Biometric Responses to Unjustified and Justified-Envy in School Choice Allocations*

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Abstract

The two most prominent strategy-proof school choice mechanisms, Deferred Acceptance and Top Trading Cycles, offer a trade-off between eliminating justified-envy and Pareto efficiency, respectively. We introduce a novel, biometric approach to investigate welfare under each property. Using an experimental design that randomly varies whether subjects learn about others' assignments in a school choice game, we measure discontentment through galvanic skin response and facial expressions when subjects experience envy with and without justification. We find increased arousal associated with receiving subsequently lower-ranked allocations, i.e., the (unjustified) envy of the allocation(s) of others. Additionally, we note additional arousal when that envy is justified, but that result requires an explicit message to accentuate the justification to subjects. Eye-tracking data confirm that subjects do not notice the property of justified-envy until prompted.

JEL classification: C90, D47, D82, D87, I24

Keywords: eye-tracking, facial expressions, galvanic skin response, justified-envy, matching, school choice

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1 Introduction

School choice mechanisms affect the placement and educational outcomes of many students around the world. These matching mechanisms may be a vehicle for providing access to high-quality schools to disadvantaged populations. In designing practical markets for matching students to schools, institutions have relied on theoretical properties for efficiency, fairness, and strategy proofness to advocate for the subjective value of certain mechanisms over others. The classical "Boston" Mechanism (a.k.a. "Immediate Acceptance," IA) was replaced in Boston, Chicago and greater New England, as matching theorists and experimentalists favored and directly influenced the adoption of the Deferred Acceptance (DA) mechanism because of its strategy-proofness property, meaning it provides (weak) incentives for respondents to reveal their preferences truthfully (Abdulkadiroğlu et al., 2005; Chen and Sönmez, 2006; Pathak and Sönmez, 2013).

Deferred Acceptance is currently the predominantly-used school choice mechanism because of another property, the elimination of justified-envy. Justified-envy occurs when one student i observes another student j at a school s they prefer (causing envy) and student j is not preferred to i by the desired school (making the envy justified), and also unstable. While the property is desirable all-else-equal, it comes with trade-offs. Indeed, it is well-known that no mechanism can generate Pareto efficient outcomes and simultaneously eliminate justified-envy in equilibrium (Abdulkadiroğlu and Sönmez, 2003). Another mechanism, the Top Trading Cyles (TTC) mechanism can achieve Pareto efficient outcomes in equilibrium but cannot satisfy the elimination of justified-envy. These two mechanisms are the main choices for strategy-proof mechanism design in the school choice environment.

The choice between these two mechanisms may be viewed as a classic trade-off between fairness and efficiency, with no clear answer. Justified-envy is a very specific form of fairness, and unlike equality, it is not simple to describe or well-known to most populations. In fact, Morrill (2013, 2015a,b) shows that the TTC can achieve many other notions of fairness in equilibrium assignments. Thus it is an open question whether people actually identify and value the elimination of justified-envy, or alternatively, feel and react differently about justified-envy compared to (unjustified) envy. Our paper provides the first experiment to test this question. We use biometric measures to compare subjects who receive identical payoffs, one in the presence of justified-envy and one in the presence of envy without justification. Using a random assignment design, we vary whether subjects learn the payoffs of others, allowing the possibility subjects notice their justified-envy.

We use biometric measures in our experiment because they provide involuntary measures of a subject's (potential) negative affect which can be interpreted as a measure of welfare. We correlate emotional reactions to subject earnings to determine whether the loss in aggregate welfare due to an inefficient mechanism is offset by the gain in welfare in imposing a fairness concern.[1] Our experiment induces a particular four-player game and valuation structure under two school choice mechanisms, the Top Trading Cycles (TTC) and Deferred Acceptance (DA). The valuation structures are specifically chosen so that two players receive their third choice under either mechanism in the focal equilibrium. The other two players receive their first choice under TTC and second choice under DA. In the TTC equilibrium outcome one of the players who did not receive their first choice experiences justified-envy while the other does not. We exogenously vary (at the subject level) whether a subject observes the assignments of the other subjects in their group at the conclusion of the game, opening the possibility for subjects to realize and experience justified-envy, depending on their assignment.

Our results find the comparative statics of theory and previous experimental results hold well. The TTC mechanism achieves Pareto efficient outcomes in 45.9% of observations compared to only 11.1% under the DA. The DA eliminates justified-envy in 88.9% of observations compared to 43.2% in the TTC. Focal equilibrium assignments are achieved in 45.9% and 66.7% of cases in the TTC and DA mechanisms, respectively. Subjects appear roughly aware

[1] An alternative approach might use an incentivized BDM mechanism instead to measure subjects' willingness-to-pay to avoid situations resulting in justified-envy. However, this approach is problematic. There is evidence that most subjects are unable to play dominant strategies in dominant strategy elicitation mechanisms, even when the value of preferences is induced and trivial (Cason and Plott, 2014; Danz et al., 2022; Brown et al., 2024). It is unlikely that in an environment like ours where values are more intangible that subject responses will improve. Further, subjects that misreport values on a BDM may also have difficulty responding to other dominant strategy mechanisms. This could lead to an identification problem for elicited values obtained by the BDM on willingness to use other dominant strategy mechanisms. Indeed, Basteck and Mantovani (2018) find that individuals who score higher on intelligence tasks are more likely to respond truthfully in the strategy-proof DA mechanism. There are likely unobserved correlations between responses (and hence outcomes) on dominant strategy mechanisms.

of their strategic situation: subjects who will not receive their first choice in equilibrium exhibit a tendency to “skip-the-top” (Basteck and Mantovani, 2018) and rank their second choice first. Subjects generally do not exhibit this tendency when equilibrium dictates they will receive their top ranked choice.

Equilibrium assignments in TTC allow us to directly test whether the presence of justified-envy differentially impacts subjects with identical earnings by capturing biometric responses of the players that did not receive their first choice. We document a differential emotional response among subjects who experience any kind of envy in the school choice game–specifically, for every rank a subject’s assignment drops below their most preferred, subjects experience an additional 0.055–0.070μS peak arousal measured in galvanic skin response,[2] consistent with higher levels of arousal resulting from negative evaluations associated with envy; i.e., knowledge that another subject has an item they prefer to their allocation. We then similarly show that when subjects are informed about others’ assignments and primed on their specific condition of justified-envy, an unstable matching imposes 0.190-0.198μS greater peak arousal measured in galvanic skin response, all else equal.

While our results suggest greater arousal due to the presence of justified-envy, we can only infer that this type of arousal is due to negative feelings, and hence consistent with welfare loss. We base our inference on the Circumplex model which suggests negative affect is associated with a higher magnitude of arousal than positive affect.[3] To examine the robustness of our results, we conduct a second experiment to directly measure the emotional response to justified-envy using valence from facial expressions. The study features the same strategic incentives of the first study. However, to maximize observations of justified-envy, all subjects will play the role of the player who experiences justified-envy. The choices of the

[2]Skin conductance is not consciously controlled. Instead, it is autonomously regulated by sympathetic activity, which influences human behavior, cognition, and emotions at a subconscious level. The amount of sweat glands varies across the human body, being highest in hand and foot regions. The response of the skin and muscle tissue to external and internal stimuli, as bio-electrical phenomena, can be captured with a device that measures changes in electrical conductance that is typically measured in units of electric conductance known as microSiemens (μS).

[3]Specifically, the model suggests that while both positively and negatively valenced emotions can induce arousal, negative affective states are associated with higher arousal than positive affective states (Russell, 1980). This model has found consistent support in the empirical literature (Gatti et al., 2018; Lang, 2014; Kreibig, 2010; Jones and Troen, 2007; Posner et al., 2005; Haag et al., 2004; Sinha et al., 1992; Ekman et al., 1983).

other players are determined by the past play of subjects in the original study. As before, we exogenously vary whether a subject observes the assignments of the other subjects in their group.

Contrary to our prediction, we do not find evidence for an effect of justified-envy on valence. There appears to be a negative effect on emotions from observing the allocations of other subjects, but it occurs prior to many subjects realizing their envy is justified. We speculate our results may be due to (i) a differential effect of justified-envy on arousal and valence; (ii) an attenuated emotional response from subjects due to the fact they are observing past play of others rather than contemporary subjects; (iii) a misidentification of the treatment effect in our initial study. While we cannot determine which of these three explanations is correct and discuss further in our conclusion, we note that in either study subjects consistently do not notice their condition of justified-envy until prompted. Additionally, subjects appear to respond negatively to additional strategic information about their unfavorable assignments.

To our knowledge, we are the first study to use biometric measures to infer welfare properties of school choice mechanisms. Originating with Chen and Sönmez (2006), a variety of papers have compared theoretically predicted comparative statics of mechanisms with actual performance (e.g., Calsamiglia et al., 2010; Pais and Pintér, 2008; Stephenson, 2022). We draw on Basteck and Mantovani (2018) who specifically look at markers of bounded rationality and strategic play in these environments, but they do not measure biometric responses. Across our two studies, we measure gaze allocation through eye-tracking, arousal through galvanic skin response and valence through facial expressions. Other studies have used some of these measures with different strategic games. Eye-tracking is particularly common and has been used to infer social preferences, social orientation, and value in a variety of games (e.g., Fiedler et al., 2013; Fischbacher et al., 2022; Hausfeld et al., 2020; Hutcherson et al., 2015; Jiang et al., 2016; Smith and Krajbich, 2019, 2021). Perhaps closest to our work, Joffily et al. (2014) measures galvanic skin response and infers affect from surveys in a public goods setting. We use a different strategic environment and directly measure both arousal and valence.

The remainder of the paper is organized as follows. Section 2 characterizes the simplified and stylized school choice game that we will study in both a theoretical setting and its experimental application, including a description of Study 1 and predictions. Section 3 provides the results of Study 1. Section 4 explains the motivations behind Study 2, its procedures and provides results. Section 5 provides a general discussion of the implications of the findings of our two studies.

2 School Choice Mechanisms and the Experiment

In a school choice problem, there is a finite number of students and schools. Each student has a strict preference over all schools, whereas each school has a maximum capacity and a strict priority ordering of all students. School priorities are imposed by the school district based on state and local laws, and a random lottery. The outcome of a school choice problem is referred to as a matching (μ), which is an assignment of seats to students such that each student is assigned one seat and no school assigns more seats than its capacity. The three relevant measures for comparing the performance of school choice mechanisms are efficiency, justified-envy and strategy-proofness.

Definition 1 (efficiency) *A matching μ is Pareto efficient if there is no other matching which assigns each student a weakly better school and at least one student a strictly better school.*

Definition 2 (justified-envy) *A matching μ is said to eliminate justified-envy if there is no student-school pair (i, s) such that: (i) student i prefers school s to her assignment under μ, and (ii) student i has a higher priority at school s than some other student j who is assigned a seat at school s under μ.*

Definition 3 (strategy-proofness) *A mechanism is strategy-proof if reporting preferences truthfully is a weakly dominant strategy.*

Our experiment concerns two mechanisms, Deferred Acceptance (DA) and Top Trading Cycles (TTC). Both are strategy-proof. The dominant strategy equilibrium implemented by the DA satisfies justified-envy while the equilibrium implemented by the TTC satisfies efficiency. No mechanism can satisfy both (Abdulkadiroğlu and Sönmez, 2003). A generalized description of both matching algorithms follows.

2.1 Deferred Acceptance

DA asks applicants to submit a rank order list of schools. Together with the pre-announced capacity of each school, DA uses pre-defined rules and a random lottery to determine school priority rankings over students and consists of the following rounds:

Round 1: Every student applies to her first choice. Each school rejects the lowest ranked students in excess of its capacity and temporarily holds the others.

Round 2: Every student who is rejected in Round 1 applies to the second choice on her list. Each school pools together new applicants and those on hold from Round 1. It then rejects the lowest ranked students in excess of its capacity. Those who are not rejected are temporarily held.

Generally, in Round ($k \geq 3$): Every student who is rejected in Round $k-1$ applies to the next highest choice on her list. Each school pools together new applicants and those on hold from Round $k-1$. It then rejects the lowest ranked students in excess of its capacity. Those who are not rejected are temporarily held. The process terminates after any Round k in which no rejections are issued. Each school is then matched with those students whom it is currently holding.

2.2 Top Trading Cycles

TTC asks applicants to submit rank order lists of schools. For each school, a priority ordering of students is determined. TTC assigns students to schools following the process below:

Round 1: Each school points to its highest priority student and each student points to her most preferred school according to her reported preferences. Since there are a finite number of schools and students, the directed graph will have at least one cycle. Students who are part of a cycle are assigned to the school they point to. Participants, as well as their assignments, are removed from the system.

Round 2: The remaining applicants point to their most preferred school that still has open seats. Each school points to their highest priority student among those that remain unassigned. Since there are a finite number of schools and students, the directed graph will have at least one cycle. Students who are part of a cycle are assigned to the school they point to.

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2.3 The Experimental Game

Our experiment featured a 4-player game with four students and four schools. Each student had unique and strict preferences over schools that can be expressed in monetary terms (Table 1). School priorities were fixed over the four students (Table 2) with each school having a capacity of one.

Table 1: Student Preferences over Schools for the 4-person game

Utility of Assignment				
	School A	School B	School C	School D
Player 1	\$20	\$14	\$7	\$0
Player 2	\$20	\$14	\$0	\$7
Player 3	\$14	\$20	\$7	\$0
Player 4	\$14	\$20	\$0	\$7

Table 2: School Priorities

Priority Ranking				
	School A	**School B**	**School C**	**School D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3

Both the DA and TTC mechanisms implement a game where truth-telling is a (weakly) dominant strategy Nash Equilibria. Under the DA mechanism, the following assignment of students to schools occurs when all players play dominant (i.e., truthful) strategies,

$$\mu = \begin{Bmatrix} 1 & 2 & 3 & 4 \\ \\ C & B & A & D \end{Bmatrix}. \tag{1}$$

In the focal equilibrium assignment of DA, μ, Player 1 is assigned to School C, Player 2 is assigned to School B, Player 3 is assigned to School A and Player 4 is assigned to School D.[4] Under the TTC mechanism, a different assignment of students to schools occurs when all players play dominant (i.e., truthful) strategies,

$$\mu' = \begin{Bmatrix} 1 & 2 & 3 & 4 \\ \\ C & A & B & D \end{Bmatrix}. \tag{2}$$

In this matching, μ', Players 1 and 4 are assigned to the same schools as in matching μ, but Players 2 and 3 are assigned to strictly better schools. While matching μ' Pareto dominates μ, it does not eliminate justified-envy. Player 4 prefers School A over School D, and has a higher priority at School A than Player 2.

