School Choice: Biometrically-Informed Mechanism Design*

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Abstract

It is well-known that no school choice mechanism can achieve both the elimination of justified envy and Pareto efficiency in equilibrium. The two most prominent strategy-proof mechanisms, Top-Trading-Cycles and Deferred Acceptance, provide a fundamental tradeoff in property realization. We provide a novel approach to measure their welfare tradeoffs. Using an experimental design that randomly varies whether subjects learn about others' allocations in a school choice game, we measure discontentment through galvanic skin response and eye-tracking when subjects experience envy with and without justification. We find increased discontentment due to justified-envy only when such information is accentuated with explicit messages. A separate study shows how eye-tracking reveals the use of certain levels of sophisticated play in the Boston mechanism, further supporting the agenda of biometrically-informed mechanism design for school choice problems.

JEL classification: D47, D82, D87, I24

Keywords: eye-tracking, 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 to provide 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 (i.e, envy) and student j is not preferred to i by the desired school (i.e., justified envy). While the property is desirable in the abstract, it comes with tradeoffs. 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 school choice mechanism design.

While the tradeoff between these two mechanisms may be viewed as a classic tradeoff of fairness and efficiency, the answer is not so clear. 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) has shown 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 only the presence of envy. Using a random assignment design we vary whether subjects learn the payoffs of others, triggering the possibility to experience envy.

We use biometric measures in our experiment because they provide involuntary measures of a subject's emotional toll 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. An alternative approach might use an incentivized BDM mechanism instead to measure subject's willingness-to-pay to avoid situations resulting in justified envy. However, this approach is problematic. First, there is evidence that most subjects cannot use dominant-strategy mechanisms correctly, even when the value of preferences is induced and trivial (Cason and Plott, 2014). It is unlikely that in an environment like ours where values are more intangible that subject responses will improve. Second, 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 strategy-proof school choice mechanisms and we confirm this finding. There are likely unobserved correlations between responses (and hence outcomes) on these two dominant strategy mechanisms.

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 valuations structures are specifically chosen so that two players receive their third choice under either mechanism. 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 allocations of the other subjects in their group at the conclusion of the game, opening the possibility for subjects to experience either justified or unjustified envy, depending on their assignment.

Our results find the comparative statics of theory and previous experiments hold well (Chen and Sönmez, 2006; Pais and Pintér, 2008; Calsamiglia et al., 2010; Chen et al., 2016; Featherstone and Niederle, 2016; Stephenson, 2022). 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 54.1% in the TTC. Equilibrium assignments are achieved in 45.9% and 77.8% of cases in the TTC and DA mechanisms, respectively.

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 for the players that did not receive their first choice. We document a differential emotional arousal response among subjects who experience any kind of envy in the school choice game —specifically, subjects with lower earnings showcase a higher level of emotional arousal upon learning their assignments. The well adapted Circumplex model of affect 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). Our results are consistent with higher levels of arousal resulting from negative evaluations associated with envy. We then show that when subjects have information about others' allocations, an unstable matching imposes sustained arousal for subjects who experience envy with justification but not for those who experience envy without justification suggesting that justified-envy negatively affects subjects, all else equal.

We find other results align to previous literature. Subjects who perform above the median level on the Raven's Progressive Matrices task, a test used to measure fluid intelligence, are more likely to play truthful strategies in strategy-proof mechanisms, similar to Basteck and Mantovani (2018). We note a self-attribution effect (i.e., Jones and Davis, 1965) where subjects with higher earnings are more likely to credit their own ability for their performance while subjects with lower earnings are more likely to blame the mechanisms.

In an appendix section, to reemphasize how biometric measurement may inform mechanism design, we note that under a different non-strategy-proof mechanism, the Boston mechanism (IA), eye-tracking can predict a subject's level of strategic sophistication through level-k reasoning. While previous studies have noted how level-k would apply to school choice (Zhang, 2021), and how eye-tracking would correspond to level-k strategies (Wang et al., 2010), ours is the first to do both.

