# Research Statement: Clayton Thomas

I am a theoretical computer scientist studying mechanism and market design. This modern field studies algorithms and *incentives*, for example, those present in important real-world auctions for combinatorially-constrained broadcasting rights [LMS17] or thousand-per-second web-search advertisement slots [Var07].

One distinctive contribution of my research is developing principled approaches to ***explaining*** important algorithms to their participants. A natural example of the connection between theoretical computer science and explainability is given by the *verification* interpretation of the complexity class *NP*: A problem is in *NP* if there is always an easy-to-check proof that a proposed outcome is correct. In real-world mechanisms such as assigning students to public schools, the students (and parents) may not care *how* the school district calculated the outcome. However, they often care deeply that the school district *got the correct answer*. This highlights the value of easy-to-check (and, ideally, easy-to-understand for real-world participants) proofs of the outcome's correctness and the mechanism's properties—precisely what my work provides.

Beyond explainability, my research explores several innovative directions in TCS and economic design. For instance, my work investigates a new notion of the robustness of auctions (particularly relevant in blockchain settings) when the auctioneer can commit to a specific attack [GTW24], considers new questions and techniques for communication-complexity lower bounds in strategyproof auctions [RSTWZ21; RTWZ24], and addresses the tradeoff in matching problems between fairness and efficiency [CT22; Tho24]. My work also has broad interdisciplinary appeal, drawing on core ideas from economic theory to advance computer science, and conducting empirical human-subject laboratory experiments reminiscent of methods used in the field of human-computer interaction.[1]

In the remainder of this research statement, I first discuss my work on explaining mechanisms, and second discuss my other research, highlighting directions for future work throughout.

## Strategyproofness-Exposing Mechanism Descriptions

Stable matchings are a celebrated algorithmic problem introduced by [GS62] with deep roots in theoretical computer science [e.g., Knu74; IL86; KT06], widespread practical deployments [e.g., Rot02; AS03; Sön23], and a thriving modern research community [e.g., Dav13; EIV23]. These mechanisms match students to schools (and workers to firms and medical residents to hospitals) using the students' reported preferences over the schools. They aim to simplify participation by being *strategyproof*, which means that students can never benefit by misreporting their preferences.

Unfortunately, growing evidence suggests that participants in matching mechanisms often do not *understand* strategyproofness, and hence misreport their preferences in a way that only hurts them [HK21; RS23]. Prior work—including my paper single-author paper [Tho21] (EC 2021)—has attempted to mitigate this by changing the interactive protocol used. Unfortunately, much

[1]Journal versions of two of my EC papers are currently under review at leading economics venues, contributing theory and behavioral experiments. Our closely related paper [GT24] appeared in STOC 2024, highlighting the strong interdisciplinary breadth of my work.

work has shown that "strategyproofness exposing" interactive protocols are of *extremely limited* applicability, motivating other approaches.

In [GHT23] (EC 2023) we propose a fundamentally new approach to exposing strategyproofness. We study *menu descriptions*, which explain student $i$'s match in the mechanism—while making strategyproofness hold via a simple argument—using the following outline:

**Step (1)** uses only other students' reports to describe $i$'s *menu* of potential schools.

**Step (2)** uses student $i$'s reported preference to select $i$'s favorite school from her menu.

To see the strategyproofness of a menu description, $i$ need only observe that her report cannot affect her menu, and that reporting her true preference gets her favorite outcome from her menu.

