analysis for Project Schedules
*Lev Virine*

Project management is an art of making complex decisions. Project managers are making decisions under uncertainty not only related to project duration or cost, but also safety, security, quality, etc. Project scheduling is one of the critical project management processes. Project managers also use risk management and assign risks to a project schedule. Decision analysis can be integrated to the project scheduling, which simplifies acceptance of the decision analysis. One of the tools is probabilistic and conditional branching. In a process of Monte Carlo simulations some tasks within a project schedule can be executed based on certain conditions for example, if duration of predecessors exceed certain value. Also, decisions nodes can be integrated to the process schedule and the schedule can be automatically converted to a decision tree. These processes allow to perform mitigation and response planning, and particularly estimate efficiency of different mitigation plans. Also, decision analysis is performed on a regular basis during a course of project as part of project controls and incorporate actual project performance. The presentation includes case studies how decision analysis based on project schedules is used in some industries, such as defense and pharmaceutical.

## Don't Leave Me on Read! How Avoidance-Based vs. Busyness-Based Attribution of Read Receipts Influences Relationship Outcomes
*David Fang*

In 2012 Instant messaging (IM) services such as Facebook Messenger and Whatsapp released the read receipt feature, allowing users to see when someone has read their message. Through a series of 4 online studies (N = 1421) this paper investigated whether individuals would provide a "desire to avoid" attribution or "too busy to respond" attribution when they send a message that was read without reply (RWR) or when they received a

message that they (RWR) and how interpersonal relationships (e.g., trust, closeness, and reliability) become affected by RWR messages. Studies 1 and 2 found that both senders and receivers were more likely to attribute RWR messages to busyness (vs. desire to avoid). Study 3 posited that perceptions of interpersonal factors such as trust, reliability and closeness all dropped for both senders and receivers of RWR messages and that the drop was moderated by an individual's desire to avoid attribution level. Study 4 further examined this effect in three relationship scenarios of varying closeness levels (parents, friends, and strangers) and found that strangers who sent a message that was RWR tended to underestimate the other party's desire to avoid them, whilst experiencing greater decreases in trust, closeness, and reliability.

### Execution Game in a Markovian Environment
*Makoto Shimoshimizu, Masamitsu Ohnishi*

This paper examines a execution game model in a Markovian environment. We focus on how two risk{averse large traders execute a large volume of a risky asset to maximize the expected utility of each large trader from the terminal wealth over a finite horizon. The price impact caused by each large trader and the Markovian environment are assumed to affect the market and execution price. A formulation as a Markov game model enables us to solve this problem. We obtain an equilibrium execution strategy and its associated value function under a Markov perfect equilibrium via the backward induction method of dynamic programming.

### Generalized Maturity Model for Decision Analytics Organizations
*Kyle Ebersole, Gene Loughran*

Maturity models and analytic continuum diagrams often assume that organizations continually evaluate the same sorts of data and are striving to achieve more sophisticated analysis on that data. These models are most appropriate for an organization incorporating steady streams and consistent types of data, building from descriptive analysis through intermediary forms until they are able to model prescriptive analytics. These models can be rigid, but also have value for organizations that actually operate in this way. However, many organizations are more likely to use varying data sets developed or discovered and analyzed in support of specific, individual decisions. Once the supported decision is made, new questions are posed, new data discovered, and new analysis performed; so, while analysis is continual no one analytic is regularly repeated.

We propose a generalized analytic maturity model for organizations that routinely and repeatedly perform project level analytics. Using a familiar model of five

maturity levels and the phases of Cross-Industry Standard Process for Data Mining we describe a set of behaviors and practices that represent increasing maturity for organizations that continually incorporate analytics but not the same data or methods into their decision process.

### Market Economies for Eliciting and Combining Judgemental Forecasts
*Majid Karimi, Arthur Carvalho*

Judgemental forecasts are often combined to obtain a better predictive performance than individual forecasts. Researchers and practitioners often use statistical aggregation methods to find an optimal transformation of individual forecasts based on their statistical properties. Motivated by the recent advancements in the Wisdom of Crowds literature, we present market economies as an alternative for combining judgemental point forecasts. Unlike statistical aggregation methods, we argue that market economies present a practical solution for eliciting and aggregating a crowd's judgemental point forecasts. We provide a prescriptive analysis in an Inventory Planning and Control setting and illustrate the impact of our proposed market economies on inventory decisions.