2 Related Literature

In an incomplete information setting, Chen and Sönmez (2006) present the first experimental study comparing the three school choice mechanisms. They find that DA outperforms TTC in truthful preference revelation, despite the strategy-proofness of both mechanisms. Furthermore, they show that TTC does not outperform DA in efficiency, although theoretically TTC is efficient whereas DA is not. Among the three mechanisms, IA performs the worst in terms of truthful preference revelation and efficiency. While a stability comparison is not presented in Chen and Sönmez (2006), using the same experimental setting, Calsamiglia et al. (2010) find that DA is more stable than TTC, which in turn is weakly more stable than IA. Chen et al. (2016) compare the performance of the three mechanisms using the same design as Chen and Sönmez (2006) under a complete information setting. They find that TTC outperforms DA, which in turn outperforms IA in truth-telling. Consistent with theory, TTC outperforms both DA and IA in efficiency, whereas DA and IA generate similar efficiency levels. In terms of stability, DA outperforms TTC and IA by a large margin, whereas IA and TTC achieve the same level of stability. Pais and Pintér (2008) find results that are consistent with theory – the TTC mechanism outperforms both IA and DA mechanisms in terms of efficiency and it is slightly more successful than DA regarding the proportion of truthful preference revelation, whereas manipulation is stronger under the Boston mechanism. Pais and Pintér (2008) find that under the IA and DA mechanisms the amount of information has a significant effect on the average efficiency achieved by participants, while under the TTC mechanism average efficiency does not depend on the implemented information setting. In comparing stability between DA and TTC, Pais and Pintér (2008) find that DA is more successful than the TTC mechanism which is in accordance with theory. Basteck and Mantovani (2018) study DA and IA in a setting where subjects know induced values of others but where priorities of schools are determined according to a centralized lottery. In their design, there is general consensus about the rank-order preference of schools where intensities may slightly differ across subject types. They find that higher cognitive ability subjects manipulate IA better by engaging in Skip-the-Middle and Skip-the-Top strategies. They find that there is a significant ability segregation across schools in IA, but not in DA where lower ability subjects are over-represented at the worst schools. Recognizing heterogeneous sophistication of applicants, Zhang (2021) uses the level-k model to summarize students' strategies under IA in a complete information environment with strict school priorities. His results show that after a certain level of reasoning, assignments do not exhibit justified-envy and converge to the same allocations as those obtained under DA. We examine the extent to which different mechanisms achieve equilibrium assignments by providing subjects with feedback about their assignments only after all reports are finalized; Stephenson (2022) finds all three mechanisms achieve more equilibrium assignments under real-time feedback than discrete feedback. Finally we elicit subjects' attribution of their assignments and gauge their experiences. Specifically, we ask them whether the mechanism or their ability was more responsible for their assignment. This question was designed to test for a self-serving bias which would cause subjects to attribute weight differentially depending on their earnings. Kassas and Palma (2019), for example, find that subjects have a tendency for utilizing a self-serving bias that can help them escape unfavorable social norms.

Table 1 of Stephenson (2022) provides a comprehensive list of school choice experiments. Other studies in that table, not previously mentioned include Klijn et al. (2013), Featherstone and Niederle (2016), Chen et al. (2018), Guillen and Hakimov (2018), Ding and Schotter (2019), Chen and Kesten (2019), Dur et al. (2018), Gong and Liang (2020), Klijn et al. (2019), Bó and Hakimov (2020).

There are a couple studies that examine preferences for fairness by complementing experiments with eye-tracking data. Jiang et al. (2016) examine eye movements while subjects make choices in simple three-person distribution experiments and characterize choices in terms of three different types of social preferences: efficiency, maxi-min and minimize envy. Their findings suggest that distributional choices are consistent with the choice rule implied by eye movements. Fischbacher et al. (2022) extend the use of eye-tracking and apply it as a communication device by providing (real-time) eye-tracking information of one participant to another. They find that untrained observers can judge the prosociality of decision-makers from their eye-tracked gaze alone, but only if there are no strategic incentives to be chosen for a future interaction. Our study attempts to shed light on the perception of school choice boards and some theorists that justified envy is a sound fairness criterion in matching students to schools. Specifically, we test whether justified and unjustified envy produce different emotional reactions holding earnings (quality of schools) constant.

