



Search under Uncertainty: Cognitive Biases and Heuristics

A Tutorial on Modeling Search Interaction using Behavioral Economics

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ABSTRACT

Modeling how people interact with search interfaces is core to the field of Interactive Information Retrieval. While various models have been proposed ranging from conceptual (e.g., Belkin's ASK[12], Berry picking[11], Everyday-life information seeking, etc.) to theoretical (e.g., Information foraging theory[50], Economic theory[4], etc.), more recently there has been a body of working explore how people's biases and the heuristics that they take influence how they search. This has led to the development of new models of the search process drawing upon Behavioural Economics and Psychology. This half day tutorial will provide a starting point for researchers seeking to learn more about information searching under uncertainty. The tutorial will be structured into two parts. First, we will provide an introduction of the biases and heuristics program put forward by Tversky and Kahneman [59] which assumes that people are not always rational. The second part of the tutorial will provide an overview of the types and space of biases in search [6, 42], before doing a deep dive into several specific examples and the impact of biases on different types of decisions (e.g., health/medical, financial etc.). The tutorial will wrap up with a discussion of some of the practical implication for how we can better design and evaluate IR systems in the light of cognitive biases.

CCS CONCEPTS

• **Information systems** → **Search interfaces**; *Task models*; *Retrieval tasks and goals*; • **Human-centered computing** → **HCI theory, concepts and models**; *Graphical user interfaces*.

KEYWORDS

Information Retrieval, Web Search, Search Behaviour, User Models, Retrieval Strategies, Evaluation, Cognitive Bias

ACM Reference Format:

Leif Azzopardi and Jiqun Liu. 2024. Search under Uncertainty: Cognitive Biases and Heuristics: A Tutorial on Modeling Search Interaction using Behavioral Economics. In *Proceedings of the 2024 ACM SIGIR Conference on Human Information Interaction and Retrieval (CHIIR '24)*, March 10–14, 2024, Sheffield, United Kingdom. ACM, New York, NY, USA, 4 pages. <https://doi.org/10.1145/3627508.3638297>

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CHIIR '24, March 10–14, 2024, Sheffield, United Kingdom

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ACM ISBN 979-8-4007-0434-5/24/03

<https://doi.org/10.1145/3627508.3638297>

1 INTRODUCTION

Information Seeking and Retrieval (IS&R) encompasses the processes of searching, discovering, and retrieving relevant, valuable, and trustworthy information [25]. This multifaceted journey involves various factors that impact how individuals participate in this process, influence their search behaviors, and affect their search performance. To understand IS&R comprehensively, a variety of conceptual and descriptive models have been proposed. These models, such as Bates' Berry Picking Model [11] and the IS&R framework presented by Ingwersen and Kalvero [26], provide valuable insights into the intricacies of how people browse, forage and search for information. Moreover, researchers have explored a diverse array of determinants in this field, including user characteristics, such as expertise, background, topic knowledge, and cognitive abilities. They have also investigated system functionalities, such as interface design, presentation, and quality, along with task attributes like difficulty, complexity, and topicality [33, 36]. These models and determinants collectively contribute to a deeper understanding of the dynamic nature of information seeking and retrieval, shedding light on the complex interplay between users, systems, and the information itself. However, they have been largely agnostic of the cognitive biases that impact people's IS&R behaviour.

Over the past decade there has been growing interest in understanding the influence of cognitive biases on IS&R and their consequences for information processing, knowledge acquisition, and decision-making. This concern is particularly relevant in an era marked by instant access to vast information volumes, as well as the potential exploitation of cognitive biases by search engines, content creators, and Artificial Intelligence (AI) systems [9, 14, 16].

Moreover, questions arise about the potential interaction between cognitive biases and biases present in search engines, algorithms, and content, and whether these biases may contribute to or reinforce one another, creating a "*bias begets bias*" cycle [9]. The amalgamation of system- and user-sided biases can mutually amplify effects, both positively and negatively [40].

As an increasing portion of the population relies on search and recommender systems for essential life decisions, such as medical, political, social, personal, and financial choices, understanding and

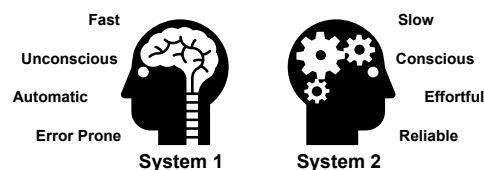


Figure 1: Thinking, Slow and Fast [28]: Cognitive biases [59], or simple heuristics that make us smart? [58]

mitigating the (negative) impact of cognitive biases is of considerable economic and societal significance and is also essential for building and implementing human-centered, responsible information systems [15, 43].

Thus, this tutorial aimed to bring greater attention to this growing body of research, provide participants with an overview of cognitive biases in search, and facilitate the discussions on the potential opportunities, methodological challenges, and practical implications of research on bias-aware IS&R. Armed with the knowledge about human biases, we hoped to inspire participants to develop more psychologically valid user models and evaluation measures, as well as performing better designed user studies [42].

2 INTENDED LEARNING OUTCOMES

By the end of the tutorial, participants should be able to:

- Describe the main biases and heuristics;
- Explain the difference between rational and irrational behaviour (from behavioral economics perspective);
- Explain how different biases can impact online search behaviours and user judgments on documents;
- Generate hypotheses regarding user behaviour under different biases in search interactions and design appropriate experiments to test the hypotheses.
- Identify and mitigate cognitive biases that may impact the design, interpretation and outcome of user studies.