### Measuring Supply Chain Resilience
*Wenqing Zhang, Prasad Padmanabhan, Chia Hsing Huang, Chung-Yean Chiang*

Recent political or social crisis events highlight the degree of vulnerability of the supply chains of firms. In this paper, we investigate the impact of industry market concentration on the ability of firms with adventurous and possibly irrational decision makers to make decisions where extreme disruptions in sequential supply chain investment decisions are likely to occur. We suggest that firms under the monopoly structure are better able to retain adventurous supply chain decision makers and survive under extreme crisis conditions than those under the perfectly competitive structure. Firms in perfectly competitive environments are more likely than monopoly firms to curtail projects when facing negative returns caused by extreme disruptions, regardless of decision maker characteristics. Market power allows firms to benefit from protection against extreme supply chain disruptions and keep irrational/adventurous decision makers longer on the payroll hoping that their actions may eventually lead to positive long run returns. The obvious policy implication is that firms under perfect competition should move towards a structure that allows them some barriers to entry.

### On the Distributional Robustness of Rational Inattention Models

*Emerson Melo*

In this paper we study the distributional robustness of the Rational Inattention model introduced by Matejka and McKay (2015). We make three contributions. First, we fully characterize the distributional robustness of the RI model in terms of an index of robustness. Second, we provide necessary and sufficient conditions for the formation of consideration sets in environments where the decision maker (DM) has uncertainty about the true prior describing the states of the world. Third, we quantify the effect of uncertainty about the true priors on DM's optimal payoffs. We provide a simple closed form expression that quantify the impact of model uncertainty on DM's welfare.

## Product Development for Environmental Sustainability Practice: Barriers to Adoption & Sustaining Value
*Mehnuma Tabassum, Gül E. Okudan Kremer*

Although environmental sustainability has been discussed for decades, adopting practices to advance sustainability has been sluggish in many industries; one such industry is metal component manufacturing. Because raw material extraction is costly, metal components should be designed with remanufacturability, reuse, and value gain from recycling in mind. However, literature review and interviews with practitioners indicate many barriers for adopting design for sustainability practices such as product design stage not considering end-of-life strategies sufficiently, design sustainability performance being considered unimportant during design optimization, inertia of cost-profit decision-making being hard to overcome unless the volume considered is substantial, etc. Due to these difficulties, the value of sustainability is not perceived appropriately. In this paper, using a realistic case-study and a multi-criteria decision framework, we investigate the visibility of sustainability-related terms in design decision-making. We look at the sustainability front from various perspectives and scales. We also propose potential actions to increase the sustainability value and provide a guideline for practitioners to incorporate the sustainability element into the decision-making process.

## Responsible Preferences
*Francesco Rocciolo*

This paper provides the axiomatization and studies the properties of a class of preferences employed in recent financial economics studies in which preferences under risk are combined with preferences for sustainability. The axiomatization of responsible preferences requires the generalization of the assumptions of Weak Order, Continuity, and Weak Monotonicity. Moreover, two further new axioms are necessary. Responsibility states that, for each lottery, the decision-maker always prefers the alternative that pairs the lottery with a higher ESG score. Consistency with Expected Utility instead rules the behavior of the decision-maker in choices between alternatives characterized by the same ESG score. Unless special assumptions are made, responsible preferences violate first order stochastic dominance and do not allow for a classification of the decision-maker as a risk-averse, seeker, or neutral. This suggests that this kind of preferences should be employed carefully.

## Revealing What Really Matters (For Choice)
*Illia Pasichnichenko, Christopher Kops, Paola Manzini, Marco Mariotti*

Choice is driven by the features that describe alternatives. But not all conceivable features may matter for decision-makers and different features may matter for different decision makers. An analyst cannot observe directly the description of an alternative used by a decision maker. To what extent do choices reveal which features matter? We develop a theory of relevant feature identification. In particular, we characterize which kinds of choice observations are informative, partially or fully, about the features that matter for choice, on the assumption of preference maximization.

## Running it Twice (or Thrice): Double-Header and Triple-Header Baseball Arbitration
*Michael Hasday*

I propose variations of final offer arbitration (FOA) that maintain the core elements of the mechanism but lessen the award variance. Double-Header Baseball Arbitration (DHBA) plays out like regular FOA, except that two arbitrators independently decide which of the parties' numbers to award. If both agree, then that is the award. If they disagree, then the award is the midway point between the two parties' numbers. In Triple-Header Baseball Arbitration (THBA), three arbitrators independently decide. If all three agree, then that is the award. If the arbitrators split 2–1, the award is set at the applicable two-thirds point between the parties' numbers.

My paper compares DHBA and THBA to the version of FOA that Major League Baseball currently uses to determine player salaries, in which three arbitrators, deciding the matter collectively, select either the player's or the team's salary figure. Through probability analysis, I demonstrate that DHBA and THBA will lead to awards that are substantially more accurate, predictable, and fair.