Using biometrics our study sheds light on the perception and repercussions of envy; both justified and unjustified. Griffin et al. (2012) rely on skin conductance measures to isolate the positive effects of cognitive-behavioral therapy on subjects diagnosed with post-traumatic stress disorder (PTSD). They find successful cognitive-behavioral treatment of PTSD is associated with a quantifiable reduction in physiological responding to loud tones as captured by GSR magnitude. Joffily et al. (2014) study emotions in a voluntary contribution mechanism with punishment by complementing their study with GSR measures and survey responses to capture the valence of emotions. Upon learning about others' contributions, they find that free-riders are less aroused than subjects who learn that others contributed less than them. Free riding is associated with reports of positive valence on the perception of outcomes meanwhile subjects that learned they contributed more than others reported on average a more negative emotional state.

3 School Choice Mechanisms and the Experimental Environment

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 is Pareto efficient if there is no 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 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.[1]

3.1 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.

[1] A third mechanism, the Boston mechanism (a.k.a Immediate Acceptance, IA), is described in the Appendix. The Boston mechanism is not strategy-proof, but it eliminates justified envy in equilibrium.

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 k$^{\text{th}}$ 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 or the only students who remain unassigned have listed no more than k choices. Each school is then matched with those students whom it is currently holding.

3.2 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: Remaining applicants point to their most preferred school that still has open seats. Each school points to their highest priority student among those students 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.

Generally, in Round ($k \geq 3$): Remaining applicants point to their most preferred school that still has open seats. Each school points to their highest priority student among those students 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. This process repeats until all participants are assigned to a school.

3.3 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

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

one. When the capacity of each object assigned is only one as in our context, TTC may be thought of as the most fair among strategy-proof and efficient mechanisms (Morrill, 2015a). Although TTC is strategy-proof and efficient, it does not eliminate justified envy; Morrill (2015a) provides an eloquent characterization of TTC's justness, which is a weaker fairness concept than justified envy. Morrill also proposed two simple variations of TTC, namely (First) Clinch and Trade, that preserve its desirable properties of strategy proofness and efficiency, and mitigate the extent of the presence of justified-envy when schools have a greater capacity than one (Morrill, 2015b). In our setting, the capacity of each object assigned is one and these variations generate the same equilibrium allocations as TTC. Since an instance of justified envy is necessary for an assignment to be unjust, clearly if an assignment has no justifiable envy, then it is just. Therefore, since DA eliminates justified envy, it is just. The Boston (IA) mechanism is not necessarily just with truthful reporting though in equilibrium it is just.

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

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

In the 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. Under the TTC mechanism, a different allocation 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 options as in matching μ, but Players 2 and 3 are assigned to strictly better options. 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.

3.4 Experimental Design and Procedures

The experiment implemented the game described in Section 3.3 in a 2×2 design. Subjects experienced the two aforementioned mechanisms {DA, TTC} under FULL feedback where they learned the assignments of all other players after the game concluded, or PARTIAL feedback, where they only learned 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.

Subject emotional arousal was measured using Galvanic Skin Response (GSR) and visual attention was assessed using eye-tracking. GSR data were analyzed for two separate screens during the feedback stage. First, GSR monitored subjects at the time they were informed of their assignment. If a subject was randomly assigned to the FULL treatment, the subject also observed the assignments of other group members. Second, immediately after, these subjects received a message that was designed to accentuate justified envy when present. The structure of the message can be found in the Appendix. If a subject was assigned to treatment PARTIAL, he was never informed about the assignments of other group members and received a neutral message saying "This concludes the stage of this game."[2] The two pages at the feedback stage were displayed for a fixed duration of thirty seconds each since emotional arousal reaction may last anywhere between ten to thirty seconds. The data analysis is based on the GSR magnitude and functional GSR tests

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

in the one-shot incentivized school choice game.[3] We take an approach based on functional data analysis, where temporal galvanic skin response data is 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 discreet 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 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).