Our first main result in [GHT24] (journal submission version of [GHT23]) provides a simple and streamlined menu description of the classic stable matching mechanism, Deferred Acceptance (DA). We prove that student $i$'s menu in (student-proposing) DA is all institutions that prefer $i$ to their outcome in *school-proposing* DA excluding student $i$. This yields an intuitive menu description of DA; in contrast, prior to our work, it was not clear how to construct DA's menu, except via a trivial solution involving running the traditional description many times to separately check if different institutions are on $i$'s menu. Our other main results in [GHT24] investigate descriptions of the other canonical matching mechanism Top Trading Cycles (TTC), and characterize simple menu descriptions using algorithmic tools from computer science, providing a very complete picture of the concepts introduced.[2]

In our companion empirical paper [GHIT24] (EC 2024), we test this new description of DA using a lab experiment in the tradition of behavior economics. We find that, like DA's traditional description, many participants can (using a novel GUI we developed) learn our new menu description and calculate its outcomes. Additionally, we find that, in a suitably stripped-down form, a menu description conveys strategyproofness quite well (indeed, even outperforming a textbook description of strategyproofness), highlighting its potential for real-world use.

Our closely-related paper [GT24] (STOC 2024) delves into many complexity questions inspired by our framework of menu descriptions. For one example, we show that while stability—and thus the outcome of DA—can be explained using one "cutoff" per school, explaining the outcome of TTC requires a cutoff per *pair* of schools (formalizing the contrast between TTC and DA suggested by [AL16; LL21]). Along with our other results, we holistically find that explaining the outcome of TTC is more complex than explaining the outcome of DA, corroborating prior concerns on TTC's complexity (in spite of the simplicity of TTC's strategyproofness which we identify in [GHT24]) and elucidating the structure of these mechanisms.

Significant open directions remain regarding how to best explain mechanisms and algorithms to participants. Building on my work, future directions include explaining the strategyproofness of other mechanisms, or exploring equilibria beyond truthful ones. More broadly, one could develop protocols to explain properties like fairness, optimality, privacy, or accuracy, with approaches tailored to the specific settings (e.g., using the promising axiomatic explanation framework investigated for voting rules in [Pro19; PPPZ20]). Additionally, the principled approach of my research may offer valuable insights for investigating explainability in other fields, such as AI.

[2] The working paper version [GHT23] also investigates an extension of our theoretical results for auctions, and runs an experiment in an auction and voting setting.

## Other Topics and Future Directions

Beyond explainability, my research contributes to a range of topics in theoretical computer science and economic design. I particularly value works that apply principled methods to new and innovative questions.

**Auction Design for Blockchains.** In [GTW24], we study a platform (specifically, a blockchain) designing a mechanism that an untrusted third party (a blockchain miner) must actually implement. We show that the state-of-the-art auction protocol (the EIP-1559 transaction-fee mechanism underpinning the Ethereum blockchain) is vulnerable to a novel and simple-to-implement attack. Where prior models (e.g., Akbarpour and Li [AL20] and Roughgarden [Rou21]) assume that the auctioneer cannot commit to following the protocol and instead acts greedily whenever possible, our model instead crucially allows the auctioneer to **strategically exploit commitment power**. In our attack, the auctioneer makes a **credible threat**: committing to a loss of revenue when participants do not give-in to the threat, but extracting more revenue when participants best-respond and comply with the threat. Beyond the blockchain setting, future work using our model may inform the design of mechanisms where a platform designs a mechanism that a seller, separate from the platform, must actually implement.[3]

**Communication Complexity and Implementation Theory.** A recurring topic in my work is communication complexity, a foundational concept in theoretical computer science that takes on practical significance in mechanism design, where agents must communicate their preferences and cannot send prohibitively complex messages.

In [RTWZ24] (FOCS 2024), we prove a new style of **impossibility result** in algorithmic mechanism design for which **previous techniques were demonstrably insufficient**. In [RSTWZ21] (STOC 2021), we show that even within the class of strategyproof mechanisms, the choice of solution concept—**dominant-strategy vs. ex-post Nash equilibrium**—can dramatically impact communication complexity. In [CTW20] (ITCS 2020), we study a class of mechanisms related to **implementation in undominated strategies**, and give a novel reason why economically reasonable mechanisms may be possible even in the presence of computational hardness.