# Thursday, 4:30PM–6:00PM

## Office Hours with NSF Program Director Claudia González Vallejo
National Landing (Drop In)

# Friday, 8:30AM–10:00AM

## Applications – Homeland Security
Capital Classroom

### A Game-Theoretic Framework for Multi-Target, Multi-Layer Defense Against Strategic Attackers
*Ian Unson, Kyle Hunt, Jun Zhuang*

When defending soft targets, such as airports, subway stations, sports venues and houses of worship, it is critical to optimally allocate defensive resources across the different security layers of multiple targets. This allocation will effectively utilize human and monetary resources and reduce the risks from attacks. DHS defense components are tasked with resource allocation problems like this to protect our homeland with limited available resources. In this problem the objective of the defender is to optimally allocate resources amongst multiple targets throughout the respective security layers to decrease the expected damages, decrease the probability of a successful attack, and potentially deter the adversary from executing an attack plan on any target. The attacker aims to circumvent the security measures by adaptively allocating resources across the different targets and layers. This project expands on past resource allocation problems by focusing on different security layers across multiple targets to protect soft targets against adversarial threats. This resource allocation problem has been solved through the development of stakeholder-informed game-theoretic models, which can prescribe optimal allocation plans in the face of a strategic adversary.

### Assessing Goals and Objectives for Emergency Preparedness
*Curtis Peters, Cameron A. MacKenzie*

Determining the goals and objectives in preparing for, responding to, and recovering from disasters can help emergency managers and first responders make better decisions when a disaster occurs. These goals and objectives can be organized into an objective's hierarchy. This talk will present the findings from interviews with people involved in the emergency management process to identify and structure objectives in emergency preparedness and response. People in different emergency preparedness roles have different objectives which result in multiple hierarchies although we can also design an overall objectives hierarchy. The results also show the differences between emergency management in small and large counties while highlighting unique challenges that each type of county faces. The differences between first responders and emergency managers will be presented to show the challenges each faces along with the ways each group approaches decision-making. Our findings can help decision-makers in emergency management proactively think about their goals to make better decisions while preparing for and responding to disasters.

### Near-repeat Terrorism: Identifying and Analyzing the Spatiotemporal Attack Patterns of Major Terrorist Organizations
*Kyle Hunt, Brandon Behlendorf, and Jun Zhuang*

Previous research has found that single terrorist attacks can elevate the risk of subsequent attacks nearby, referred to as the near-repeat phenomenon. In the context of terrorism, a near-repeat pair consists of two attacks that occur within a time period T and a spatial distance D of one another (e.g, 1 week and 10 miles). While preliminary research in this domain has laid the foundations for examining the contagion of terrorism, there is a lack of knowledge regarding (i) whether or not near-repeat attack patterns generalize across major terrorist organizations, and (ii) the major risk factors associated with near-repeat terrorism. Using over 50,000 data points, which each represent a historical terrorist attack, this study fills these gaps in knowledge by studying near-repeat attack patterns both across and within 30 major terrorist organizations.

### Systemically Important
*Jonathan Welburn*

In 2020, the cyberspace solarium commission (CSC)—an intergovernmental body stood up to develop a strategy for protecting the nation against cyberthreats—released its final report. In a list of recommendations, the CSC recommended the creation of a new designation of entities that are systemically important. Perhaps borrowing from the Dodd-Frank era designation of systemically important financial institutions – or SIFI, the CSC recommended that the designation of systemically important critical infrastructure or SICI. While the concept has been taken up by congress, it has yet to be defined. How is an entity designated SICI, what evidence supporting evidence is needed, what is the theoretical basis? We begin to answer these questions. We reflect on lessons learned from SIFI, define the concept of systemic importance, and present an approach

for data-driven analysis. We present an approach for estimating the systemic importance of an entity based on its interconnectedness in large inter-firm networks with the potential for cascading failures. Finally, we reflect on the potential implications for future policy surrounding the SICI concept.

## Behavioral Decision Making (2)
Arlington Classroom

### A Rational Account of the Repulsion Effect
*Rahul Bhui, Yang Xiang*

The attraction effect occurs when the presence of an inferior option (the decoy) increases the attractiveness of the option that dominates it (the target). Despite its prominence in decision science, recent evidence points to the puzzling existence of the opposite phenomenon—a repulsion effect. In this project, we formally develop and experimentally test a normative account of the repulsion effect. A low-value decoy can signal that the target also has low value when both are believed to be generated by a similar process. We formalize this logic using a hierarchical Bayesian cognitive model that makes predictions about how the strength of the repulsion effect should vary with statistical properties of the context. This theory can help account for several documented phenomena linked to the repulsion effect, as well as new experimental data. Our results shed light on the key drivers of context dependence across both economic and perceptual decision making and sharpen our understanding of when decoys can be detrimental.