Before the experiment began, the instructions were read aloud and any questions were answered privately. Given the relatively complex nature of matching mechanisms, we allowed subjects to read instructions again at their own pace if they wished to do so. After subjects finished reading instructions, a quiz was administered to ensure comprehension. Questions were intended to check that subjects understood (i) option capacities, (ii) how to read payoff and priority ranking tables, and (iii) solving a simple allocation problem given others' reports.[4]

Subjects were then randomly assigned to groups of four and each subject was randomly assigned to one of four preference types (1, 2, 3 and 4). Subjects played four unpaid "practice" rounds of similar school choice games so they could become familiar with the decision environment and the nature of the matching mechanisms. In each practice round, subjects faced a new set of preference profiles and priorities; all differed from those shown in Tables 1 and 2. The overall structure of preferences were 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 featured the game described in Section 3.3 and was the sole basis for (differential) payoffs for subjects.

After the school choice game, subjects answer an open-ended question on how they played the game and other questions on their perception of a mechanism's manipulability.[5] Finally, they

[3]GSR data were collected with Shimmer3 units at a 128 Hz sampling rate. The GSR magnitude was calculated as the difference between the signal amplitude at the peak and the onset times with the measurement unit being a microSiemen (μS). Signals were visually inspected before further analysis and ectopic responses were removed.

[4]Instructions and the comprehension quiz are available as Supplemental Materials.

[5]Survey questions are available as Supplemental Materials.

completed a shortened version of Raven's Progressive Matrices (RPM) test (Raven, 2000).[6]

A total of 39 sessions which contained 72 groups for 288 participants took place at the Human Behavior Lab at Texas A&M University during 2021. An average session lasted about an hour and subjects earned $24.03 (sd=6.34) on average.

3.5 Predictions

Section 3.3 provides equilibrium predictions under dominant strategy play for both the TTC and DA mechanisms used in the experiment. Under equilibrium, the TTC should lead to an outcome that is efficient but creates justified envy. Conversely, allocations 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.

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

1. *The TTC treatment will produce more efficient allocations than the DA.*
2. *The DA will produce fewer allocations with justified envy than the TTC.*

Biometric response literature consistently points out 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 with lower earnings in the school choice game to exhibit higher emotional arousal. Secondly, we focus on the equilibrium outcome of TTC to test the effect of justified-envy since it is exogeneously generated in this mechanism. Equilibrium assignments of TTC are such that of the two players who earn low equilibrium payoffs, i.e., $7, Player 4 experiences justified-envy meanwhile Player 1 does not. These assignments allow us to directly test the effect of justified-envy on triggering a negative emotional response while holding earnings constant. The

[6]The Raven test is a leading non-verbal measure of analytic intelligence (Carpenter et al., 1990; Gray and Thompson, 2004). The test scores are associated with the degree of sophistication in the beauty contest (Gill and Prowse, 2016), with cooperation rates in the repeated prisoner's dilemma (Proto et al., 2014), with performance in Bayesian updating (Charness et al., 2018) and with more accurate beliefs (Burks et al., 2009). Each question of the test asks to identify a missing element that completes a visual pattern from a list of candidates. The Standard version of the Raven test consists of 60 questions split into 5 blocks of increasing difficulty, labeled A–E, with 12 questions in each. We used blocks C, D and E for a total of 36 questions as in Basteck and Mantovani (2018). Subjects were given 5 minutes for each of blocks C and D, and 8 minutes to complete block E. Each block was shown on a separate page and subjects could change their answers as many times as they wished. Participants were awarded $0.10 for each correct answer.

elimination of justified-envy in the context of school choice purportedly is a fairness criterion. From a fairness standpoint, the existence of justified-envy could be judged as an obvious conflict with the very purpose of priority orderings. Our two feedback environments, FULL and PARTIAL, allow us to directly test whether the presence of justified-envy triggers a negative emotional reaction to payoffs both when an explicit message makes it salient (FULL) and also when there is no information about the assignments of other players (PARTIAL). Relatedly, holding earnings constant, we expect subjects in the FULL condition to visually attend more toward school priorities where they experience justified-envy than envy without justification.