2.4 Experimental Design and Procedures

The experiment implements the game described in Section 2.3 in a 2×2 between-subject design. Subjects experience the two aforementioned mechanisms {DA, TTC} under FULL feedback where they learn the assignments of all other players after the game concludes, or PARTIAL feedback, where they only learn their own assignment. In the FULL feedback condition, subjects also receive a message with their relative rank at a more desirable option if they are not assigned to their most preferred option. In the PARTIAL feedback condition, subjects are informed of their assignment only, with no knowledge of others' assignments. Mechanism assignment was randomly assigned at the session level, but feedback was randomly assigned at the individual level.

[4]Player 4 is bossy in DA and decides whether players 2 and 3 are assigned to their first or second choice.

Subject emotional arousal is measured using Galvanic Skin Response (GSR) and visual attention is assessed using eye-tracking. GSR data are analyzed for two separate screens during the feedback stage. On the first screen, which lasts 30 seconds, subjects are informed of their assignment. If a subject is randomly assigned to the FULL treatment, the subject also observes the assignments of other group members. Immediately after, on a second screen, subjects receive a message that is designed to accentuate justified-envy when present. The structure of the message can be found in the Supplemental Appendix. If a subject is assigned to treatment PARTIAL, she is never informed about the assignments of other group members. Instead the subject receives a neutral message saying "This concludes the stage of this game."[5] GSR data are collected using Shimmer3 units at a sampling rate of 128 Hz (i.e. 128 observations per second).

Before the experiment begins, the instructions are read aloud and any questions are answered privately. Given the relatively complex nature of matching mechanisms, we allow subjects to read instructions again at their own pace if they wish to do so. After subjects finish reading instructions, a quiz is administered to ensure comprehension. Questions are intended to check that subjects understand (i) option capacities, (ii) how to read payoff and priority ranking tables, and (iii) solving a simple allocation problem given others' reports. Subjects were required to pass the quiz and correct any incorrect responses before proceeding. Instructions and the comprehension quiz are available as Supplemental Materials.

Subjects are randomly assigned to groups of four and each subject is randomly assigned to one of four preference types (1, 2, 3 or 4). Subjects play four unpaid "practice" rounds of similar school choice games so they can become familiar with the decision environment and the nature of the matching mechanisms. In each practice round, subjects are randomly matched, and face a new set of preference profiles and priorities; all differ from those shown in Tables 1 and 2. The overall structure of preferences and priorities are constant across experimental sessions and treatments. Before starting the incentivized one-shot game, subjects are informed that their earnings depend on the outcome of the following round. This round features the game described in Section 2.3 and is the sole basis for (differential) payoffs for subjects.

[5]Example screens for subjects assigned to different conditions can also be found as Supplemental Materials.

After the school choice game, subjects answer an open-ended question on how they played the game, other questions on their perception of a mechanism's manipulability, and complete a shortened version of the Raven's Progressive Matrices task (Raven, 2000); survey questions are available as Supplemental Materials.

A total of 24 sessions which contained 46 groups for 184 participants took place at the Human Behavior Lab at Texas A&M University between April 2021 and July 2022. Of these groups, 9 participated in the DA sessions and 37 in the TTC sessions. The TTC mechanism was intentionally oversampled to obtain more groups that experience justified-envy. Subjects were randomly assigned to feedback treatments using a block design at the session level, ensuring balanced sample sizes between treatments. Sessions lasted approximately one hour and subjects earned $24.14 (sd=6.342) on average including a $10 participation payment.

2.5 Predictions

Section 2.3 provides equilibrium predictions under dominant strategy play in the experiment for both the TTC and DA mechanisms. In this equilibrium, the TTC should lead to an outcome that is efficient but creates justified-envy. Conversely, assignments under the DA should have no justified-envy but they are not efficient. While it is exceedingly unlikely that every subject group will resemble equilibrium predictions exactly, we predict, consistent with previous literature (e.g., Chen and Sönmez, 2006) that comparative statics will hold.

Further, a common finding in empirical research with matching mechanisms is that people do not always play optimal strategies, but often their deviations do not affect their payoffs (Artemov et al., 2017, 2023; Chen and Pereyra, 2019; Rees-Jones, 2018; Hassidim et al., 2021; Shorrer and Sóvágó, 2018). These "strategic mistakes" are also found in experiments (Chen and Sönmez, 2006; Basteck and Mantovani, 2018). We expect some degree of similar behavior here.

Prediction 1 *Comparative statics of focal equilibria predictions will hold, that is,*

(a) The TTC will produce more efficient assignments than the DA.

(b) The DA will produce fewer assignments with justified-envy than the TTC.

(c) The comparative statics will hold because subjects will largely provide a truthful ranking of preferences at least where it is critical to the operation of the mechanism.

We measure arousal of our subjects through galvanic skin response. While we do not directly measure valence and therefore do not directly measure specific emotional responses, we use arousal to infer both. A consistent finding in the biometric response literature is that more negative evaluations of stimuli are associated with increased arousal (Russell, 1980; Gatti et al., 2018; Lang, 2014; Kreibig, 2010; Jones and Troen, 2007; Posner et al., 2005; Haag et al., 2004; Sinha et al., 1992; Ekman et al., 1983). To this end, we expect subjects that receive lower ranked choices in the school choice game to exhibit higher arousal.[6]

Prediction 2 *Subjects will exhibit higher GSR magnitudes with each subsequently lower ranked choice.*

Finally, we focus on the differential effect of justified-envy. Only Player 4s in a group will possibly incur justified-envy. While an allocation with justified-envy is endogenous to the group of players and allocation mechanism, the observation of others' allocations is exogeneously generated through randomization. A subject must be assigned to the FULL treatment to be able to observe others' allocations and realize their envy is justified.

Prediction 3 *Holding preference ranks constant, subjects who experience justified-envy will exhibit increased arousal in the FULL but not in the PARTIAL treatment. That is, subjects that receive identical assignments under justified-envy will exhibit higher GSR response in the FULL treatment.*

3 Results

Result 1 *Theoretically predicted comparative statics hold. That is,*

(a) The TTC mechanism achieves more efficient assignments than DA.

(b) The DA mechanism achieves more assignments without justified-envy than TTC.

Table 3: Group-Level Outcomes of Deferred Acceptance (DA) and Top Trading Cycles (TTC) Mechanisms

	Groups	Focal Equilibrium Assignments	Full Efficiency	Elimination of Justified-Envy
DA	9	6 (66.7%)	1 (11.1%)	8 (88.9%)
TTC	37	17 (45.9%)	17 (45.9%)	16 (43.2%)
Total	46	23 (50.0%)	18 (39.1%)	24 (52.2%)

Table 3 examines group-level outcomes of whether the two mechanisms achieved focal equilibrium assignments, full efficiency, and eliminated justified-envy. The TTC achieves full efficiency but does not eliminate justified-envy in this equilibrium. The DA, in its focal equilibrium, should eliminate justified-envy but not reach full efficiency. Consistent with Prediction 1, the comparative statics of theory hold. The elimination of justified-envy is achieved in all but 1 DA group (88.9%) and about half of the TTC groups (43.2%) (Fisher exact test, $p \approx 0.023$ two-tailed; $p \approx 0.016$ one-tailed). In contrast, only 1 (11.1%) DA group is fully efficient compared to nearly half (45.9%) the TTC groups (Fisher exact test, $p \approx 0.069$ two-tailed; $p \approx 0.057$ one-tailed). Mean group payoffs are also $1.58 higher per person under the TTC compared to DA ($11.64 vs. $10.06; Wilcoxon rank-sum test, $p \approx 0.086$ two-tailed; $p \approx 0.043$ one-tailed).[7]

We examine the robustness of Result 1 in a linear probability model. This specification controls for possible session-level correlations between groups as well as the number of subjects in the FULL treatment who received additional feedback at random.[8] We report regression results in Table 4. TTC is not more likely to achieve its focal equilibrium outcome. Consistent with Prediction 1, TTC is 35 probability points more likely to achieve

[6]A potential confound for this prediction is that surprise also generates arousal. Subjects who receive lower-ranked choices may be surprised that they do not receive higher ranked ones. We keep this possibility in mind as we interpret our results.

[7]Due to our intentional oversampling of the TTC mechanism (see Section 2.4), our power to detect a difference between these treatments is limited. However, all three of our three predictions are unidirectional. While a one-tailed test is technically more appropriate in statistics, we report both one- and two-tailed tests to avoid confusion, leaving it to the reader to decide the appropriate significance level. While this distinction is usually trivial, the Fisher exact test is unusual in that it is an exact test based on an inherently asymmetric distribution, so the one-tailed and two-tailed p-value cannot be directly derived from each other. Nonetheless we follow this convention in reporting throughout our analysis even with symmetric tests.

[8]Subjects assigned to the FULL treatment received additional feedback over the four practice rounds. While this assignment was done randomly and exogenous to other treatments, it is possible that subjects assigned to treatment FULL may act differently.

Table 4: Linear probability model of theoretical properties on mechanism and number of FULL treated subjects in group. All regression models use cluster-robust standard errors at the session level.

	(1) Focal Equilibrium Assignments	(2) Full Efficiency	(3) Elimination of Justified-Envy
TTC	-0.207	0.348**	-0.456***
mechanism	(0.173)	(0.140)	(0.146)
# of FULL	-0.091	-0.091	0.091
treated subjects	(0.131)	(0.113)	(0.091)
constant	0.848**	0.293	0.707***
	(0.309)	(0.257)	(0.220)
Observations	46	46	46
Sessions	24	24	24

p-values (two-tailed): $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$

an efficient outcome; DA is 46 probability points more likely to achieve an outcome that eliminates justified-envy.

Given that the comparative statics of theory hold and focal equilibrium outcomes are often achieved, we now examine the types of strategies played by subjects. Prediction 1(c) stated that while subjects might deviate from their truthful, weakly dominant strategy, these deviations will generally be done in ways that do not affect payoffs.

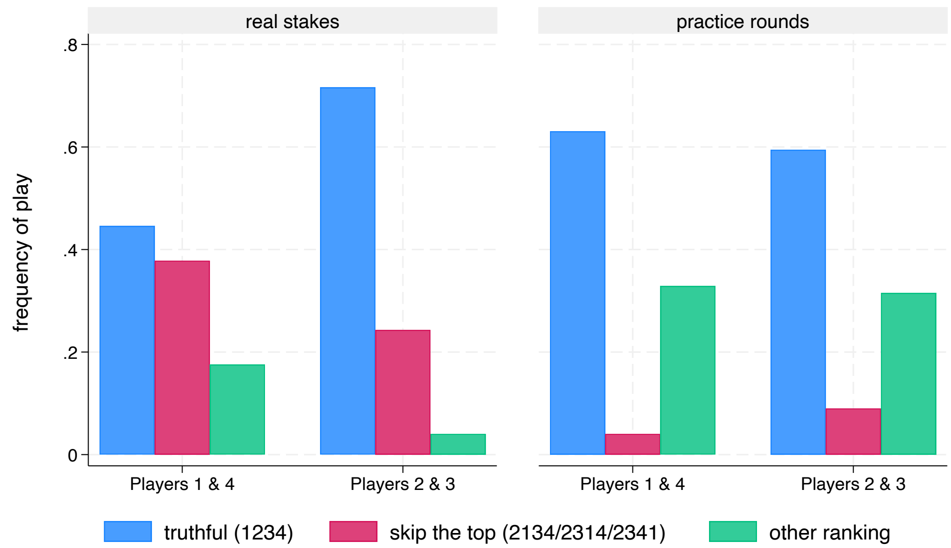
Result 2 *Subjects play different strategies dependent on their role.*

(a) Player 2 and 3 subjects, who will receive their first and second choice in the equilibrium of the TTC and DA, respectively, rank their most preferred option first and generally play the (weakly) dominant strategy of truthful revelation.

(b) Player 1 and 4 subjects, who will receive their third choice in equilibrium, exhibit a tendency to "skip-the-top," and rank their second most preferred option first. They play this strategy with the same frequency as their truthful dominant strategy.

Subjects assigned the role of Player 2 or 3 will receive their first (second) choice option in the focal equilibrium of the TTC (DA). These subjects exhibit a general tendency to rank their top choice first (73% TTC; 78% DA), and further play the (weakly) dominant strategy of truthful revelation–ranking each option according to preferences—to a high degree (72% TTC; 67% DA).

Figure 1: Strategies played by subject role in the TTC. The left panel shows the strategies played by Player 1 & 4 and Player 2 & 3 subjects in the one incentivized round of the experiment. The right panel shows the strategies played in practice rounds where all types would receive their most preferred option in equilibrium.



Player 1 and 4 subjects will receive their third most preferred option in the focal equilibrium of either mechanism. In contrast to the previously described types, these subjects rank first their second most preferred option roughly as often as their first most (39% vs. 51% TTC; 39% vs. 50% DA). The ranking of the second-most preferred option first does not appear to be due to confusion of subjects; subjects using these strategies almost always correctly order their 2nd, 3rd and 4th preferences. Rather these strategies appear to be a version of the "skip-the-top" strategy that has been documented in previous literatures (see Basteck and Mantovani, 2018).

Figure 1 categorizes strategies played by Player 2 and 3 compared to Player 1 and 4s under the TTC mechanism. We characterize three types of strategies: (i) a truthful ranking of preferences; (ii) a skip-the-top ordering of preferences where all but the first option is correctly ordered; (iii) and other strategies. The left panel shows the proportion of play in the incentivized one-shot game while the right panel shows data from 3 practice rounds where all subjects would receive their most preferred option in equilibrium.