### Predicting the Present Equivalent of Multiple Future Cash Flows
*Manel Baucells, Alessandra Cillo*

Present equivalents of future payouts elicited from individuals exhibit a high variability in the underlying discount rate, suggesting that multiple factors influence discounting. One such factor—shown to be robust—is the magnitude effect, whereby small future payouts are discounted more than larger ones. When individuals are confronted with more than one future payout, it is unknown whether the magnitude effect is driven by the sum of cash flows, or the highest cash flow, or the first, or the last, or the lowest; or perhaps each cash flow has a magnitude-dependent discount rate. We address these questions by eliciting the discount rate of diverse cash flows following a ceteris paribus design. The best predictive model has the discount rate decreasing with the sum and the highest cash flow, with noticeable effects kicking in for sums below 600 dollars and/or the maximum cash flow below 20 dollars. We do not find a

strong support for the alternative model with cash-flow specific discount rates. We also take decreasing impatience into account, and distill a somewhat more prescriptive base discount rate after removing the effects of magnitude and decreasing impatience.

### Risk Preferences in Time Lotteries
*Mark Kirstein, Yonatan Berman*

An important but understudied question in economics is how people choose when facing uncertainty in the timing of events. Here we study preferences over time lotteries, in which the payment amount is certain but the payment time is uncertain. Expected discounted utility theory (EDUT) predicts decision makers to be risk-seeking over time lotteries. We explore a normative model of growth-optimality, in which decision makers maximize the long-term growth rate of their wealth. Revisiting experimental evidence on time lotteries, we find that growth-optimality accords better with the evidence than EDUT. We outline future experiments to scrutinize further the plausibility of growth-optimality.

### Weighting the Waiting: Intertemporal Social Preferences
*Kirsten Rohde*

Many decisions have a social as well as a time dimension. This paper brings the literature on social and intertemporal preferences together by studying intertemporal social preferences. We use intertemporal dictator and ultimatum games where players decide on the timing of monetary payoffs, to study whether people distribute waiting time in a similar way as monetary payoffs. Moreover, our setting is two-dimensional rather than one-dimensional, in the sense that inequalities can arise in the time as well as in the social dimension. We find that when monetary payoffs are equal, decisions regarding waiting time show similar patterns as decisions regarding monetary payoffs in the standard dictator and ultimatum games. The results also show that decisions regarding waiting time depend on inequalities in monetary payoffs in a systematic way. Moreover, this sensitivity to inequalities in monetary payoffs is more pronounced in ultimatum than in dictator games.

## Sequential Decision Problems
National Landing

### Decision Analytic Support in Non-Cooperative Sequential Games
*Roi Naveiro, Tahir Ekin, Alberto Torres, David Rios Insua*

We present a robust framework with computational

algorithms to support decision makers in non-cooperative sequential games. Our framework includes methods to solve games with complete information, assess the robustness of such solutions and, finally, approximate adversarial risk analysis solutions when lacking complete information. This framework could be especially beneficial in application domains such as cybersecurity and counter-terrorism. Existing simulation based approaches can be inefficient for a large set of feasible decisions and uncertain outcomes; the game of interest may not even be solvable to the desired precision for continuous decisions. Hence, we provide a novel alternative solution method based on the sequential use of augmented probability simulation. While the proposed framework applies to general non-cooperative sequential games, we illustrate it with sequential defend-attack problems. Pointers to adversarial machine learning problems are presented.

### Recursive Two-Stage Evaluation Model for Dynamic Decision Making under Ambiguity
*Ying He*

In this paper, the two-stage-evaluation (TSE model for decision making under ambiguity (He 2021) is extended to intertemporal setting in an axiomatic approach. The first set of axioms employed are commonly adopted for dynamic non-expected utility models in the literature. Besides these regular axioms, we also assume dynamic consistency and assumptions which deliver a static TSE for one stage consumption plans. It is shown that these axioms hold if and only if these exists a recursively defined evaluation utility model representing decision maker (DM)'s preferences over consumption plans conditional on arriving at any node in the event tree. Such a recursive form implies that one can apply dynamic programming technique (rolling back the decision tree) to solve a dynamic decision making problem under TSE model. It can be shown that the solution for the recursively defined dynamic TSE model exits uniquely. Applying this source-dependent model to a standard consumption based asset pricing problem provides a three-component decomposition of the equity premium in term of premiums for each source and their interactions, which can be used to interpret equity premium puzzle in finance literature.