Prediction 2 *Envy of all types will be associated with increased arousal. Holding earnings constant, subjects who experience justified-envy will exhibit increased arousal in the FULL but not in the PARTIAL condition.*

1. *Subjects with lower earnings in the school choice game will exhibit higher emotional arousal which is consistent with more negative evaluations of stimuli triggering a greater response.*
2. *Subjects will visually attend more to envy with justification than envy without justification when they are provided with the assignments of other players. Holding earnings constant, justified (relative to unjustified) envy will impose an emotional toll on subjects.*

3.5.1 Attribution and Justified Envy

At the end of the school choice game, one of the survey questions asked subjects the extent to which they attributed their outcome to the mechanism vs. their own ability. The self-attribution bias suggests subjects that earn higher payoffs may attribute favorable outcomes to their own ability while attributing low payoffs to the mechanisms to avoid responsibility for a bad outcome.

Prediction 3 *Subjects self-report differential attribution to ability depending on the payoffs. Subjects attribute more weight to ability (mechanism) when they earn high (low) payoffs.*

To the extent justified envy is seen as unfair and invalidates the designer's choice of mechanism, we would also expect more blame placed on the mechanism when justified envy is revealed, all else being equal.

Prediction 4 *Subjects self-report differential attribution to ability depending on justified envy. Subjects attribute more weight to ability (mechanism) when they experience justified envy in the PARTIAL (FULL) treatment.*

3.5.2 Heterogeneity Among Cognitive Types

Under the DA and IA mechanisms, Basteck and Mantovani (2018) find subjects that perform better on a shortened version of Raven's Progressive Matrices (RPM) test are more likely to play equilibrium strategies for school choice mechanisms. In the case of the strategy-proof DA and TTC mechanisms, equilibrium strategies correspond to truth-telling. While Basteck and Mantovani (2018) find that the DA levels-the-playing-field, we do not expect this to be the case with TTC because of the algorithm's strategic complementarities.

Prediction 5 *High ability subjects on the RPM task are more likely to report truthfully than low ability subjects in strategy-proof mechanisms. Not all strategy-proof mechanisms, however, level-the-playing-field.*

4 Results

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

1. *The TTC mechanism achieves more efficient outcomes than DA.*

2. *The DA mechanism achieves more outcomes without justified envy than TTC.*

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

	Groups	Equilibrium Assignments	Full Efficiency	Elimination of Justified Envy
DA	9	7 (77.8%)	1 (11.1%)	8 (88.9%)
TTC	37	17 (45.9%)	17 (45.9%)	16 (43.2%)
Total	46	24 (52.2%)	18 (39.1%)	28 (60.9%)

Table 3 examines group-level outcomes of whether the two mechanisms achieved equilibrium assignments, full efficiency, and eliminated justified envy. In theory, both mechanisms should always achieve the equilibrium assignments. Given the specific valuations chosen (see Section 3.3), the equilibrium outcome of DA is not unique.[7] The TTC, on the other hand, should always achieve full efficiency and never eliminate justified envy. The two mechanisms did not achieve statistically different equilibrium outcome rates ($p \approx 0.139$, Fisher's exact test). The comparative statics of

[7] Player 4 is bossy in DA and decides whether players 2 and 3 are assigned to their best or second-best options. The latter outcome is reached through dominant strategy (i.e. truthful) play.

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%), ($p = 0.032$ rank sum; $p = 0.013$ t-test). In contrast, only 1 (11.1%) DA group is fully efficient compared to nearly half (45.9%) the TTC groups ($p = 0.058$ rank sum; $p = 0.057$ t-test). Mean player payoffs are also $1.58 higher under TTC compared to DA ($11.63 vs. $10.05, $p = 0.083$ rank sum; $p = 0.032$ t-test).