As the figure indicates, Player 1 and 4 subjects play different strategies than Player 2 and 3s in the incentivized round of the TTC (Fisher exact test, $p \approx 0.001$). A similar result (not shown) holds for the DA but is weaker due to a smaller sample (Fisher exact test, $p \approx 0.056$). In the three practice rounds where all four subjects would receive their most preferred option in equilbrium, we do not see differences across player roles. Across these rounds, subjects rank their most preferred option first roughly 80% of the time regardless of player role. Since subjects are randomly assigned to player roles across these practice rounds, we can confirm this number does not differ within subjects by type (paired t-test: $p \approx 0.603$ TTC, $p \approx 0.354$ DA).

The previous results suggest that in a good deal of cases the TTC and DA mechanisms will work as expected and subjects have a basic understanding of how options are allocated. Particularly, a large segment of Player 1 and 4 subjects do not expect to receive their most preferred option.

We now examine what type of outcomes generate higher arousal in galvanic skin response.

Result 3 *Higher levels of arousal in galvanic skin response are associated with being assigned to lower ranked choices.*

Over all results, only four distinct allocative assignments were realized, which comprise the complete set of equilibrium outcomes. Table 5 characterizes all four and their frequency in the experiment. Allocations μ (see equation (1)) and μ' (see equation (2)) are the dominant-strategy equilibria of the DA and TTC mechanisms, respectively. The other two allocations, ν and ν', provide useful analogues as they only differ from those allocations in that players 1 and 4 now receive their least preferred alternative. Under μ' and ν' Player 4 also experiences justified-envy despite having the identical assignment to allocations μ and ν, respectively.

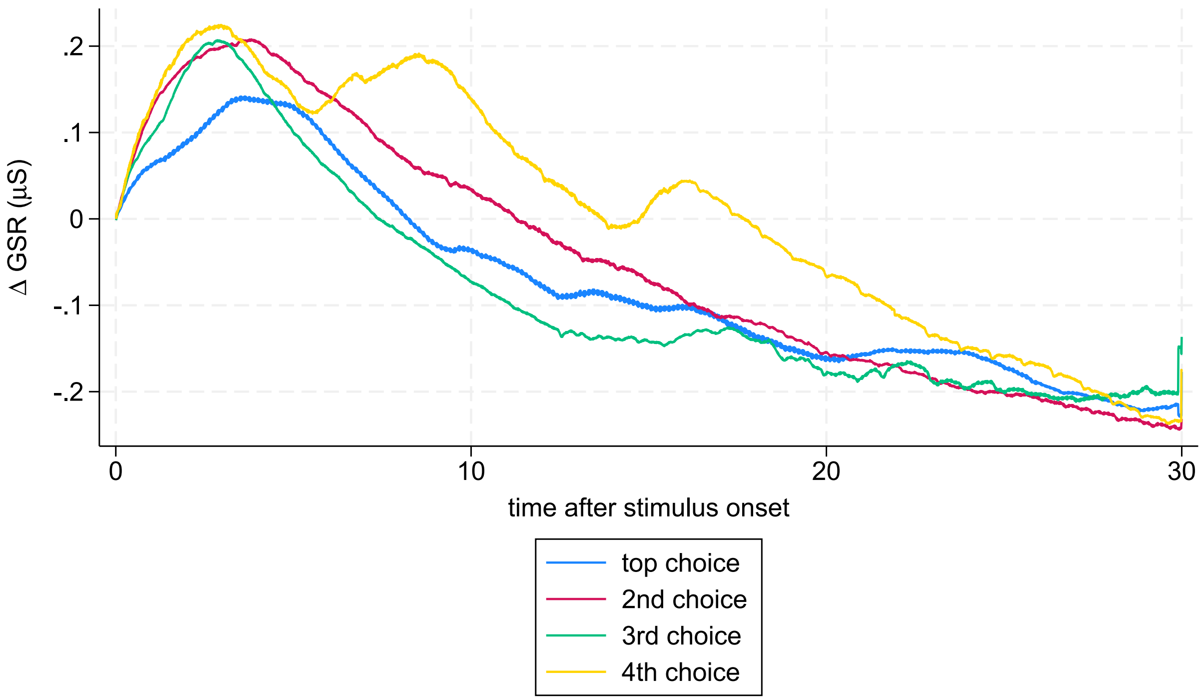
Table 5: Allocative Outcomes Observed in the Experiment

Matching Allocation	Assignment (Player-School)	Payoffs	Observances Per Group of 4
μ	1-C, 2-B, 3-A, 4-D	$(7, 14, 14, 7)$	20 (43.5%)
μ'	1-C, 2-A, 3-B, 4-D*	$(7, 20, 20, 7)$	18 (39.1%)
ν	1-D, 2-B, 3-A, 4-C	$(0, 14, 14, 0)$	4 (8.7%)
ν'	1-D, 2-A, 3-B, 4-C*	$(0, 20, 20, 0)$	4 (8.7%)

* Player 4 has justified-envy toward Player 2.

Using these four outcomes, we can examine whether subjects who experience envy exhibit higher arousal as captured by GSR magnitude which is calculated as the difference between

Figure 2: Skin Conductance by Preference Rank of Received Choice (Results Stage)



the signal amplitude at the peak and the onset times with the unit measurement being in microSiemens (μS).[9]

Figure 2 shows dynamic changes in galvanic skin response levels averaged across subjects by realized choice of outcome over the first 30 seconds after results are realized (i.e., the "Results Stage"). Peak response–usually in the first few seconds after results are shown—follows a pattern consistent (albeit not perfect) with the reverse order of preference rank received: it is highest for subjects who receive their fourth ranked choice, then third, second and first. The duration of increased arousal is noticeably different for subjects who receive their 4th choice (increasing for nearly 15 seconds) and perhaps those who receive their 2nd (increasing for over 10 seconds), and noticeably different from similar typed counterparts that receive a slightly more preferred option.

Table 6 provides a regression model of peak response during the Results Stage (models 1 & 2), the Message Stage (models 3 & 4), and a combined model of both stages that

[9]Data are limited to 130 subjects due to ectopic responses and capacity constraints in Shimmer3 units. Sample sizes are well balanced between the PARTIAL (N = 64) and FULL (N = 66) conditions. Of these 130 subjects, 31 subjects earned \$20, 41 earned \$14, 47 earned \$7, and 11 earned \$0.

features subject random effects (models 5 & 6). Note that the first four models cannot have random effects terms as they only provide one observation per subject. Models (1) and (5) both suggest that in the Results Stage for each subsequently lower ranking from one's most preferred outcome, subjects exhibit 0.055 μS higher level of measured galvanic skin response in the Results Stage ($p \approx 0.094$ two-tailed; $p \approx 0.047$ one-tailed). There is no similar effect in the Message Stage ($p \approx 0.484$–0.217 two-tailed; $p \approx 0.288$–0.108 one-tailed). When other controls are added the magnitude of the effect is slightly greater, 0.070 μS in models (2) and (6). In the latter model (6) the effect reaches its highest level of significance ($p \approx 0.048$ two-tailed; $p \approx 0.024$ one-tailed).

Taken together, we interpret these results as showing that envy in the form of lower payoffs is detected in greater arousal in galvanic skin response, supporting Prediction 2.

Result 4 *When subjects with justified-envy are alerted that their envy is justified, they exhibit greater levels of arousal in galvanic skin response.*

We now look at subject response to the realization of justified-envy. Recall that in all student-to-school assignments only Player 4 may experience justified-envy, either with their 3rd most preferred (allocation μ') or 4th most preferred option (ν'). Because it requires the observance of others' assignments, subjects can only learn their envy is justified in treatment FULL where such information is disclosed. Further, because subjects still may not realize their envy is justified, we explicitly tell subjects in the FULL treatment about this condition 30 seconds after results are disclosed, in what is called the "Message Stage."

Figure 3 provides a breakdown of GSR change by feedback stage and information treatment when subjects experience justified-envy. In general, subjects experience similar levels of arousal during the Results Stage. Upon receiving a message that alerts subjects to their case of justified-envy, subjects experience increased arousal for a substantial duration of the stage.

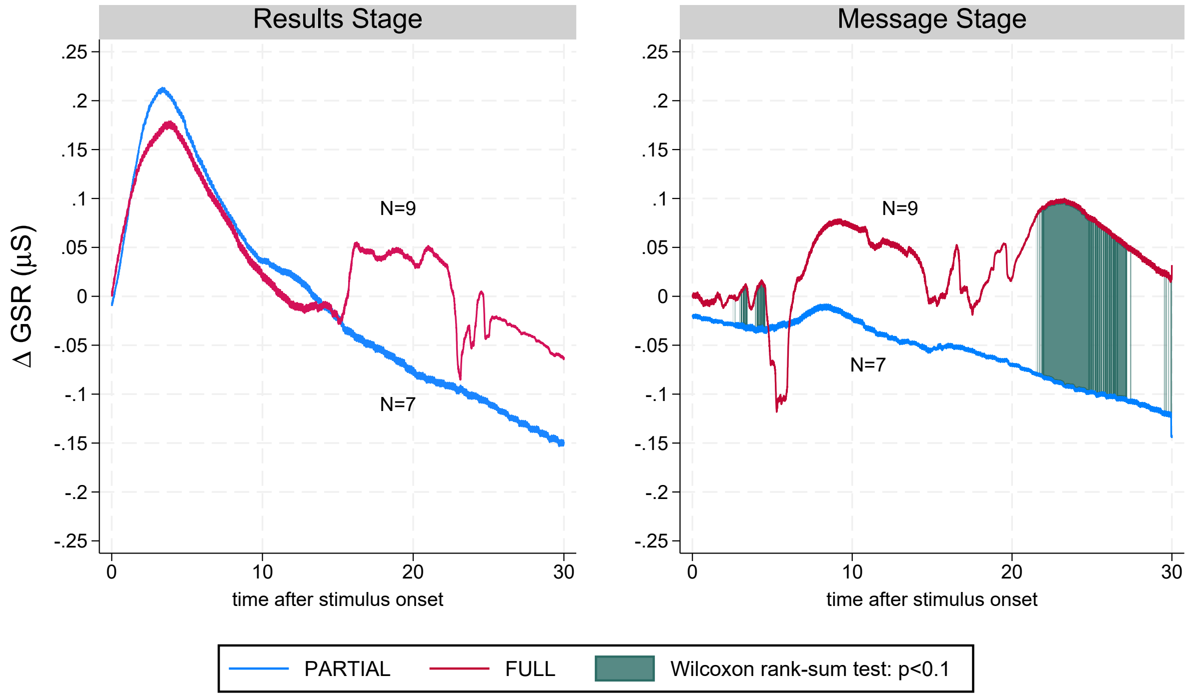
We conduct functional Wilcoxon rank-sum tests to examine if there are statistical differences between subjects who experience justified-envy in different feedback information treatments. Since GSR data were collected at 128 Hz, we conducted 3840 such non-parametric

Table 6: Regression of peak GSR magnitude on preference rank of received alternative and realization of justified-envy interacted with FULL information treatment. GSR magnitude was measured for 30 seconds after subjects learned the results of the mechanism (1) & (2) and another 30 seconds after they received a message notifying them of the end of the experiment (3) & (4). A final model (5) & (6) combines observations in a panel, utilizing subject random effects. All regression models use cluster-robust standard errors at the session level.

	Results Stage		Message Stage		Combined Panel Model	
VARIABLES	(1) GSR magnitude	(2) GSR magnitude	(3) GSR magnitude	(4) GSR magnitude	(5) GSR magnitude	(6) GSR magnitude
ranks from top	0.055*	0.070*	0.016	0.033	0.055*	0.070**
(1st=0)	(0.031)	(0.036)	(0.022)	(0.026)	(0.031)	(0.036)
message stage					-0.055	-0.048
					(0.078)	(0.095)
FULL		0.001		-0.016	0.000	0.001
		(0.070)		(0.051)	(0.043)	(0.070)
message ×					-0.039	-0.037
ranks from top					(0.039)	(0.045)
justified-envy		-0.121		-0.239***		-0.121
		(0.103)		(0.041)		(0.103)
FULL ×		-0.004		0.194*		-0.004
justified-envy		(0.113)		(0.111)		(0.113)
message ×						-0.118
justified-envy						(0.112)
message × FULL						-0.017
						(0.071)
message × FULL ×						0.198*
justified-envy						(0.102)
constant	0.266**	0.260***	0.211***	0.212**	0.266***	0.260***
	(0.055)	(0.067)	(0.048)	(0.052)	(0.057)	(0.068)
Subject Random Effects?	n/a	n/a	n/a	n/a	Y	Y
Observations	130	130	130	130	260	260

p-values (two-tailed): *** p<0.01, ** p<0.05, * p<0.1

Figure 3: Skin Conductance by Feedback Stage and Information Treatment when Justified-Envy is Realized



tests for each comparison.[10] The shaded area in the figure represents the time period comparison with a statistically significant difference between the FULL and PARTIAL information conditions.

Overall, the arousal reaction in the PARTIAL feedback condition appears more stable and flatter relative to the FULL feedback condition that has several peaks, perhaps as a result of participants processing the message. However, we note that statistical differences begin to emerge upon receiving the message (Wilcoxon rank-sum tests, $p < 0.10$, two-tailed, during the first 5 seconds) and toward the end of the Message Stage (Wilcoxon rank-sum

[10]Our approach is based on functional data analysis, where temporal galvanic skin response data are transformed into curve functions to then conduct statistical analyses on these very functions over the entire time window of thirty seconds. Crucially, this approach ensures that all of the data are used instead of an arbitrary subset of time following stimulus onset that is summarized to discrete values. Such approaches may lead to instances where effects are subtle, but false negatives may be reported. Another advantage of this approach is that while the original data is a function of time, so are the associated statistical tests with these data. To illustrate this, a Wilcoxon rank-sum test is not a single value, but a curve function that can be expressed over time, which then allows us to examine if and when statistically significant differences in arousal may have emerged. These properties eliminate concerns over arbitrariness of window time selection found in common approaches (Sirois and Brisson, 2014).

tests, $p < 0.10$, two-tailed, in the interval between 21-29 seconds). For a Player 4 subject to understand the message that accentuates justified-envy, she must attend to her own induced preferences, the assignment of Player 2, and priorities at Option A.