### Sequential Search with Acquisition Uncertainty
*David Brown, Cagin Uru*

We study a variation of the classical Pandora's problem in which a decision maker (DM) sequentially explores alternatives from a given set and learns their values in an effort to acquire the alternative with the highest value. The variations in the model we study are (i) alternatives randomly disappear from the problem and (ii) the DM's ability to acquire a remaining alternative is uncertain and depends on a chosen offer price. Such acquisition uncertainties arise in many applications but greatly complicate the resulting stochastic dynamic program, as the number of possible states grows exponentially in the number of alternatives and the state and action spaces are in general continuous. We develop and study a class of greedy threshold policies that make offers only on the most recently explored alternative, provided its value exceeds a given threshold. We show that these threshold policies are asymptotically optimal as the number of alternatives grows large with a convergence rate that we characterize and that in general these policies obtain at least $1-e^{-1}\approx 63\%$ of the optimal value. We illustrate these methods on examples from housing search using models calibrated on data from the online brokerage Redfin.

### Search in the Dark: The Normal Case
*Sasa Zorc, Manel Baucells*

The standard sequential search problem rewards the decision maker with the highest sampled value, net of the sampling cost. If the sampling distribution is unknown, then a Bayesian decision maker faces a complex balance between learning and optionality. We tackle the stopping problem of sampling from a normal distribution with unknown mean and unknown variance, a riddle that has remained open for half a century. We find that reservation prices—prevalent in search theory—are no longer optimal. Structurally, the gain to search is single-U or double-U shaped, and unbounded on both sides; hence the optimal stopping region may comprise up to two bounded intervals. We also introduce the so called internal cost function, which provides a computationally practical way to identify the optimal stopping rule for any given prior, sampling history, and remaining samples; and that can also be applied to the case of known variance.

# Friday, 10:15AM–11:45AM

## Behavioral Decision Making (3)
National Landing

### Choosing to Choose: Choice with a Default Option
*Ian Chadd, Emel Filiz-Ozbay, Erkut Ozbay*

Our experiments investigate the effect of seeing a default option on optimality of decisions. We contribute to the literature by identifying two mechanisms

through which the default option affects the choice: (i) the endogenous rejection of default option increases the likelihood of optimal choice due to selection, (ii) seeing the outside option leads to superior choice due to reference effect. While the former one has been reported in other applications such as auctions or contests, the latter one is novel. Our results indicate that the reference effect improves the likelihood of choosing better ranked options even if the subjects fail to find the first best.

### How Do Taxi Drivers Determine How Much to Work If Earnings Are Hard to Predict?
*Perke Jacobs, Florian Artinger, Gerd Gigerenzer*

A fundamental assumption of expected utility models is that agents make predictions by formulating rational expectations. Building on this assumption, the literature has addressed to what extent neoclassical or behaviorally informed utility models best describe intertemporal substitution of labor and leisure, focusing on the taxi market. Using data from 10 million taxi trips, we find that hourly earnings are barely predictable. Under such uncertainty, satisficing models predict behavior of drivers better than utility models. These models do not require calculating expected earnings but terminate shifts when reaching an aspiration level on shift duration or earnings.

### Predicting Revenues with the Multiplier Heuristic
*Florian Artinger, Nikita Kozodoi, Julian Runge*

Forecasts by statistical and machine learning methods are usually regarded as superior over those made by experts. Nonetheless, many experts still rely on simple heuristics. Are there conditions under which expert forecasts based on heuristics can match the performance of statistical and machine learning methods? We examine the case of predicting revenues per customer in 20 data sets where experts rely on the following heuristic: multiply the revenue observed in the first t days by a constant. We find that with limited sample size and a shorter prediction horizon that the heuristic can perform on par or even outperform statistical and machine learning methods. Given unpredictable changes over time, the heuristic even performs on par given very large samples and a longer prediction horizon. The results provide insights when to rely on managerial judgment and when on statistical and machine learning methods.