**Efficiency versus Stability.** Stability is a key fairness criterion in student-school matching, but comes at the cost of suboptimal student welfare. In [Tho24], I study **priority-neutral** matchings, an important new generalization of stabile matchings introduced by Reny [Ren22] that allows students to receive better matches than in DA. I **resolve the main open question** of [Ren22], and show that the set of priority-neutral matchings is **far more complex than stable matchings**.[4] My result thus establishes a precise barrier that new, more-tractable ways of balancing efficiency and fairness must overcome.

Other papers of mine investigate how stability affects students' welfare in expectation in random matching markets. In [CT22] (SOSA 2022), we give **simpler proofs** of the main result of Ashlagi, Kanoria, and Leshno [AKL17]: in **unbalanced** matching markets, the **short side is at**

[3] This connection arises both because (like our model) the seller has incentives separate from the platform, and because the platform taking a cut of the revenue is equivalent to the "money burning" novel to blockchain auctions.

[4] My work extends [Ren22] similarly to how [FZ22] extends [EM20].

**a large disadvantage** in *any* stable matching.[5] In [ABSTZ21] (ITCS 2021), we characterize the welfare effects of **heterogeneous agent-quality**.

**Additional Future Directions.** I am interested in many other areas of economics and computation, such as decision theory and information design.[6] Theoretical computer science provides powerful tools for modeling decision making [e.g., EGW11; Cam22]. My work in [GHT24; GT24] introduces novel models focused on *memory usage* rather than computation time, offering insight into decision theory and strong connections to other areas, such as streaming algorithms. Information acquisition is another often overlooked factor that is vital in many real-world settings. While there have been some promising theoretical investigations [ABKS20; ILLL20], they fail to model the success of real-world dynamic-offer designs [e.g., GHK22], motivating new approaches to bridging mechanism and information design. Holistically, I believe my research is at the forefront of economics and computation, with both significant existing contributions and bright potential for the future.

# My Papers


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[5] In conversation, two of the authors of [AKL17] have praised the simplicity of our arguments in [CT22] and/or told me they use our proof, instead of theirs, in their classes.

[6] I have two ongoing information design projects with Microsoft Research PhD interns (and with Nicole Immorlica and Brendan Lucier). With Joey Feffer, we are studying how school districts should reveal information about the schools' attributes in order to reduce congestion and improve welfare. With Ruxing Xu, we are studying the value of knowing the "source" of a piece of evidence, formalized as knowing the precise details of a signal-generating process drawn from a distribution over such processes.

[GHIT24] Yannai A. Gonczarowski, Ori Heffetz, Guy Ishai, and Clayton Thomas. "Describing Deferred Acceptance and Strategyproofness to Participants: Experimental Analysis". In: *Proceedings of the 25rd ACM Conference on Economics and Computation (EC)*. In Review at Econometrica. 2024. URL: https://arxiv.org/abs/2410.07566.

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[GTW24] Aadityan Ganesh, Clayton Thomas, and S. Matthew Weinberg. "Revisiting the Primitives of Transaction Fee Mechanism Design". In: *Proceedings of the 25th ACM Conference on Economics and Computation (EC)*. 2024. URL: https://arxiv.org/abs/2409.18166.

[RSTWZ21] Aviad Rubinstein, Raghuvansh R Saxena, Clayton Thomas, S Matthew Weinberg, and Junyao Zhao. "Exponential communication separations between notions of selfishness". In: *Proceedings of the 53rd Annual ACM SIGACT Symposium on Theory of Computing (STOC)*. 2021. URL: https://arxiv.org/abs/2012.14898.

[RTWZ24] Shiri Ron, Clayton Thomas, S. Matthew Weinberg, and Qianfan Zhang. "Communication Separations for Truthful Auctions: Breaking the Two-Player Barrier". In: *65th IEEE Symposium on Foundations of Computer Science (FOCS)*. 2024. URL: https://arxiv.org/abs/2409.08241.

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