Table 6 also estimates changes in galvanic skin response magnitude in both the Results and Message stages on FULL treatment interacted with justified-envy. As our previous result indicated, rank of received choice has predictive value in the Results Stage. In the second, Message Stage, where rank of received choice has little explanatory power, we see that subjects experiencing an assignment with justified-envy and who are not informed of this condition have typically low arousal. However, a message that accentuates the occurrence of such envy, leads to a significant increase in arousal of roughly 0.194 μS higher level of measured galvanic skin response in the Message Stage compared to other subjects that do not see the message (model 4: $p \approx 0.093$ two-tailed; $p \approx 0.046$ one-tailed). The magnitude of the effect, 0.198, is similar in the combined model with subject random effects (model 6: $p \approx 0.052$ two-tailed; $p \approx 0.026$ one-tailed). It is also apparent that there is not a similar effect in the Results Stage. The estimated term, -0.004, is roughly 0 (see models (2) and (6)). That is, subjects do not appear to differentially respond to the presence of justified-envy until they are alerted to it.

Thus we find evidence to support Prediction 3, but with one strong qualification. Subjects appear to exhibit increased arousal when receiving an allocation under justified-envy, however, such arousal will only appear when subjects are explicitly told about this occurrence.

Comparing the magnitudes of our last two results, the estimated terms for the increased arousal of justified-envy in the Message Stage (0.190–0.198 μS) and the drop of one preference rank in the Results Stage (0.055-0.070 μS) are quite consistent across our regression models. Using model (6), we can estimate the ratio of the two terms to be roughly 2.8, that is, the increased arousal of being informed of justified-envy is a little less than the increased arousal from a subject receiving their fourth choice rather than their first (a drop of 3 ranks). This term is imprecisely estimated, however, and we provide it more as a ballpark term for discussion rather than a precise estimate.

Result 5 *In the FULL treatment, subjects do not appear to notice their case of justified-envy* *until prompted in the Message Stage. Once alerted, they dedicate a disproportionate amount of their visual attention towards the accentuating message and the relevant option.*

Result 4 implies that subjects do not notice their particular case of justified-envy until they are explicitly told of its existence in the Message Stage. Using eye-tracking data, we can corroborate this claim, specifically a subject's visual focus towards the priority levels of their options and earnings of other subjects both before and after they are informed of the condition.

Figure 4 reports the mean proportion of gaze time allocated toward relevant Areas of Interest (AOIs) for Player 4 subjects in matching allocations μ' and ν'. Each subject in these specific allocations experiences justified-envy towards Player 2, but unjustified-envy towards Player 3. Figure 5 provides the same results for Player 1 subjects who envy both Players 2 and 3 without justification. Note that in both figures, because the values are proportions, subject totals are bounded above by 1; they need not sum to 1, as subjects may gaze elsewhere, including off-screen.

In the Results Stage (Figure 4(a)), neither Player 1 nor 4 subjects show interest in priority rankings relative to other AOIs. They focus instead on the earnings of the who received their top choice (Player 2 or 3), their earnings, and the allocations of others.

We use a regression framework to estimate if these gaze patterns are different. Specifically, we estimate the model

$$dwell\ time\ gaze = \sum_{i=1}^{11} \alpha_i AOI_i + \sum_{i=1}^{11} \beta_i Player\ 4 \times AOI_i + \epsilon \tag{3}$$

where each AOI is assigned an indicator variable. There are also separate indicator variables for the interaction of AOI with Player 4. Because of the high number of indicator variables, we absorb the AOI dummies and only focus on the interaction terms (see Appendix Table A1 column (1) for full table). All standard errors are clustered at the session level.

We can reject the null hypothesis that gaze time for these 11 AOIs are jointly equal across subject types (i.e., the 11 interaction terms are jointly null, $p \approx 0.014$). However the differences appear likely due to differences in the earnings and allocation tables and are least apparent in the priority ranking table where, if anything, Player 1s appear to spend

Figure 4: The proportion of gaze time is averaged for each AOI for subjects in the FULL treatment under matching allocation μ', and ν', for subjects that experience justified-envy (Player 4s). The bold rectangles represent AOIs (not visible to the subjects) and the numbers in bold correspond to the proportion of gaze time of each AOI.

(a) Results Stage

Earnings by Assignment					
	Option A	Option B	Option C	Option D	
Player 1	$20	$14	$7	$0	**0.039**
Player 2	$20	$14	$0	$7	**0.032**
Player 3	$14	$20	$7	$0	**0.050**
Player 4	$14	$20	$0	$7	**0.039**

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3
	0.022	**0.015**		

In this round, you were Player 4

My Assignment: D	**0.035**
Player 1 Assignment: C	**0.058**
Player 2 Assignment: A	**0.058**
Player 3 Assignment: B	**0.040**
Earnings: $7	**0.033**

(b) Message Stage

Earnings by Assignment					
	Option A	Option B	Option C	Option D	
Player 1	$20	$14	$7	$0	**0.024**
Player 2	$20	$14	$0	$7	**0.037**
Player 3	$14	$20	$7	$0	**0.020**
Player 4	$14	$20	$0	$7	**0.017**

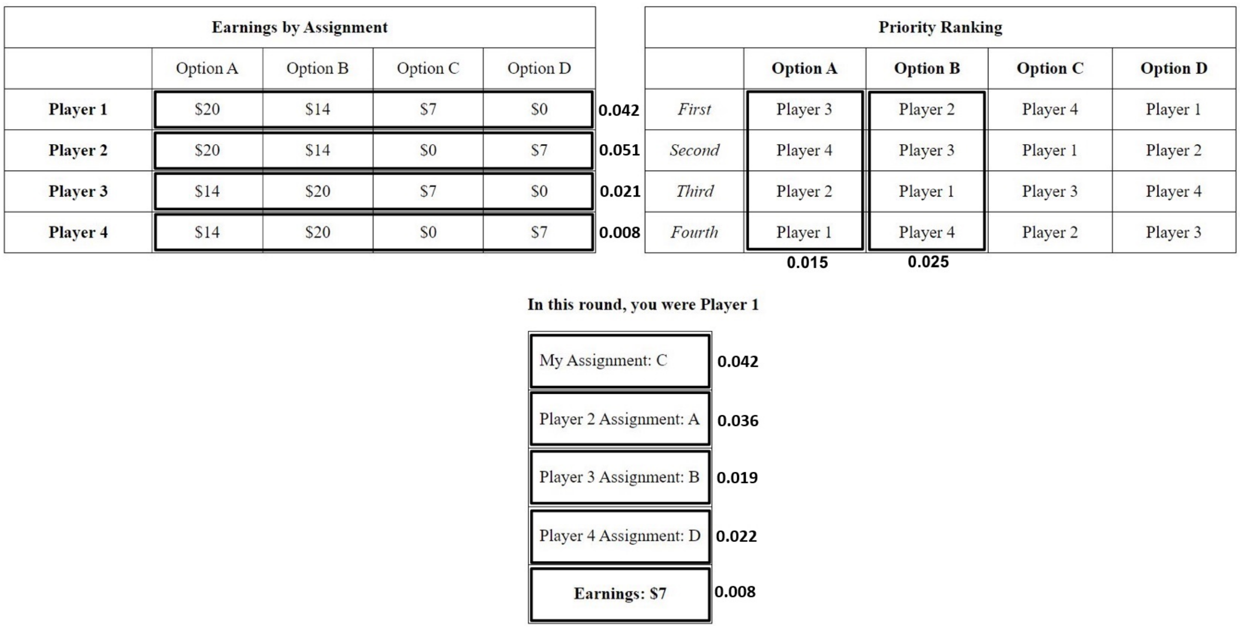
Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3
	0.082	**0.013**		

In this round, you were Player 4

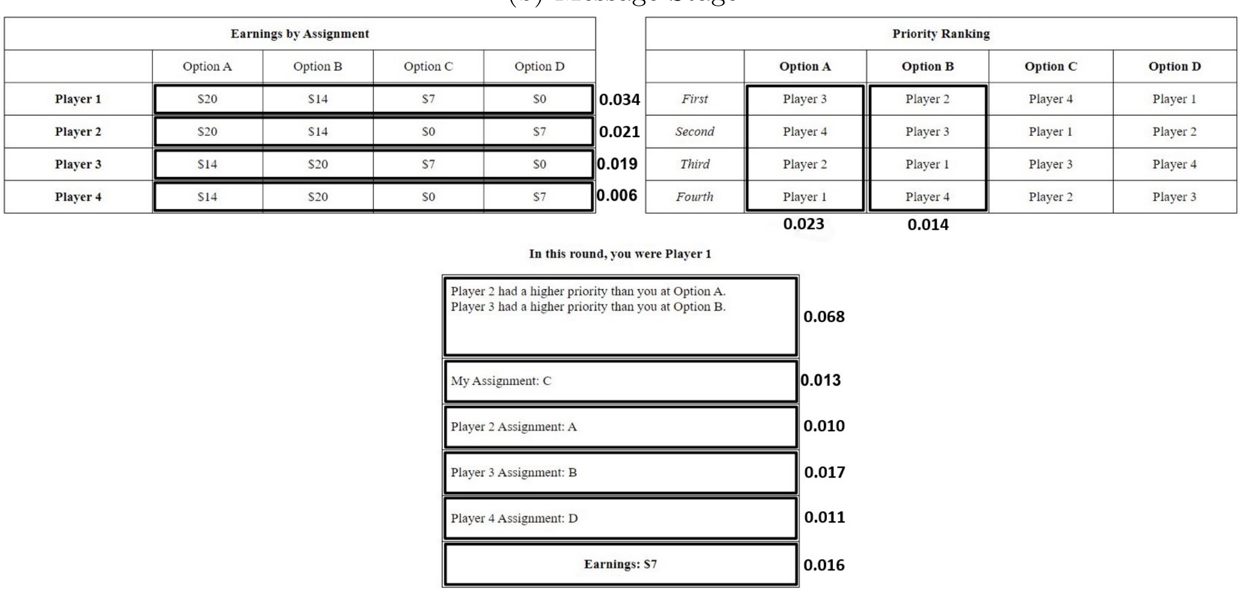
Player 2 had a lower priority than you at Option A.	**0.123**
My Assignment: D	**0.022**
Player 1 Assignment: C	**0.029**
Player 2 Assignment: A	**0.031**
Player 3 Assignment: B	**0.023**
Earnings: $7	**0.019**

Figure 5: The proportion of gaze time is averaged for each AOI for subjects in the FULL treatment under equilibrium allocation μ', or ν', for Player 1s that do not experience justified-envy. The bold rectangles represent AOIs (not visible to the subjects) and the numbers in bold correspond to the proportion of gaze time of each AOI.

(a) Results Stage



(b) Message Stage



marginally *more* focus.

In the Message Stage, Player 4 subjects receive a message designed to accentuate justified-envy towards Player 2 (see Figure 4(b)). Player 1 subjects have no justified-envy and only receive a message that accentuates envy (Figure 5(b)). Subjects assigned to the Player 4 role focus most on the message explaining the justified-envy condition and second most on the priority ranking of Option A. This pattern is not found among Player 1 type subjects. Using a similar regression framework as equation (3)—this time with one more AOI—we can reject the null hypothesis of these 12 AOIs having equal mean gaze duration across subject types ($p \approx 0.047$). Using the dependent variable of the change in gaze time, we note that the change in dwell time across all 12 AOIs is jointly different ($p \approx 0.000$, see Table A1 column (3) for full interaction dummy estimates).

As the table suggests, the pairwise differences of greatest magnitude occur in the AOIs that involve the Message and Option A (the Option that prefers Player 4 to the assigned Player 2, a situation of justified-envy). Over these two AOIs, Player 4 subjects spend 11.42 more percentage points of their gaze time than Player 1s ($p \approx 0.052$ based on sum of two dummy variables). We find effects of similar magnitude and significance if we instead look at the differential changes for Player 1s and 4s between periods—the total difference-in-difference for those two AOIs is 10.70 percentage points. In the Appendix, we repeat the same analysis for total fixations on AOI rather than dwell time. The results imply Player 4s have 14.80 more total fixations ($p \approx 0.023$) and 13.68 greater differential fixations relative to the results stage ($p \approx 0.021$) in these two AOIs.

It is difficult to think of an explanation for these findings other than the most simple. Player 4 subjects were not aware of their particular case of justified-envy in the Results Stage. After receiving a Message designed to alert them to it, subjects began to consider their particular case of justified-envy. Other subjects do not exhibit a similar pattern of visual focus which likely means this pattern is triggered by a subject considering their situation involving justified-envy.

4 Study 2: Valence and Justified-Envy

Our first study is limited by the fact that it was conducted at a time when subjects were required to wear masks. Consequently, we were unable to observe subject facial expressions and do not have direct measurement of valence response. We instead measured arousal using galvanic skin response and inferred emotional response. Arousal may or may not indicate negative valence and our results prompted further investigation. An additional limitation is that the observations of interest are Player 4 subjects under justified-envy. Despite using 184 subjects, only 16 (see Figure 3) experienced justified-envy, the main property we wish to investigate.

We address both limitations in a follow-up Study 2. To specifically measure valence, we use facial expression software. To increase the observation of justified-envy within the sample, all subjects play as Player 4 against a past profile of other player strategies.

All subjects play under the TTC mechanism. Under that mechanism in Study 1, 15 total subjects experienced justified-envy. Each Study 2 subject is randomly assigned to one of these 15 past subjects. Study 2 randomly assigns participants into the FULL or PARTIAL treatment condition similar to Study 1. For all four practice rounds and the incentivized one-shot round, the Study 2 subject encounters the same strategies from other players as their Study 1 counterpart. Since a subject still makes a strategic choice, their outcome may or may not match their Study 1 counterpart. However, the strategies of Players 2 and 3 are fixed and determine the condition of justified-envy for Player 4. Thus, a Study 2 subject will always experience that condition. The experimental instructions fully informed subjects that they are playing against past distributions and not active subjects.