### The Reliability of Decision Quality Assessments in Decision Analysis
*Hugo Yoshizaki, Gilberto Montibeller, Matthias Winkenbach, Filipe Aécio Alves de Andrade Santos*

Decision quality assessments are widely employed in Decision Analysis practice, as a way of sensitizing organizations to improve decision making. Decision makers self-assess their performance, rating their decision process on the relevant decision quality dimensions. One open question is whether this type of self-assessment is a reliable measurement of decision quality, reflecting the actual decision quality observed in the decision process under evaluation. We explore this research issue in a complex decision setting in Operations Management: the design of a distribution network in which warehouses must be located, balancing delivery times with total operation costs. We simulated this decision with fifty-one teams, who were supported by an interactive spatial decision support system that provides visual and quantitative information. Each team could explore the solution space and were tasked to agree on a solution. Subsequently, group participants were asked to self-assess their (perceived) decision quality. Here we present our early findings, analyzing the actual performance and contrasting it with the perceived decision quality. Worryingly, we find weak links between perceived and actual decision quality, and weak correlation between commitment to action and actual performance.

## Forecasting
Capital Classroom

### Aggregating Privacy-Sensitive Forecasters
*Marat Salikhov, Ruslan Momot*

Organizations often make forecasts by asking their internal experts for inputs which are then aggregated and used for decision-making. Experts are generally interested in providing quality forecasts because they benefit from good decisions being made (e. g. by receiving a share of company's profit). However, in some cases their incentives might be distorted by fears of external interference—for example, an expert might be reluctant to share pessimistic forecasts because that might displease that expert's manager. Therefore, allowing experts to have some "plausible deniability" about the forecasts might improve both the participation rates and forecast quality. We propose to introduce such deniability by adding noise to all publicly made forecasts. Adding noise has two effects on forecasting performance: a negative effect, since noisy forecasts are less efficient to aggregate, and a positive effect, since the experts have weaker incentives to bias their forecasts. We construct an analytical model that describes the optimal level of noise and analyze its implications for forecast aggregation.

### A Formal Bayesian Framework for Ensemble Decision

**Making**
*Kenichiro McAlinn*

We consider decision making with multiple sources of information from a foundational Bayesian perspective. Many decision-making processes utilize multiple agents, including forecasters and models, to improve decisions. Ensemble methods, where several forecasts are combined, have received considerable interest for this purpose. On the other hand, the Bayesian paradigm provides a rational, coherent framework for decision-making. It is, however, unclear how a Bayesian should ensemble, and what assumptions a certain strategy entails. We provide a formal Bayesian framework for ensemble methods that generalizes existing ensemble strategies and can be broadly extended. We consider several extensions for sequential and spatial forecasting. We further provide asymptotic and finite sample theoretical guarantees, where we identify a class of extensions that are superior to all linear ensemble methods. Several applications are presented to highlight the applicability and efficacy of these extensions, including macroeconomics, epidemiology, real-estate, ecology, and climatology.

**Improving the Wisdom of Crowds with Social Forecasts and Coherence Measures**
*David Budescu, Mark Himmelstein, Emily Ho*

We report results of a longitudinal forecasting study designed to (1)test whether accuracy can benefit from social belief judgments (predicting how "others" would forecast the target events); (2)assess the ability of a new measure of probabilistic coherence (Ho 2020) to predict forecasting skills; and (3)assess the interaction between coherence and time to forecast resolution. Judges forecasted 20 events (political, economic and COVID related) five times approximately three weeks apart. The original sample consisted of 300 forecasters. We analyze results of 175 of them who participated in all five waves. The social forecasts were slightly more accurate than the actual forecasts and the mean of the two was more accurate than either source. This suggests that social forecasts tap into unique information not accessed by traditional forecasting methodology, possibly by reducing certain biases that plague the latter. Forecasters' coherence was a better predictor of accuracy than other individual difference measures. We find that as the temporal gap between the forecast and event resolution decreases, participants tend to be more accurate, and the individual-level coherence closely tracks this relationship.

**Perspectives on Diversity: Lessons for Decision Analysis**
*Jack Soll, Yael Grushka-Cockayne, Victor Jose, David Budescu*

Across disciplines, scholars have observed that diversity is an essential ingredient to the wisdom of crowds. Yet research paradigms vary in how they define and operationalize diversity. In this talk, we distinguish between two dimensions of diversity that have been the focus of different literatures—knowledge-based diversity (differences among people) and statistical diversity (differences among judgments). Although statistical diversity is generally recognized as the proximate cause of crowd wisdom, many social scientists have focused on the differences in knowledge that can potentially produce it. We consider both direct and indirect sources of knowledge-based diversity. Direct sources are those that most immediately cause judgment, such as the information people hold and how they combine it. In contrast, indirect knowledge-based diversity refers to social and dispositional factors that lead to people to encounter or use information differently in the first place. An example would be having different life experiences that lead people to interpret the meaning of a given piece of information differently. We explore how these different dimensions of diversity interrelate, with an emphasis on implications for the wisdom of crowds.