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 32 probability points less likely to achieve an equilibrium outcome. Consistent with theory, TTC is 35 probability points more likely to achieve an efficient outcome; DA is 46 probability points more likely to achieve an outcome that eliminates justified envy.

Table 4: Linear probability model of theoretical properties on mechanism and number of FULL feedback subjects in group.

	(1) Equilibrium assignments	(2) Full efficiency	(3) Elimination of Justified Envy
TTC	-0.318**	0.348**	-0.456***
mechanism	(0.147)	(0.140)	(0.146)
No. of FULL	-0.091	-0.091	0.091
feedback subjects	(0.131)	(0.113)	(0.091)
Constant	0.960***	0.293**	0.707***
	(0.298)	(0.257)	(0.220)
Observations	46	46	46
Sessions	24	24	24
R-squared	0.080	0.097	0.147

Notes: All three regression models use cluster-robust standard errors at the session level.
***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

Result 2 *Envy of all types is associated with increased arousal. Holding earnings constant, subjects who experience justified-envy exhibit more sustained arousal.*

1. *Subjects with lower earnings in the school choice game exhibit higher emotional arousal which is consistent with more negative evaluations of stimuli triggering a greater response.*

2. *Subjects visually attend to justified-envy only upon receiving a message that accentuates it. Holding earnings constant, justified (relative to unjustified) envy imposes an emotional toll*

[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.

on subjects.

We begin by examining whether subjects who experience envy exhibit higher arousal due to more negative evaluations of stimuli as captured by the GSR magnitude. Biometric response literature consistently points out to this phenomenon (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). Table 5 reports the average arousal based on the GSR magnitude by type of envy for equilibrium assignments in TTC. We observe that envious subjects of all types exhibit higher average arousal as captured by the GSR magnitude after learning their earnings in both feedback conditions (Table 5(a)). We do not find meaningful differences in GSR magnitude between subjects who experience envy with and without justification in either feedback condition at this stage. We find subjects who experience envy without justification are more aroused than those who experience justified-envy in the PARTIAL condition when these subjects receive a neutral message (rank-sum test, $p < 0.05$). This difference could have emerged due to Player 1 subjects recognizing they had unfavorable priority orderings at their two most preferred options.

Table 5: Average GSR Magnitude (Arousal) by Envy

Feedback Condition	(1) No Envy	(2) Justified-Envy	(3) Unjustified-Envy	(4) Hypothesis	(5) p-value
FULL	0.263 (0.198) $N = 10$	0.311 (0.303) $N = 8$	0.356 (0.259) $N = 4$	(2) $\neq$ (3)	0.497
PARTIAL	0.171 (0.175) $N = 14$	0.336 (0.357) $N = 4$	0.290 (0.229) $N = 8$	(2) $\neq$ (3)	0.865

(a) Results Stage

Feedback Condition	(1) No Envy	(2) Justified-Envy	(3) Unjustified-Envy	(4) Hypothesis	(5) p-value
FULL	0.102 (0.159) $N = 10$	0.235 (0.363) $N = 8$	0.140 (0.207) $N = 4$	(2) $\neq$ (3)	0.497
PARTIAL	0.210 (0.258) $N = 14$	0.047 (0.082) $N = 4$	0.388 (0.406) $N = 8$	(2) $\neq$ (3)	0.049

(b) Message Stage

Notes: standard deviations in parentheses. Only the equilibrium outcome of TTC included. In this outcome (i) players 1 and 4 earned \$7 each, and (ii) players 2 and 3 earned \$20 each. Player 4 experienced envy with justification and Player 1 experienced envy without justification. p-values are based on rank-sum tests.