Subjects' affective responses are also assessed during the two feedback stages using a facial expression analysis software called AFFDEX by Affectiva (McDuff et al., 2016; Stöckli et al., 2018).[11] This software captures slight changes in facial muscle movement in anatomical features (i.e., mouth, nose, eyebrows, etc.) and can measure the extent to which a subject experiences each of eight emotional states (joy, sadness, anger, disgust, contempt, fear, surprise and confusion). It is noninvasive and operates through any high-resolution

[11] We smooth out ectopic response artifacts prior to conducting mean and dynamic analyses. We use the Stata *lowess* package for this purpose.

webcam.[12] The primary outcome of interest from facial expressions data in our study is *valence* which tracks a subject's general emotional state, taking positive values when facial expressions indicate positive emotions and negative values when facial expressions indicate negative emotions.[13]

A total of 84 Texas A&M undergraduate students participated in Study 2. Data were collected in September 2025. An average session lasted about 45 minutes and subjects on average earned $16.00 (sd=2.464). The experiment was pre-registered at AsPredicted (#241742) with a commitment to enroll 80 subjects (40 subjects/treatment arm) which would suggest the study is powered to detect medium to large effect sizes (Cohen's d≈0.63; two-sided t-test; significance level=0.05; power=0.8).

4.1 Prediction

Study 2 allows us to further isolate responses to justified-envy while eliminating path of play concerns. We focus on an analogue of Prediction 3 that subjects will have a greater negative emotional reaction once being informed of justified-envy in the Message Stage.

Prediction 4 *Subjects will exhibit greater negative valence in the FULL than in the PARTIAL treatment. This will be a reaction to justified-envy that is only manifested in the Message Stage after subjects are alerted their envy is justified.*

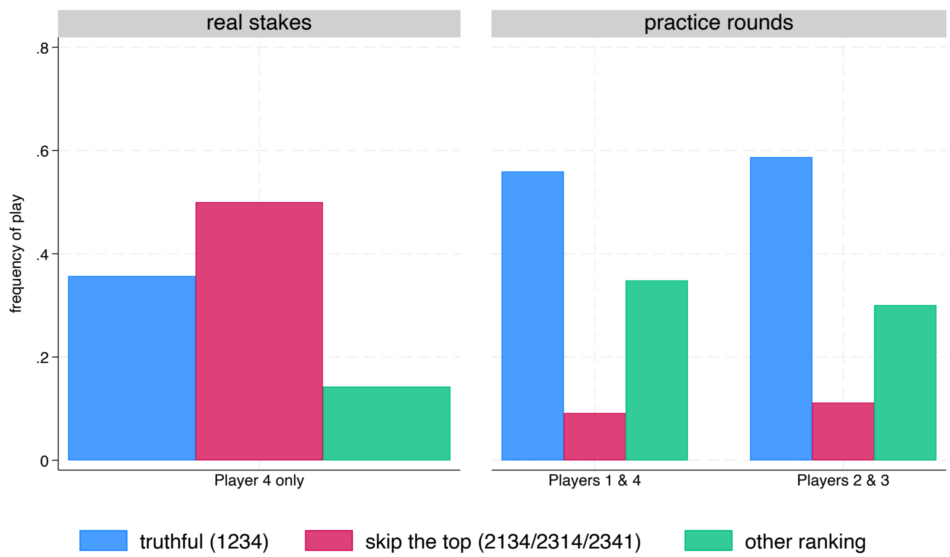
4.2 Results

We begin our analysis of Study 2 by confirming that subjects responded to the experiment in similar fashion as subjects in Study 1. While the strategic incentives are the same, subjects in

[12]Once a subject's face is recognized by the software, it registers key facial landmarks that are used to detect emotion-related features. This information is then fed to a computer algorithm that uses a database of facial expressions of over 5.3 million faces from across the globe to determine the subject's emotional state (Zijderveld, 2017). AFFDEX then generates an index for each emotional state that reflects the degree to which the subject's expression aligns with a particular emotion. The index for each emotional state is unidirectional and ranges between 0 and 100, where 0 indicates no expression of a particular emotion (e.g., surprise) whatsoever, and 100 is the highest level of confidence in a specific expression of emotion. AFFDEX has been previously validated as an accurate tool for measuring emotions (González-Rodríguez et al., 2020; Kulke et al., 2020).

[13]This measure ranges between -100 and +100 and is constructed as an index intended to capture facial expressions of overall positive or negative emotions, with zero indicating a neutral state.

Figure 6: Strategies played by subject role (Study 2). The left panel shows the proportion of strategy types played in the incentivized round of the experiment (all subjects were Player 4s). The right panel shows the proportion of strategy types played in practice rounds where all player roles would receive their most preferred option in equilibrium.



Study 2 were playing against past distributions of subject play rather than actual subjects in the same room. We specifically examine similarities in strategic play and eye-tracking gaze.

Result 6 *Study 2 subjects make similar strategic choices and have similar gaze patterns as Player 4 subjects in Study 1. They also appear similarly unaware of their condition of justified-envy until alerted.*

In Study 1, subjects in the Player 4 role exhibited a tendency to "skip-the-top," ranking their second-most preferred option first and all but their most preferred option in order. Subjects appeared to only use these types of strategies when they are harmless; they were rarely employed when a subject would obtain their most preferred option in equilibrium.

Figure 6 shows similar results hold in Study 2, where all subjects played the role of Player 4. Subjects give their truthful ranking, a weakly dominant strategy, slightly less often than a skip-the-top strategy, where a subject ranks their second option first and all but the first option in order (50%). The proportion of strategy choices does not differ significantly with Player 4 subjects in Study 1 ($p \approx 0.891$, Fisher exact test). Also consistent with Study

1, in practice rounds where their most-preferred option would be obtained in equilibrium, subjects rank their most-preferred option first with high frequency (79%) and play their truthful weakly dominant strategy a majority of the time (58%). Like in Study 1, Figure 6 indicates there are no differences across types in these practice rounds (Fisher exact test, $p \approx 0.693$).

While a number of subjects appear to be aware that they will not receive their most preferred option in equilibrium, there is little evidence they are aware of the condition of justified-envy until notified. Using eye-tracking data, we compare the gaze duration for subjects that were assigned to treatments FULL and PARTIAL in both the Results and Message stage (Figures 7 and 8).

As the figures indicate, subjects in the FULL treatment had 11 AOIs compared to only 8 in the PARTIAL treatment. To compare across treatments, we focus our comparison on the 8 common AOIs (9 in Message Stage). We follow a similar regression framework as before (recall Equation (3)) except that we use 8 and 9 AOIs in our summation indices for the Results and Feedback Stages, respectively. Equation (4) shows our regression specification where the proportion of dwell time is the dependent variable.[14]

$$\textit{dwell time gaze} = \sum_{i=1}^{8} \alpha_i AOI_i + \sum_{i=1}^{8} \beta_i \textit{Full Information} \times AOI_i + \epsilon \qquad (4)$$

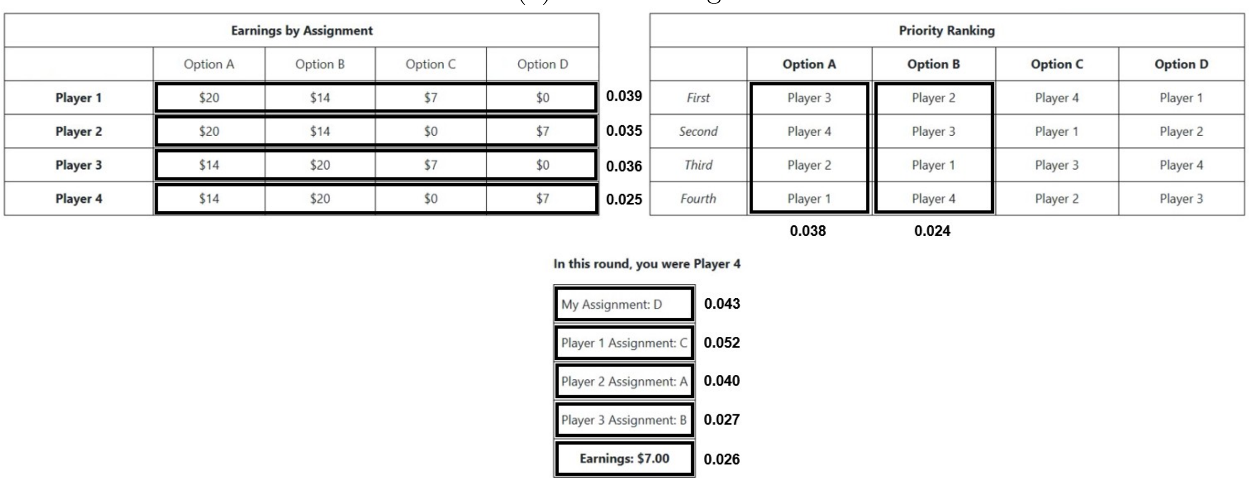
As before, each AOI is assigned an indicator variable. There are also separate indicator variables for the interaction of AOI with the FULL information treatment. Because of the high number of indicator variables, we absorb the AOI dummies and only focus on the interaction terms (see Appendix Table A5 column (1) for the full table). While subject decisions have no effect on other subjects, certain subjects experience the same random profile of past opponent strategies; we cluster standard errors at this opponent profile level.

In the Results Stage, there is a differential pattern of dwell time across the 8 comparable AOIs, that is, the 8 interaction terms are jointly significant different from 0 ($p \approx 0.045$). However, the result is unrelated to justified-envy. Subjects in the FULL information treat-

[14] Our Study 1 eye-tracking analysis compared the Player 1 and 4 subjects rather than FULL and PARTIAL treatments (see Result 5). We provide tables for FULL vs. PARTIAL analysis in Study 1 for both dwell and fixation in Appendix Tables A3 and A4.

Figure 7: Proportion of gaze time averaged for each AOI for subjects in the FULL treatment in Study 2. All subjects played the role of Player 4.

(a) Results Stage



(b) Message Stage

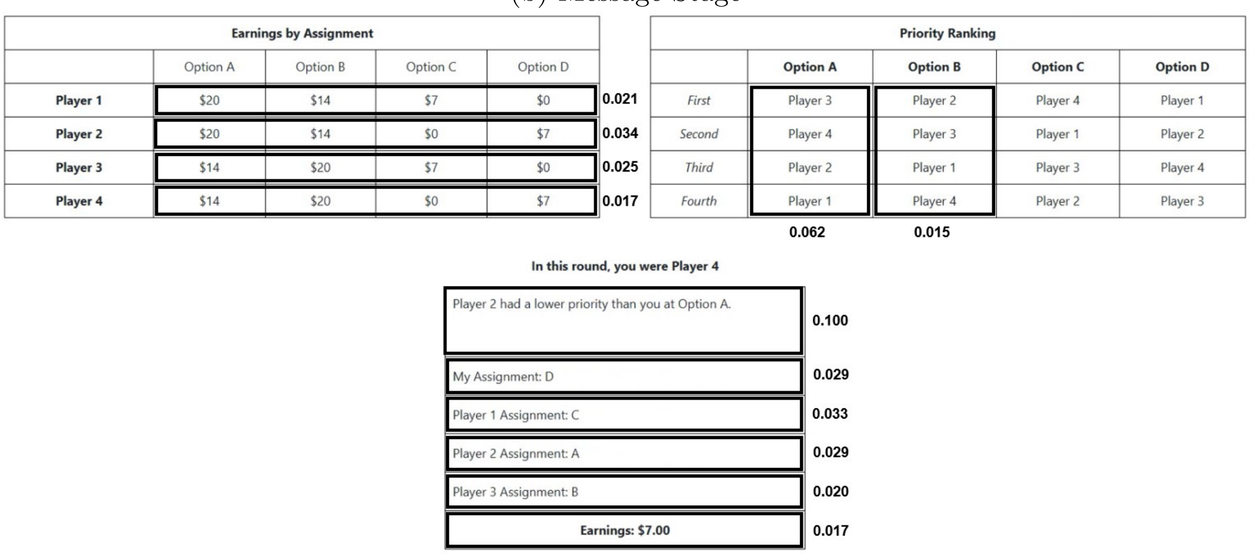


Figure 8: Proportion of gaze time averaged for each AOI for subjects in the PARTIAL treatment in Study 2. All subjects played the role of Player 4.

(a) Results Stage

Earnings by Assignment					
	Option A	Option B	Option C	Option D	
Player 1	$20	$14	$7	$0	**0.028**
Player 2	$20	$14	$0	$7	**0.028**
Player 3	$14	$20	$7	$0	**0.042**
Player 4	$14	$20	$0	$7	**0.031**

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3
	0.042	**0.031**		

In this round, you were Player 4

Assignment: Option D	**0.039**
Earnings: $7.00	**0.039**

(b) Message Stage

Earnings by Assignment					
	Option A	Option B	Option C	Option D	
Player 1	$20	$14	$7	$0	**0.023**
Player 2	$20	$14	$0	$7	**0.029**
Player 3	$14	$20	$7	$0	**0.043**
Player 4	$14	$20	$0	$7	**0.017**

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3
	0.034	**0.032**		

In this round, you were Player 4

This concludes the stage of this game.	**0.059**
Assignment: Option D	**0.025**
Earnings: $7.00	**0.028**

ment focus more on the upper two rows of the payoff table rather than the lower two rows, which may suggest they are more focused on the payoffs of others. Subjects in the FULL treatment appear less concerned with the two priority rankings.

In the Message Stage we also find a differential pattern of dwell time; we can reject the null hypothesis that the 9 interaction dummy AOIs are jointly 0 ($p \approx 0.002$). Here the differences appear to be concentrated on the markers of justified-envy. Using a slightly different dependent variable–the change in dwell time from the Results to the Message stage–produces similar results ($p \approx 0.012$).

Looking at the results for individual dummy variables (Tables A5), we can confirm that the major drivers for these result are areas related to justified-envy. In the Message Stage, subjects in the FULL treatment spend a 6.81 percentage point greater amount of dwell time on the message and relevant Priority A than subjects in the PARTIAL stage ($p \approx 0.007$). The results are similar in looking at the changes between the two stages: subjects in the FULL treatment increase their dwell time from the Results to the Message stage by 7.19 percentage points more than PARTIAL subjects increase it.