## Value of Information
Arlington Classroom

**Balancing Risk and Trust for Strategic Alliance Formation Decisions**
*Zachary A. Collier, Matthew D. Wood, Dale A. Henderson*

Trust entails the assumption of risk by the trustor to the extent that the trustee may act in a manner unaligned with the trustor's interests. Before a strategic alliance is formed, each firm formulates a subjective assessment regarding whether the other firm will behave in a trustworthy manner and not act opportunistically. To inform this partner analysis and selection process, the authors leverage the concept of value of information to quantify the benefit of information gathering activities on the trustworthiness of a potential trustee. In this paper, the authors develop a decision model that explicitly operationalizes trust as the subjective probability that a trustee will act in a trustworthy manner. The authors integrate the concept of value of information related to information gathering activities, which would inform a trustor about a trustee's trustworthiness. Trust inherently involves some degree of risk, and the authors find that there is practical value in carrying out information gathering activities to facilitate the partner analysis process. The authors present a list of trustworthiness indicators, along with a scoring sheet, to facilitate learning more about a potential

strategic alliance partner.

### Flipping the Script on Environmental Forecast Product Design Using Value-of-Information
*Eva Regnier, Joel Feldmeier*

When environmental forecasters develop new capabilities, they want to know what products users would find most valuable. Commonly, they reach out to the user community with open-ended questions about potential applications, preliminary designs of forecast products and performance metrics, and identify products similar to existing products that are relatively easy for users to understand and integrate into their current decision processes. However, this doesn't work well to identify new users and applications that emerge with new forecasting capabilities.

To identify high-value potential forecast products—variables, lead time, regions, and seasons—that could be produced using a new 10–45-day earth systems prediction capability, we used a value-of-information model in a large-scale experiment. We find value relative to climatology (skill) at lead times where conventional metrics do not, depending on user characteristics such as risk tolerance and operational limits with respect to environmental variables. We identified high-value forecast products paired with characteristics of users who would be able to extract high value that the forecasting community can use to target outreach to users and potential users, and to provide user-relevant measures of forecast impacts.

### The Impact of Connectivity on the Production and Diffusion of Knowledge
*Farzad Pourbabaee, Gustavo Manso*

We study a social bandit problem featuring production and diffusion of knowledge. While higher connectivity enhances knowledge diffusion, it may reduce knowledge production as agents shy away from experimentation with new ideas and free ride on the observation of other agents. As a result, under some conditions, greater connectivity can lead to homogeneity and lower social welfare.

### Qualitative Value of Information
*Michael Runge, Clark S. Rushing, Madeleine Rubenstein, James E. Lyons*

The value of information is a central concept in decision analysis, used to quantify how much the expected outcome of a decision would be improved if epistemic uncertainty could be resolved prior to committing to a course of action. One of the challenges, however, in quantitative analysis of the value of information is that the calculations are demanding, especially in requiring predictions of outcomes as a function of alternative actions and sources of uncertainty. But the concept of value of information is important in early framing of some decisions, before such predictive tools are available. In this presentation, we propose a novel qualitative measure of the value of information (QVOI), grounded in the algebra of the expected value of perfect information (EVPI), but requiring less of experts and analysts. The QVOI calculation decomposes EVPI into a contribution representing the relevance of the uncertainty to the decision and a contribution representing the magnitude of uncertainty; qualitative constructed scales are then proposed for each contribution. We briefly demonstrate the use of QVOI to identify research priorities related to migratory bird management in the face of climate change.
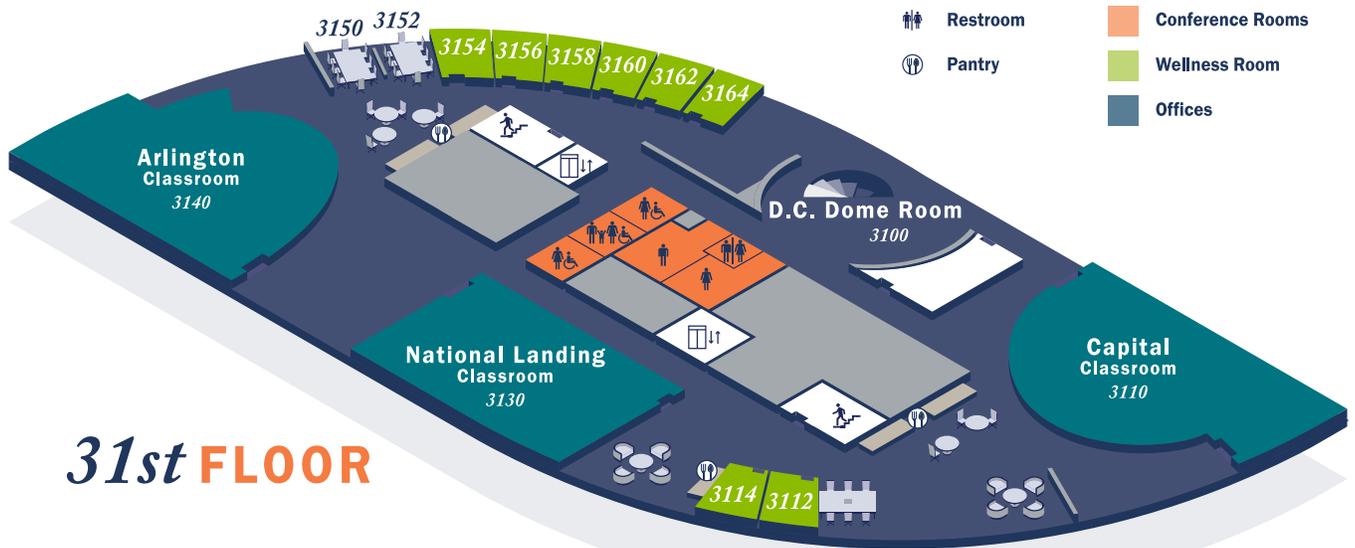
# Friday, 12:00PM–1:00PM