3 FORMAT AND SCHEDULE

The first half of the tutorial focuses on the background theory from behavioral psychology and economics, and the second half focuses on providing examples in the context of IS&R.

3.1 Session 1: Biases and Heuristics

The tutorial was structured as follows. To kick off the tutorial, an ice breaker exercise was performed to test "How biased are you?", based on standard psychological instruments used to identify different types of cognitive biases. This was a fun way to get participants actively involved in understanding the different biases and how they are measured in psychology. Next an overview of the space and spectrum of cognitive biases was presented and how they can impact information seekers (see Table 1[6, 42]). This was then followed by presenting an overview of the key (theoretical) works that led to the field of behavioral economics and the program of study on heuristics and biases:

- Expected Utility Theory and Rational Choice[60].
- Judgment under Uncertainty: Heuristics and Biases [27, 57, 59].
- Fast and Frugal Heuristics [22, 58]
- Bounded Rationality and Satisficing [56].
- Prospect Theory and Reference Dependence[29]

3.2 Session 2: Cognitive Biases in IS&R

The second part of the tutorial focuses on key works from the IS&R literature regarding impact of cognitive biases on behaviour, evaluation and experimental design, where we discussed the methodological challenges and practical implications of modeling users'

search interactions from a behavioral economics perspective[6, 42]. The following works were used as key examples based around:

- Interacting and using ranked lists (Trust and Position biases in web search due to order effects [32, 46, 64]).
- Looking for evidence to support your prior beliefs (confirmation biases in health search [1, 51, 62, 63]).
- Seeing lots of evidence that supports a particular belief (anchoring, availability, exposure, etc. in health search).
- Mitigating cognitive biases during the search process (priming and anchoring[52, 65]).
- Evaluating and assessing results (order, bandwagon and decoy effects [17] and reference dependence when judging and rating results and systems [15, 44]).

More details of the tutorial can be found at: <https://beir.github.io/>.

4 BIOGRAPHY

Leif Azzopardi is a Associate Professor at the University of Strathclyde, UK, within the Department of Computer and Information Sciences. Leif specializes in modelling and measuring how people interact with search and recommendation systems using theory from economics to ecology. He has over 200 peer reviewed publications on Interactive Information Retrieval focus on how user behaviour (with over 6500 citations). Key works relevant to this tutorial include his work modelling people as economic actors [2–5, 7, 8], and his work summarizing the different cognitive biases affecting search [6]. They have given numerous invited talks on Formal Models of Information Seeking and Retrieval throughout the world and lectured at the Information Foraging Summer School (2011, 2012 and 2013) and Symposium of Future Directions in Information Access (2007–2013). He has given various tutorials at leading conferences, on for example, the Economics Models and Measures of Search (SIGIR 2019, ICTIR 2016), Modelling the Costs and Benefits of Interaction, (CHIIR CHI2019, CHIIR 2017), Simulation of Interaction (SIGIR 2016), Formal Models of Search (CIKM 2015, ICTIR 2015).

Jiqun Liu is currently an assistant professor of data science and affiliated assistant professor of psychology at the University of Oklahoma. He directs the OU human-computer interaction and recommendation (HCIR) Lab where he advises students from different backgrounds on intelligent search and recommendation, human-centered computing, and responsible AI research. His current research program focuses on the intersection of human-AI interaction, machine learning, and cognitive psychology. His work applies the knowledge learned about people interacting with information in user modeling, adaptive search and recommendation, bias mitigation and human-centered fairness evaluation. His research on bias-aware user modeling and IR evaluation received grant support from National Science Foundation (NSF) and has been published at premier venues, such as ACM SIGIR, CHIIR, CIKM, JCDL, IP&M, EMNLP, and TheWebConf. His work has also been introduced in a research monograph entitled "A Behavioral Economics Approach to Interactive Information Retrieval: Understanding and Supporting Boundedly Rational Users" by Springer Nature and presented through numerous invited talks to both academic audiences and industry practitioners.

Table 1: A reading list of IS&R papers investigating different cognitive biases across domains and different parts of the search process.

	Cognitive Biases	Domains			Search Process			
		Health	Political	Web	Querying	Examining	Judging	Sat.
Too Much Information	Confirmation Bias	[21] [37] [51] [53] [61] [62] [66]	[30] [39] [38]	[52]	[37] [52] [53]	[61] [62] [30] [39]	[21] [51] [38] [30] [39]	
	Anchoring	[41] [51]	[47] [48]	[17] [55]		[47] [48]	[17] [41] [51] [55]	
	Availability	[21] [51] [63]	[47] [48]			[47] [48]	[21] [51]	
	Framing Effects		[47] [48]			[47] [48]		
No Meaning	Bandwagon Effects	[18] [21] [23]	[17]	[13] [34]	[34]	[13]	[17] [18] [23] [21]	
	Exposure Effects	[21] [41] [51]	[38] [19]				[19] [21] [38] [41] [51]	
	Reinforcement Effects	[41]	[38] [19]				[19] [38] [41]	
Act Fast	Decoy Effects			[17]			[17]	
	Ambiguity Effects		[38] [30]	[17] [24] [31]		[30]	[17] [24] [31] [38]	
	Less is More			[49]				[49]
	Dunning-Kruger Effect			[20]			[20]	
Remember	Priming Effect		[47] [48]	[35] [52] [54] [65]	[52] [65]		[47] [48] [54]	[35]
	Order Effects	[10] [41] [51] [1]	[19]	[13] [32] [46] [64]		[13] [32] [46] [64] [1]	[10] [19] [41] [51]	
	Peak End Rule			[45]				[45]

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