Appendix Table A6 also provides results when the dependent variables are in terms of number of fixations rather than dwell time. They are largely similar to what we have described with dwell time.

Result 7 *Subjects who experience justified-envy under treatment FULL exhibit lower levels of valence in facial expressions during both feedback stages. The effect appears to be meaningful only in the Results Stage.*

All subjects in Study 2 played the role of Player 4 against past distributions of Player 1-3s. By design, all experienced justified-envy because of a pre-determined two-way cycle formed between Players 2 and 3 for their first choices. We now examine subject response to this realization of justified-envy. Note that in this context the notion of envy is in regards to a subject in a past experiment not one present in the room with the subject.

Table 7 estimates mean valence response in both the Results and Message stages on FULL treatment. We observe that subjects who learn others' assignments in the group show a roughly 3.976 lower level of measured valence response in the Results Stage compared to

Table 7: Regression of mean valence on preference rank of received alternative and FULL information treatment when justified-envy is realized. Valence was measured for 30 seconds after subjects learned the results of the mechanism (1) and another 30 seconds after they received a message notifying them of the end of the experiment (2). A final model (3) combines observations in a panel, utilizing subject random effects.

	Results Stage	Message Stage	Combined Panel Model
	(1)	(2)	(3)
VARIABLES	mean valence	mean valence	mean valence
FULL	-3.976*	-1.885	-3.976*
	(2.060)	(1.346)	(2.066)
message stage			-1.817
			(4.226)
message × FULL			2.092
			(1.325)
constant	3.076	1.260	3.076*
	(1.836)	(1.124)	(1.842)
Subject Random Effects?	n/a	n/a	Y
Observations	83	83	166

p-values (two-tailed): *** p<0.01, ** p<0.05, * p<0.1

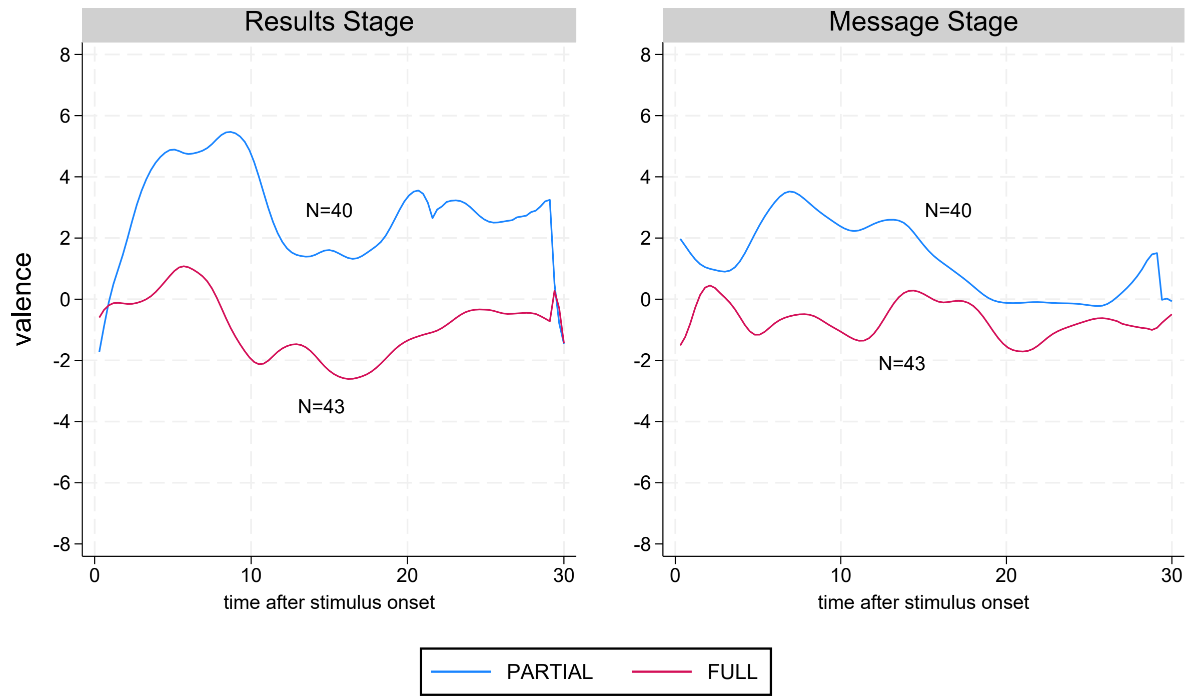
other subjects who are only informed of their own assignment (model 1: $p \approx 0.074$ two-tailed; $p \approx 0.037$ one-tailed). In the second, Message Stage, the difference points in the expected direction but is not statistically significant (model 2: $p \approx 0.183$ two-tailed; $p \approx 0.092$ one-tailed). The magnitude of the treatment effect in the Results Stage is identical in the combined model with subject random effects (model 3: $p \approx 0.054$ two-tailed; $p \approx 0.027$ one-tailed). It is also apparent that there is not a similar effect in the Message Stage. The estimated term, $-3.976 + 2.092 = -1.885$, is similarly not significant ($p \approx 0.163$ two-tailed; $p \approx 0.082$ one-tailed – see models (2) and (3)).

Figure 9 provides a breakdown of valence by feedback stage and information treatment in Study 2. In general, subjects appear to show lower valence levels in the FULL treatment during both feedback stages. As with Study 1, we conduct functional Wilcoxon rank-sum tests to examine if there are statistical differences between subjects in different feedback information treatments at any specific moment since stimulus onset.[15] We find no meaningful

[15]Since valence data were collected at a rate of 10-13.33 Hz, we conducted 100 such non-parametric tests for each comparison. We use every third (fourth) observation of data collected at 10 (13.33) Hz so we compare subjects at the same elapsed times since stimulus onset.

differences during either stage (Wilcoxon rank-sum tests, $p > 0.10$, two-tailed).

Figure 9: Valence by Feedback Stage and Information Treatment



Our results in general do not provide support for Prediction 4. Based on Study 1, we expected to find a treatment effect of increased negative valence but only in the Message Stage. Instead, we find some evidence for a negative effect of FULL information but only in the Results Stage. We do not believe this effect is due to the realization of justified-envy. As our eye-tracking data indicate, subjects do not appear to be aware of their condition of justified-envy until they are alerted in the Message Stage, just like in Study 1. The results here may be consistent with envy in general, as subjects appear to have more negative emotions when learning the allocations of others, even if these allocations reflect those of past and not contemporary subjects. However, we did not expect this result ex-ante.

5 Discussion

In this paper, we propose a novel approach to examine welfare properties under mechanism design: through involuntarily provided biometric feedback. In Study 1, we look at whether subjects exhibit more arousal in the form of increased galvanic skin response in the presence of envy with and without justification. In Study 2, we examine a similar question using subject valence measured through facial expressions.

The preference profiles that underlie the theoretical framework of our design are specifically chosen so that two out of four players will not attain their first or second choice. Both subjects will envy the assignment of the other two subjects that received their first (or second) choice. In the focal equilibrium outcome of the TTC, one player profile will lead to justified-envy. That specific subject would have been preferred by the school that selected another subject. We randomly vary across subjects whether the assignments of others are observed and whether we emphasize this particular type of (justified) envy.

In Study 1, we initially document the perceived importance of envy, specifically, preferring another subject's assignment, through increased arousal as captured by dynamic galvanic skin response and magnitude. We then follow through by noting additional arousal of similar types in the presence of justified-envy. It is paramount we emphasize, however, that subjects do not actively seek information about whether they may be prone to justified-envy. We do note, though, that when justified-envy is accentuated with explicit messages, subjects show greater arousal having received this information.

In Study 2, we look to see if this increased arousal due to justified-envy could be due to negative valence. We reproduce the strategic environment from the previous study, but only have subjects play the role of Player 4 in situations where they will experience justified-envy. The strategies for Players 1-3 are determined based on past play from Study 1: each Study 2 subject encounters the exact profile of other players' strategies of a Player 4 in Study 1. We find that Study 2 subjects make similar strategic choices and display similar gaze patterns as their Study 1 counterparts, suggesting these subjects do not notice the condition of justified-envy until they are alerted to it. However, informing subjects of their condition of justified-envy does not lead to significantly lower valence. Further, if anything, the main treatment effect on negative valence occurs in the Results Stage prior to subjects having been informed of their condition of justified-envy.

We see three possible explanations for the differential impact of being informed of justified-envy on arousal and valence across our two studies. First, we may take our results at face value and infer that subjects exhibit greater arousal, e.g., surprise, by being informed of their justified-envy, but do not have an emotional response, at least not one that produces a negative facial expression. Second, in Study 1, Players 2 and 3, who received their top choice, were represented by actual subjects who left the experiment with $20. In Study 2, outcomes were based on past distributions of these subjects' choices, and no subject was assigned the role of Player 2 or 3; as a result, no one left the experiment with more than $7. Not having an actual person present to target for envy may greatly attenuate feelings of justified-envy as it distances the participants from higher earning subjects in past sessions. Third, the key comparison of justified-envy in Study 1 is based on a comparison of only a few subjects, so even if the treatment effect is comparable for arousal and valence, it may be that the true treatment effect varies considerably from what was estimated. Depending on how this true effect size varied, we may or may not be able to detect such an effect in Study 2 with high probability. Future research will need to determine which of these explanations, if any, is correct.

Nonetheless, subjects in our experiment do not appear to notice their case of justified-envy until notified. Given that subjects cannot notice justified-envy in such a simplified environment, it is natural to ask how accurately anyone can identify violations of fairness criteria in a considerably more complicated field scenario. One possibility is that a longer time horizon in real world school choice scenarios allows the affective reaction of justified-envy to be processed gradually. People might first focus on the negative outcome of not being assigned to their preferred school choice and subsequently process any available information provided with the negative outcome. Some previous work separates the role of anxiety and anger on executive function (Shields et al., 2016). The conclusion is that anxiety and not anger seems to affect cognitive performance. This result would imply that in our experiment an increase in arousal might sequester cognitive resources and endogenously reduce a participant's ability to detect justified-envy until they are explicitly told about it. Our stylized lab setting is limited in capturing the dynamics of processing such information. In the field analogue the stakes involved are much higher and likely to be lived and dealt with over a longer time span.

However, the field application is further complicated because student placements and priority orderings may not be fully known or observed. For one, priority rankings are generally more difficult to determine as they could be based on current and sibling attendance, or geographic proximity. Or they may involve cutoffs that are not determined until applications are final. Similarly, individual-level placement outcomes are not made public, thus making it difficult to identify every case of justified-envy, even with full rationality. Under such circumstances, an applicant's grievances with an allocation process would largely be based on anecdotal evidence such as word of mouth, increasing their inaccuracy.

Given all of these factors, there are serious concerns that individuals may develop doubts about whether student-to-school assignments were computed correctly or, at a deeper level, whether the promised admissions procedure was even used. Hakimov and Raghavan (2025) provide some guidance. In settings where admission procedures are based on merit, providing information on cutoff scores at the school level can alleviate concerns about transparency while keeping applicant information confidential. Further, they show that additionally allowing applicants to submit preferences after cutoffs are known can lead to better understanding of the mechanisms.

Our results provide a subtle counterpoint. While these informational interventions allow applicants to better understand school choice mechanisms and interpret fairness criteria more effectively, they may also trigger greater negative feelings in the form of envy and justified-envy. In both our studies, feelings of greater intensity are generated when more information is revealed. We suspect that in such merit-based settings feelings of envy and justified-envy would be more salient. There may be a careful welfare trade-off between revealing strategic information and protecting an applicant's feelings.

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A Regression results with eye-tracking data

Table A1: Regression of eye gaze duration (in percentage) by Area of Interest (AOI) between Player 4 and Player 1, restricted to outcomes with justified-envy only (outcomes μ' and ν'). Values from Results Stage (1), Message Stage (2) and difference between the two stages (3) shown. Dummy terms for each AOI are included and absorbed in each regression model. All regression models use cluster-robust standard errors at the session level.

VARIABLES	(1) percentage of dwell time (Results Stage)	(2) percentage of dwell time (Message Stage)	(3) percentage of dwell time (Change between Stages)
Player 4 × . . .			
Assignment	-0.634	0.924	1.558
Notification	(2.075)	(0.720)	(2.284)
Earnings	2.494**	0.212	-2.282
Statement	(0.982)	(1.580)	(1.944)
Message		5.503	5.503
(Message Stage Only)		(3.435)	(3.435)
Player 1	-0.232	-1.058	-0.826
Earnings Table	(1.151)	(1.618)	(1.190)
Player 2	-1.912	1.595	3.507
Earnings Table	(1.853)	(1.188)	(2.390)
Player 3	2.981	0.061	-2.920*
Earnings Table	(1.780)	(1.076)	(1.394)
Player 4	3.170***	1.166*	-2.004**
Earnings Table	(0.871)	(0.636)	(0.820)
Option A	0.720	5.918	5.198
Priority Table	(1.276)	(3.623)	(3.454)
Option B	-0.952	-0.020	0.932
Priority Table	(0.906)	(0.920)	(1.259)
Other Player	2.202	1.945**	-0.257
Assignment (Row 1)	(2.084)	(0.843)	(2.291)
Other Player	3.931**	1.484	-2.447
Assignment (Row 2)	(1.474)	(1.513)	(1.494)
Other Player	1.803*	1.170	-0.634
Assignment (Row 3)	(0.972)	(1.239)	(1.006)
constant	2.606***	2.099***	-0.290
	(0.526)	(0.232)	(0.547)
AOI dummies?	Y	Y	Y
Observations	198	216	216
No of AOIs	11	12	12
F-test of Player 4×AOI interaction terms	0.014	0.047	0.000

*** p<0.01, ** p<0.05, * p<0.1

Table A2: Regression of total fixations by Area of Interest (AOI) between Player 4 and Player 1, restricted to outcomes with justified-envy only (outcomes μ' and ν'). Values from Results Stage (1), Message Stage (2) and difference between the two stages (3) shown. Dummy terms for each AOI are included and absorbed in each regression model. All regression models use cluster-robust standard errors at the session level.