## Keynote 3: Ariel Procaccia
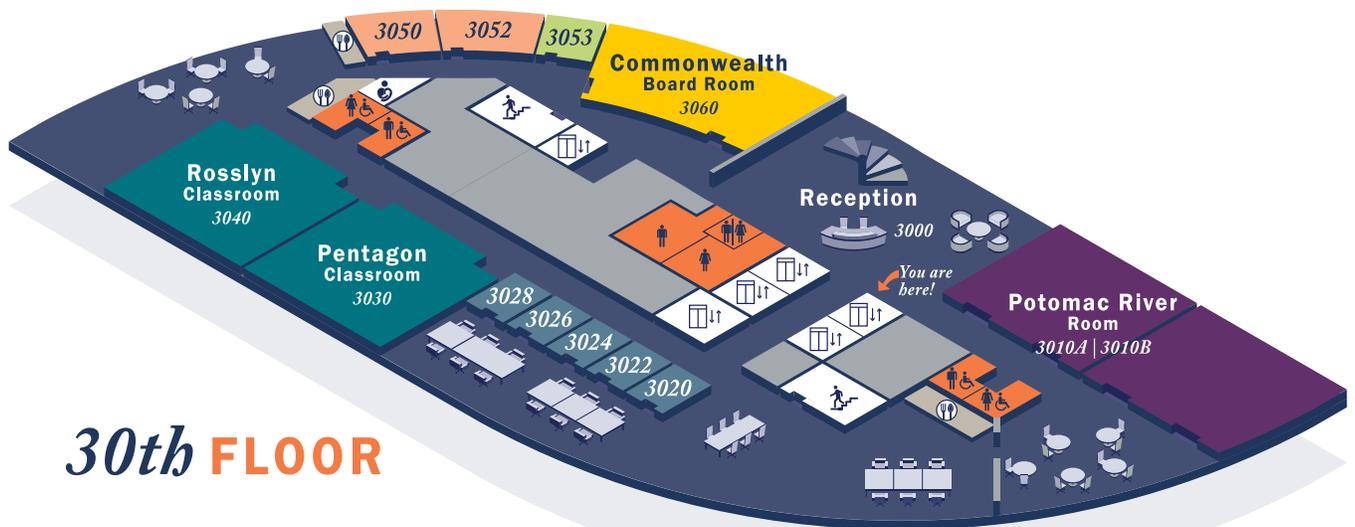Capital Classroom

# DC METRO *at the*
# SANDS FAMILY GROUNDS

**Stairs**

**Elevators**

**Mother's Room**

**Restroom**

**Pantry**

**Classrooms**

**Team Rooms**

**Restrooms**

**Conference Rooms**

**Wellness Room**

**Offices**

## 31st FLOOR

3150  3152  3154  3156  3158  3160  3162  3164

**Arlington**
Classroom
*3140*

**D.C. Dome Room**
*3100*

**National Landing**
Classroom
*3130*

**Capital**
Classroom
*3110*

3114  3112

## 30th FLOOR

3050  3052  3053

**Commonwealth**
Board Room
*3060*

**Rosslyn**
Classroom
*3040*

**Reception**
*3000*

**Pentagon**
Classroom
*3030*

3028  3026  3024  3022  3020

*You are here!*

**Potomac River**
Room
*3010A | 3010B*