We run an ordinary least squares regression (Table 6) to confirm that the well-established empirical observation that describes the relationship between arousal and the evaluation of stimuli holds in our data upon subjects learning their school assignments. Both feedback conditions separately reaffirm the negative relationship between earnings and arousal although these results are not significant under conventional levels (FULL condition, $p = 0.251$; PARTIAL condition, $p = 0.149$). After controlling for earnings, we do not find that envy with justification causes higher arousal in either condition. In specifications (3) and (4), we pool observations from the two feedback conditions. After controlling for feedback condition and whether the experienced envy was justified, we find that a \$1 increase in earnings is associated with a 0.01 μS decrease in arousal ($p = 0.060$) in specification (3) - this effect is similar in magnitude to those obtained in specifications (1) and (2). In specification (4) we examine whether justified-envy differentially impacts subjects in the FULL compared to the PARTIAL condition and find the effect is not statistically significant ($p = 0.983$). In this specification too, the magnitude of the effect of earnings on arousal is similar to the previous specifications in the Results Stage ($p = 0.061$). Regression results from the Message Stage suggest earnings do not impact subjects' emotional arousal if captured by the GSR magnitude. In specification (6) where we examine the arousal of subjects in treatment PARTIAL, we find subjects who experience justified envy are less aroused even though they cannot internalize this information since they are not informed about others' assignments ($p = 0.081$) – this effect could be driven by Player 1 subjects recognizing they had unfavorable priority rankings at their top two options. In specification (8), we do not find that justified envy differentially impacts subjects assigned to condition FULL relative to those assigned to treatment PARTIAL ($p = 0.312$).

We now turn to the question of whether justified (relative to unjustified) envy differentially impacts subjects, all else equal. First, we investigate how attention is allocated among envious subjects in the feedback stage of our main treatment (FULL) without directly eliciting their views. Specifically, we assess how subjects assigned to the Player 1 and 4 roles in the TTC mechanism allocate their attention toward the allocations of other subjects. Recall that in TTC, two two-way cycles form in equilibrium where players 2 and 3 point to each other's provisionally assigned option and are assigned to their top choices, and players 1 and 4 point to each other's provisionally assigned option and are assigned to their third choices. While equilibrium assignments exogenously generate justified-envy in TTC, it is endogenously generated in DA given the multiple equilibria.[9]

[9] Only 1 out of 36 subjects experienced justified-envy in DA. Because justified-envy in DA is endogenously generated since Player 4 is bossy and dictates whether players 2 and 3 are assigned to their top or second choice, we focus on the effects of justified-envy in TTC.

Table 6: Determinants of GSR Magnitude (Arousal)

	Results Stage				Message Stage			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Earnings	-0.009	-0.011	-0.010*	-0.010*	-0.002	-0.006	-0.004	-0.005
	(0.008)	(0.008)	(0.005)	(0.005)	(0.009)	(0.007)	(0.005)	(0.005)
FULL			0.002	0.002			0.008	-0.016
			(0.063)	(0.068)			(0.062)	(0.066)
Justified-envy	-0.116	-0.128	-0.123	-0.121	-0.029	-0.248*	-0.128	-0.236
	(0.132)	(0.164)	(0.103)	(0.150)	(0.149)	(0.140)	(0.102)	(0.148)
FULL x Justified-envy				-0.004				0.194
				(0.194)				(0.191)
Constant	0.459***	0.486***	0.473***	0.473***	0.266**	0.329***	0.295***	0.308***
	(0.111)	(0.110)	(0.082)	(0.083)	(0.125)	(0.093)	(0.081)	(0.082)
Feedback	FULL	PARTIAL	Pooled	Pooled	FULL	PARTIAL	Pooled	Pooled
Observations	66	64	130	130	66	64	130	130
R-squared	0.024	0.035	0.030	0.030	0.001	0.051	0.014	0.014

Notes: standard errors in parentheses and clustered at the session-level. Observations pooled from DA and TTC. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