VARIABLES	(1) no. of fixations (Results Stage)	(2) no. of fixations (Message Stage)	(3) no. of fixations (Change between Stages)
Player 4 × ...			
Assignment	0.875	1.300	0.425
Notification	(1.372)	(3.027)	
Earnings	3.600**	0.875	-2.725
Statement	(1.353)	(1.673)	(2.084)
Message		8.775*	8.775*
(Message Stage Only)		(4.449)	(4.449)
Player 1	0.625	-1.100	-1.725
Earnings Table	(2.245)	(2.321)	(1.543)
Player 2	-1.950	2.200	4.150
Earnings Table	(2.340)	(1.942)	(3.009)
Player 3	4.075*	1.150	-2.925
Earnings Table	(2.138)	(1.507)	(1.734)
Player 4	4.725***	0.950	-3.775***
Earnings Table	(1.546)	(1.001)	(1.205)
Option A	1.125	6.025*	4.900*
Priority Table	(1.579)	(3.157)	(2.717)
Option B	-0.275	0.400	0.675
Priority Table	(1.068)	(1.109)	(1.318)
Other Player	4.525	2.725*	-1.800
Assignment (Row 1)	(3.264)	(1.458)	(3.639)
Other Player	6.675***	2.350	-4.325*
Assignment (Row 2)	(1.780)	(1.643)	(1.987)
Other Player	3.475**	1.025	-2.450
Assignment (Row 3)	(1.275)	(1.179)	(1.458)
constant	2.966***	2.427***	-0.292
	(0.724)	(0.455)	(0.810)
AOI dummies?	Y	Y	Y
Observations	198	216	216
No of AOIs	11	12	12
F-test of Player 4×AOI interaction terms	0.000	0.000	0.000

*** p<0.01, ** p<0.05, * p<0.1

Table A3: Regression of eye gaze duration (in percentage) by Area of Interest (AOI) of Player 4s between FULL and PARTIAL information treatments, restricted to outcomes with justified-envy only (outcomes μ' and ν'). Values from Results Stage (1), Message Stage (2) and difference between the two stages (3) shown. Dummy terms for each AOI are included and absorbed in each regression model. All regression models use cluster-robust standard errors at the session level. Note that the FULL treatment features three more AOIs concerning the allocations of other subjects that are not included in the PARTIAL treatment. Thus, the three AOIs are excluded from the regression analysis.

VARIABLES	(1) percentage of dwell time (Results Stage)	(2) percentage of dwell time (Message Stage)	(3) percentage of dwell time (Change between Stages)
Full information × . . .			
Assignment	-1.594	-0.844	0.750
Notification	(1.168)	(1.004)	(1.655)
Earnings	-1.304	-0.903	0.401
Statement	(0.997)	(0.705)	(1.230)
Message		4.158	4.158
(Message Stage Only)		(3.209)	(3.209)
Player 1	0.415	1.068	0.653
Earnings Table	(1.022)	(0.751)	(1.128)
Player 2	-1.310	2.281*	3.591
Earnings Table	(1.812)	(1.249)	(2.101)
Player 3	-0.707	0.136	0.843
Earnings Table	(2.175)	(0.758)	(2.027)
Player 4	-3.355	-4.700*	-1.345
Earnings Table	(2.756)	(2.273)	(2.069)
Option A	-0.863	2.418	3.281
Priority Table	(1.642)	(4.676)	(3.823)
Option B	-3.000	-1.274	1.726
Priority Table	(1.966)	(1.480)	(1.170)
constant	4.802***	3.711***	-0.558
	(0.444)	(0.626)	(0.709)
AOI dummies?	Y	Y	Y
Observations	136	153	153
No of AOIs	8	9	9
F-test of Player 4×AOI interaction terms	0.000	0.100	0.002

*** p<0.01, ** p<0.05, * p<0.1

Table A4: Regression of total fixations by Area of Interest (AOI) of Player 4s between FULL and PARTIAL information treatments, restricted to outcomes with justified-envy only (outcomes μ' and ν'). Values from Results Stage (1), Message Stage (2) and difference between the two stages (3) shown. Dummy terms for each AOI are included and absorbed in each regression model. All regression models use cluster-robust standard errors at the session level. Note that the FULL treatment features three more AOIs concerning the allocations of other subjects that are not included in the PARTIAL treatment. Thus, the three AOIs are excluded from the regression analysis.

VARIABLES	(1) no. of fixations (Results Stage)	(2) no. of fixations (Message Stage)	(3) no. of fixations (Change between Stages)
Full information × . . .			
Assignment	-3.786	-1.557	2.229
Notification	(2.599)	(1.766)	(3.233)
Earnings	-3.114	-1.500	1.614
Statement	(1.913)	(1.131)	(2.241)
Message		6.186*	6.186*
(Message Stage Only)		(2.958)	(2.958)
Player 1	-0.500	1.543	2.043
Earnings Table	(2.289)	(1.243)	(2.298)
Player 2	-3.986	3.200	7.186*
Earnings Table	(3.032)	(1.821)	(3.317)
Player 3	-3.729	-0.171	3.557
Earnings Table	(3.518)	(1.261)	(3.339)
Player 4	-6.400	-8.086**	-1.686
Earnings Table	(3.743)	(2.999)	(2.333)
Option A	-1.143	1.971	3.114
Priority Table	(1.999)	(4.383)	(3.222)
Option B	-3.471	-1.600	1.871
Priority Table	(2.736)	(1.599)	(1.969)
constant	7.929***	4.968***	-2.079**
	(0.792)	(0.745)	(0.846)
AOI dummies?	Y	Y	Y
Observations	136	153	153
No of AOIs	8	9	9
F-test of Player 4×AOI interaction terms	0.000	0.014	0.035

*** p<0.01, ** p<0.05, * p<0.1

Table A5: Regression of eye gaze duration (in percentage) by Area of Interest (AOI) between FULL and PARTIAL information treatments (Study 2). Values from Results Stage (1), Message Stage (2) and difference between the two stages (3) shown. Dummy terms for each AOI are included and absorbed in each regression model. All regression models use cluster-robust standard errors at the session level. Note that the FULL treatment features three more AOIs concerning the allocations of other subjects that are not included in the PARTIAL treatment. Thus, the three AOIs are excluded from the regression analysis.

VARIABLES	(1) percentage of dwell time (Results Stage)	(2) percentage of dwell time (Message Stage)	(3) percentage of dwell time (Change between Stages)
Full information × ...			
Assignment	0.348	0.392	0.044
Notification	(0.755)	(0.603)	(1.072)
Earnings	-1.319	-1.113	0.206
Statement	(0.993)	(0.782)	(0.976)
Message		4.050**	4.050**
(Message Stage Only)		(1.434)	(1.434)
Player 1	1.166	-0.242	-1.408
Earnings Table	(0.704)	(0.507)	(0.814)
Player 2	0.688	0.404	-0.284
Earnings Table	(0.679)	(1.059)	(0.919)
Player 3	-0.636	-1.829	-1.194
Earnings Table	(0.644)	(1.286)	(1.212)
Player 4	-0.669	0.019	0.689
Earnings Table	(0.635)	(0.734)	(0.913)
Option A	-0.382	2.759*	3.141*
Priority Table	(1.017)	(1.440)	(1.636)
Option B	-0.704	-1.616**	-0.912
Priority Table	(1.080)	(0.746)	(1.351)
constant	3.508***	3.222***	0.104
	(0.265)	(0.314)	(0.275)
AOI dummies?	Y	Y	Y
Observations	648	729	729
No of AOIs	8	9	9
F-test of Player 4×AOI interaction terms	0.044	0.003	0.010

*** p<0.01, ** p<0.05, * p<0.1

Table A6: Regression of total fixations by Area of Interest (AOI) between FULL and PARTIAL information treatments (Study 2). Values from Results Stage (1), Message Stage (2) and difference between the two stages (3) shown. Fixed effects for each AOI are included and absorbed in each regression model. All regression models use cluster-robust standard errors at the session level. Note that the FULL treatment features three more AOIs concerning the allocations of other subjects that are not included in the PARTIAL treatment. Thus, the three AOIs are excluded from the regression analysis.

VARIABLES	(1) no. of fixations (Results Stage)	(2) no. of fixations (Message Stage)	(3) no. of fixations (Change between Stages)
Full information × ...			
Assignment	1.176	0.418	-0.758
Notification	(1.086)	(0.786)	(1.554)
Earnings	-1.974**	-0.985*	0.989
Statement	(0.773)	(0.461)	(0.644)
Message		6.412***	6.412***
(Message Stage Only)		(1.892)	(1.892)
Player 1	1.863*	0.159	-1.703
Earnings Table	(0.976)	(0.995)	(1.151)
Player 2	0.951	1.015	0.064
Earnings Table	(0.900)	(1.199)	(1.013)
Player 3	-0.280	-0.716	-0.436
Earnings Table	(0.843)	(1.283)	(1.378)
Player 4	-0.476	-0.037	0.440
Earnings Table	(1.034)	(0.879)	(1.363)
Option A	0.134	2.473	2.339
Priority Table	(0.894)	(1.456)	(1.450)
Option B	-0.451	-1.505	-1.055
Priority Table	(1.061)	(0.975)	(1.480)
constant	4.769***	4.083***	-0.157
	(0.291)	(0.398)	(0.354)
AOI dummies?	Y	Y	Y
Observations	648	729	729
No of AOIs	8	9	9
F-test of Player 4×AOI interaction terms	0.088	0.002	0.000

*** p<0.01, ** p<0.05, * p<0.1

SUPPLEMENTAL MATERIALS

Instructions (DA)

Introduction

This is an experiment in economic decision making. If you pay attention to these instructions, you can earn a significant amount of money. If you have any questions, raise your hand and we will come to assist you. Your earnings will depend on the decisions you make and the decisions made by other participants during the experiment. These earnings will be paid in addition to your $10 show-up payment.

Instructions

This experiment consists of 1 round, and your earnings depend on the decisions you make and the decisions made by other players in that round. First, there will be 4 practice rounds for you to familiarize yourself with the decision environment. These practice rounds will not affect your earnings. At the beginning of each round, you will be randomly assigned to groups of 4. Each round has 4 options: Option A, Option B, Option C and Option D. Each option will be exclusively assigned to one of the players in the group. For every round, each player submits a preference ranking for every option from the most preferred to the least preferred. The ranking reports submitted by the four players determine the options that they will receive. Your earnings are based on the option you receive.

At the beginning of each round, the computer will assign each option a priority ranking for all players. A priority ranking is a list of all players in order from highest priority to lowest priority. Each option may be assigned a different priority ranking, so you may have a different level of priority for each of the four options. After all players submit their ranking reports, the computer uses the following method to decide which player is assigned to which option:

Step 1: Players are considered for the option they ranked first. If only 1 player is considered for that option, the player is provisionally assigned to it. If more than 1 player is considered for the same option, the option is provisionally assigned to the player with the highest priority rank at that option. Players that are not provisionally assigned to an option are permanently excluded from that option.

Step 2: Players that have been provisionally assigned in Step 1 are considered again for the respective option. Players that were rejected in Step 1 are considered for the next option in their ranking report. If only 1 player is considered for an option, the player is provisionally assigned to it. If more than 1 player is considered for the same option, the option is provisionally assigned to the player with the highest priority rank. Players that are not provisionally assigned to an option are permanently excluded from that option.

Step 3: Players that have been provisionally assigned in Step 2 are considered again for the respective option. Players that were rejected in Step 2 are considered for the next option in their ranking report. If only 1 player is considered for an option, the player is provisionally assigned to it. If more than 1 player is considered for the same option, the option is provisionally assigned to the player with the highest priority rank. Players that are not provisionally assigned to an option are permanently excluded from that option.

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The computer continues to follow this process until all players are provisionally assigned to an option. At this step, all provisional assignments become permanent assignments.

After all players in your group submit their ranking reports, you will find out the option you were assigned to and the corresponding earnings.

Instructions (TTC, Study 1)

Introduction

This is an experiment in economic decision making. If you pay attention to these instructions, you can earn a significant amount of money. If you have any questions, raise your hand and we will come to assist you. Your earnings will depend on the decisions you make and the decisions made by other participants during the experiment. These earnings will be paid in addition to your $10 show-up payment.

Instructions

This experiment consists of 1 round, and your earnings depend on the decisions you make and the decisions made by other players in that round. First, there will be 4 practice rounds for you to familiarize yourself with the decision environment. These practice rounds will not affect your earnings. At the beginning of each round, you will be randomly assigned to groups of 4. Each round has 4 options: Option A, Option B, Option C and Option D. Each option will be exclusively assigned to one of the players in the group. For every round, each player submits a preference ranking for every option from the most preferred to the least preferred. The ranking reports submitted by the three players determine the options that they will receive. Your earnings are based on the option you receive.

At the beginning of each round, the computer will assign each option a priority ranking for all players. A priority ranking is a list of all players in order from highest priority to lowest priority. Each option may be assigned a different priority ranking, so you may have a different level of priority for each of the four options. After all players submit their ranking reports, the computer uses the following method to decide which player is assigned to which option:

Step 1: Each player is provisionally assigned to the option at which he/she has the highest priority. If a player ranks his/her provisionally assigned option first, a 1-way cycle is formed and he/she is permanently assigned to that option (see Figure 1a).

Assignments may also be resolved by 2-way, 3-way or 4-way cycles. For example, if Player 1 ranks Player 3's provisionally assigned option first, and Player 3 ranks Player 1's provisionally assigned option first, this is a 2-way cycle (see Figure 1b). Both players are permanently assigned to their first-ranked option. (This example is for illustrative purposes; other similar combinations of players and options also form 2-way cycles.)

A 3-way cycle is formed, for example, if Player 1 ranks Player 2's provisionally assigned option first, Player 2 ranks Player 3's provisionally assigned option first and Player 3 ranks Player 1's provisionally assigned option first (see Figure 1c). All three players are permanently assigned to their first-ranked option. (This example is for illustrative purposes; other similar combinations of players and options also form 3-way cycles.)

A 4-way cycle is formed in a similar fashion.

Options that are permanently assigned are removed from the list of available options.

Step 2: If a player is not permanently assigned and his/her first-ranked option is not permanently assigned to another player after Step 1, assignments may be resolved by 2-way or 3-way cycles with the first-ranked option in his/her ranking report and the available options. Step 2 is repeated until either (a) a player is permanently assigned to his/her first ranked option or (b) until his/her first-ranked option is permanently assigned to another player.

Options that are permanently assigned are removed from the list of available options.

Step 3: If a player is not permanently assigned and his/her first-ranked option is permanently assigned to another player after Step 2, assignments may be resolved by 1-way, 2-way or 3-way cycles with the second-ranked option in his/her ranking report and the available options. Step 3 is repeated until either (a) a player is permanently assigned to his/her second-ranked option or (b) until his/her second-ranked option is permanently assigned to another player.

Options that are permanently assigned are removed from the list of available options.

Step 4: If a player is not permanently assigned and his/her second-ranked option is permanently assigned to another player after Step 3, assignments may be resolved by 1-way or 2-way cycles with the third-ranked option in his/her ranking report and the available options. Step 4 is repeated until either (a) a player is permanently assigned to his/her third-ranked option or (b) until his/her third-ranked option is permanently assigned to another player.

Options that are permanently assigned are removed from the list of available options.

Step 5: If a player is not permanently assigned after Step 4, a 1-way cycle is formed with the fourth-ranked option in his/her ranking report, and he/she is permanently assigned to his/her provisional assignment.

After all players in your group submit their ranking reports, you will find out the option you were assigned to and the corresponding earnings.

Figure 1a: 1-way cycle

Figure 1b: 2-way cycle

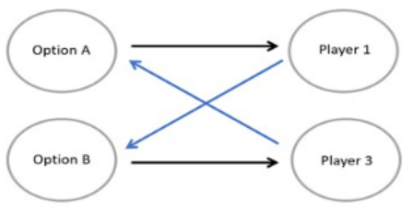
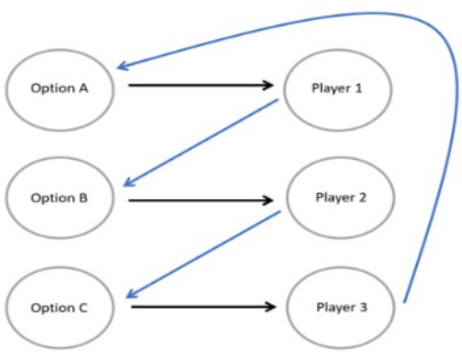


Figure 1c: 3-way cycle



Instructions (TTC, Study 2)

Introduction

This is an experiment in economic decision making. If you pay attention to these instructions, you can earn a significant amount of money. If you have any questions, raise your hand and we will come to assist you. Your earnings will depend on the decisions you make during the experiment. These earnings will be paid in addition to your $10 show-up payment.

Instructions

This experiment consists of 1 round, and your earnings depend on the decisions you make and the decisions made by other players in that round. First, there will be 4 practice rounds for you to familiarize yourself with the decision environment. These practice rounds will not affect your earnings. At the beginning of each round, you will be matched with three other participants. These participants are not here today, but they participated in this **same study** in previous sessions conducted in person here at the Human Behavior Lab. Each round has 4 options: Option A, Option B, Option C and Option D. Each option will be exclusively assigned to one of the players in the group. For every round, each player submits a preference ranking for every option from the most preferred to the least preferred. (Note: the preference ranking reports of participants you will be matched with have already been submitted.) The ranking reports submitted by the four players determine the options that they will receive. Your earnings are based on the option you receive.

At the beginning of each round, the computer will assign each option a priority ranking for all players. A priority ranking is a list of all players in order from highest priority to lowest priority. Each option may be assigned a different priority ranking, so you may have a different level of priority for each of the four options. After all players submit their ranking reports, the computer uses the following method to decide which player is assigned to which option:

Step 1: Each player is provisionally assigned to the option at which he/she has the highest priority. If a player ranks his/her provisionally assigned option first, a 1-way cycle is formed and he/she is permanently assigned to that option (see Figure 1a).

Assignments may also be resolved by 2-way, 3-way or 4-way cycles. For example, if Player 1 ranks Player 3's provisionally assigned option first, and Player 3 ranks Player 1's provisionally assigned option first, this is a 2-way cycle (see Figure 1b). Both players are permanently assigned to their first-ranked option. (This example is for illustrative purposes; other similar combinations of players and options also form 2-way cycles.)

A 3-way cycle is formed, for example, if Player 1 ranks Player 2's provisionally assigned option first, Player 2 ranks Player 3's provisionally assigned option first and Player 3 ranks Player 1's provisionally assigned option first (see Figure 1c). All three players are permanently assigned to their first-ranked option. (This example is for illustrative purposes; other similar combinations of players and options also form 3-way cycles.)

A 4-way cycle is formed in a similar fashion.

Options that are permanently assigned are removed from the list of available options.

Step 2: If a player is not permanently assigned and his/her first-ranked option is not permanently assigned to another player after Step 1, assignments may be resolved by 2-way or 3-way cycles with the first-ranked option in his/her ranking report and the available options. Step 2 is repeated until either (a) a player is permanently assigned to his/her first ranked option or (b) until his/her first-ranked option is permanently assigned to another player.

Options that are permanently assigned are removed from the list of available options.

Step 3: If a player is not permanently assigned and his/her first-ranked option is permanently assigned to another player after Step 2, assignments may be resolved by 1-way, 2-way or 3-way cycles with the second-ranked option in his/her ranking report and the available options. Step 3 is repeated until either (a) a player is permanently assigned to his/her second-ranked option or (b) until his/her second-ranked option is permanently assigned to another player.

Options that are permanently assigned are removed from the list of available options.

Step 4: If a player is not permanently assigned and his/her second-ranked option is permanently assigned to another player after Step 3, assignments may be resolved by 1-way or 2-way cycles with the third-ranked option in his/her ranking report and the available options. Step 4 is repeated until either (a) a player is permanently assigned to his/her third-ranked option or (b) until his/her third-ranked option is permanently assigned to another player.

Options that are permanently assigned are removed from the list of available options.

Step 5: If a player is not permanently assigned after Step 4, a 1-way cycle is formed with the fourth-ranked option in his/her ranking report, and he/she is permanently assigned to his/her provisional assignment.

After all players in your group submit their ranking reports, you will find out the option you were assigned to and the corresponding earnings.

Figure 1a: 1-way cycle

Figure 1b: 2-way cycle

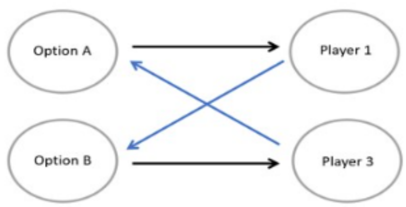
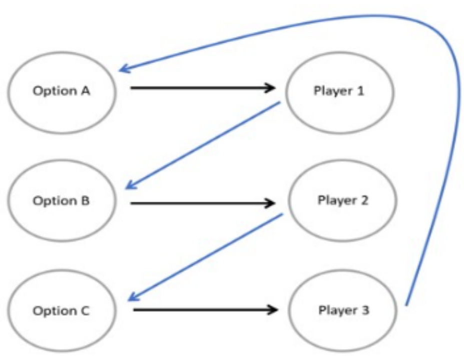


Figure 1c: 3-way cycle



Comprehension Quiz - Each question was displayed on a different page

1. An option can be assigned to more than 1 player in a group.
   - ○ True
   - ○ False
2. In the figure below, the player who is viewing the screen is:
   - ○ Player 1
   - ○ Player 2
   - ○ Player 3
   - ○ Player 4

Practice Round 1: In this round, you are Player 3

Earnings by Assignment				
	Option A	Option B	Option C	Option D
Player 1	$20	$7	$14	$0
Player 2	$14	$0	$20	$7
Player 3	$7	$20	$0	$14
Player 4	$14	$7	$0	$20

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 1	Player 3	Player 2	Player 4
Second	Player 4	Player 2	Player 3	Player 1
Third	Player 3	Player 4	Player 1	Player 2
Fourth	Player 2	Player 1	Player 4	Player 3

Please mark your ranking below:

First Choice: --------- Second Choice: --------- Third Choice: --------- Fourth Choice: ---------

3. According to the figure below, if I'm assigned to option A, my payoff would be:
   - ○ $0
   - ○ $7
   - ○ $14
   - ○ $20

Practice Round 1: In this round, you are Player 3

Earnings by Assignment				
	Option A	Option B	Option C	Option D
Player 1	$20	$7	$14	$0
Player 2	$14	$0	$20	$7
Player 3	$7	$20	$0	$14
Player 4	$14	$7	$0	$20

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 1	Player 3	Player 2	Player 4
Second	Player 4	Player 2	Player 3	Player 1
Third	Player 3	Player 4	Player 1	Player 2
Fourth	Player 2	Player 1	Player 4	Player 3

Please mark your ranking below:

First Choice: --------- Second Choice: --------- Third Choice: --------- Fourth Choice: ---------

4. According to the figure below, I have a higher priority than Player 1 at Option C.

○ True

○ False

Practice Round 1: In this round, you are Player 3

Earnings by Assignment				
	Option A	Option B	Option C	Option D
Player 1	$20	$7	$14	$0
Player 2	$14	$0	$20	$7
Player 3	$7	$20	$0	$14
Player 4	$14	$7	$0	$20

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 1	Player 3	Player 2	Player 4
Second	Player 4	Player 2	Player 3	Player 1
Third	Player 3	Player 4	Player 1	Player 2
Fourth	Player 2	Player 1	Player 4	Player 3

Please mark your ranking below:

First Choice: --------- Second Choice: --------- Third Choice: --------- Fourth Choice: ---------

5. Based on the figure below, if I submit Option B as my first choice, and players 2, 3 and 4 submit Options A, D and C as their first choice, respectively, I would be assigned to:

○ Option A

○ Option B

○ Option C

○ Option D

Practice Round 4: In this round, you are Player 1

Earnings by Assignment				
	Option A	Option B	Option C	Option D
Player 1	$14	$20	$0	$7
Player 2	$20	$7	$0	$14
Player 3	$14	$7	$0	$20
Player 4	$7	$14	$20	$0

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 4	Player 3	Player 1	Player 2
Second	Player 2	Player 1	Player 3	Player 4
Third	Player 3	Player 2	Player 4	Player 1
Fourth	Player 1	Player 4	Player 2	Player 3

Please mark your ranking below:

First Choice: --------- Second Choice: --------- Third Choice: --------- Fourth Choice: ---------

Survey - Each question was displayed on a different page

1. Please describe how you decided to rank options from first to last.

2. How difficult was this game? Please indicate your answer by moving the slider accordingly.

   Very Easy — Very Difficult

3. To what extent do you think your ability affected your assignment versus to what extent do you think the computer was responsible for your assignment? Please indicate your answer by moving the slider accordingly.

   The Computer — My Ability

4. It was always in my best interest to report my most preferred option (the option that yielded $20) as my first choice.
   - True
   - False
   - I don't know

Accentuating Justified-Envy

<u>FULL</u>

- If assigned to the best option:
  - If highest priority: "You had the highest priority at Option X."
  - If 2nd highest priority: "You were second in priority at Option X."
  - If 3rd highest priority: "You were third in priority at Option X."
  - If 4th highest priority: "You were fourth in priority at Option X."
- If assigned to the 2nd best option:
  - with justified-envy:
    - "Player I had a lower priority than you at Option X."
  - without justified-envy
    - "Player I had a higher priority than you at Option X."
- If assigned to the 3rd best option:
  - with justified-envy:
    - once: "Player I had a lower priority than you at Option X."
    - twice: "Player I had a lower priority than you at Option X.
      Player J had a lower priority than you at Option Y."
  - without justified-envy
    - "Player I had a higher priority than you at Option X.
      Player J had a higher priority than you at Option Y."
- If assigned to the 4th best option:
  - with justified-envy:
    - once: "Player I had a lower priority than you at Option X."
    - twice: "Player I had a lower priority than you at Option X.
      Player J had a lower priority than you at Option Y."

    * thrice: "Player I had a lower priority than you at Option X.
      Player J had a lower priority than you at Option Y.
      Player K had a lower priority than you at Option Z."

  - without justified-envy

    * "Player I had a higher priority than you at Option X.
      Player J had a higher priority than you at Option Y.
      Player K had a higher priority than you at Option Z."

<u>PARTIAL</u>

- "This concludes the stage of this game."

Example Screenshots from the Feedback Stage

FULL - Results Stage

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Round 5: Results

Earnings by Assignment				
	Option A	Option B	Option C	Option D
Player 1	$20	$14	$7	$0
Player 2	$20	$14	$0	$7
Player 3	$14	$20	$7	$0
Player 4	$14	$20	$0	$7

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3

In this round, you were Player 2

My Assignment: B
Player 1 Assignment: C
Player 3 Assignment: A
Player 4 Assignment: D
Earnings: $14.00

FULL - Message Stage

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Round 5: Results

Earnings by Assignment				
	Option A	Option B	Option C	Option D
Player 1	$20	$14	$7	$0
Player 2	$20	$14	$0	$7
Player 3	$14	$20	$7	$0
Player 4	$14	$20	$0	$7

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3

In this round, you were Player 2

Player 3 had a higher priority than you at Option A.
My Assignment: B
Player 1 Assignment: C
Player 3 Assignment: A
Player 4 Assignment: D
Earnings: $14.00

PARTIAL - Results Stage

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Round 5: Results

Earnings by Assignment				
	Option A	Option B	Option C	Option D
Player 1	$20	$14	$7	$0
Player 2	$20	$14	$0	$7
Player 3	$14	$20	$7	$0
Player 4	$14	$20	$0	$7

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3

In this round, you were Player 1

Assignment: Option C

Earnings: $7.00

PARTIAL - Message Stage

Time left on this page: **0:19**

Round 5: Results

Earnings by Assignment				
	Option A	Option B	Option C	Option D
Player 1	$20	$14	$7	$0
Player 2	$20	$14	$0	$7
Player 3	$14	$20	$7	$0
Player 4	$14	$20	$0	$7

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3

In this round, you were Player 1

This concludes the stage of this game.

Assignment: Option C

Earnings: $7.00