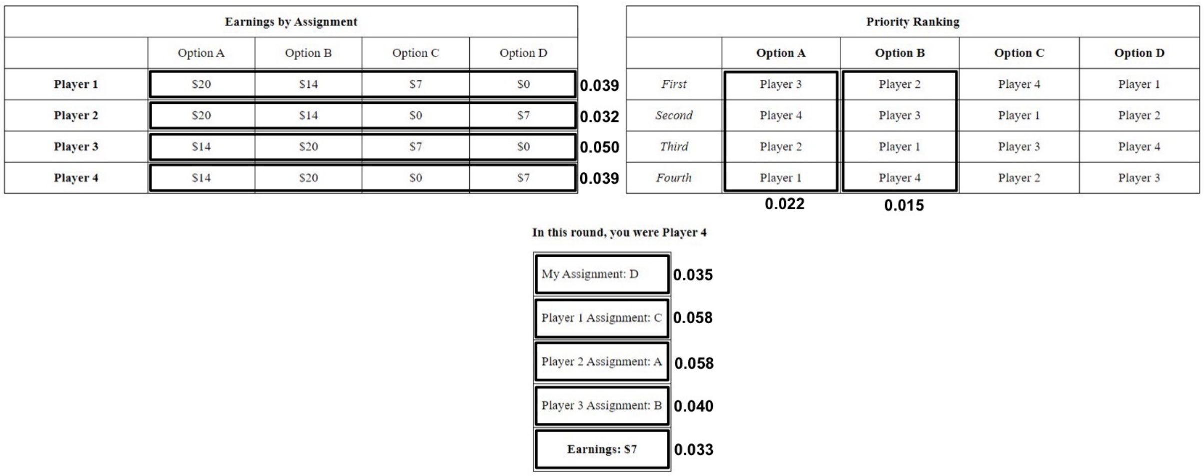
First, we study attention dispersion of subjects assigned to the role of Player 4 conditional on a two-way efficient cycle forming between players 2 and 3.[10] Such a cycle creates an instance where Player 4 experiences justified-envy towards Player 2 but unjustified envy towards Player 3.[11] Hence, the initial within-subject analysis focuses on whether subjects are more attentive to justified than unjustified envy when subjects towards whom envy is experienced have identical earnings. Figure 1 reports the proportion of gaze time allocated toward relevant Areas of Interest (AOI) when a subject experienced justified-envy in treatment FULL. We initially observe that subjects do not only study their earnings but also the earnings of the other group members when this information is provided. We evaluate possible statistical differences in the mean percentage of gaze time spent by participants toward (i) their own and others' assignments, (ii) assignments of players 2 (justified-envy) and 3 (unjustified-envy), (iii) their own and others' induced payoffs, (iv) induced payoffs of players 2 (justified-envy) and 3 (unjustified-envy), and (v) priority orderings at options A (justified-envy) and B (unjustified-envy). Results from the initial feedback stage show that conditional on Player 4 experiencing justified envy and being assigned to treatment FULL, the only statistically significant difference is in comparison (i) where these subjects spend less time fixating on their assignment than the assignments of other players (Wilcoxon paired test, $N = 10$, $p = 0.084$). This difference could be simply due to earnings information being provided in the last cell box thereby reducing the need to reference their own payoff row and assignment for Player 4 to deduce earnings. The rest of the comparisons in (ii)-(v) are not significant in the first feedback stage (Wilcoxon paired test, $p > 0.1$, in all four comparisons). Crucially, thus far, this suggests subjects pay similar attention to envy with and without justification. Results from the second feedback stage (Figure 1(b)) where these subjects received a message designed to accentuate justified envy (towards Player 2) suggest they spent more time fixating on the priorities at Option A compared to the priorities at Option B (Wilcoxon paired test, $N = 10$, $p = 0.055$) indicating the message attracted the visual attention of subjects as intended.[12] These subjects did not spend significantly different times fixating on the assignments of players 2 and 3 at this stage (Wilcoxon paired test, $N = 10$, $p = 0.141$) although this is marginally insignificant under conventional levels. These data provide clear evidence that subjects visually attend to justified-envy only when they are directed

[10] We do not impose that a two-way efficient cycle needs to also occur between players 1 and 4 which is the case in equilibrium. It is sufficient for players 1 and 4 to report their third most preferred option ahead of their fourth for such a cycle to materialize although one of players 1 or 4 failing to do so results in both of them earning \$0 in the school choice game.

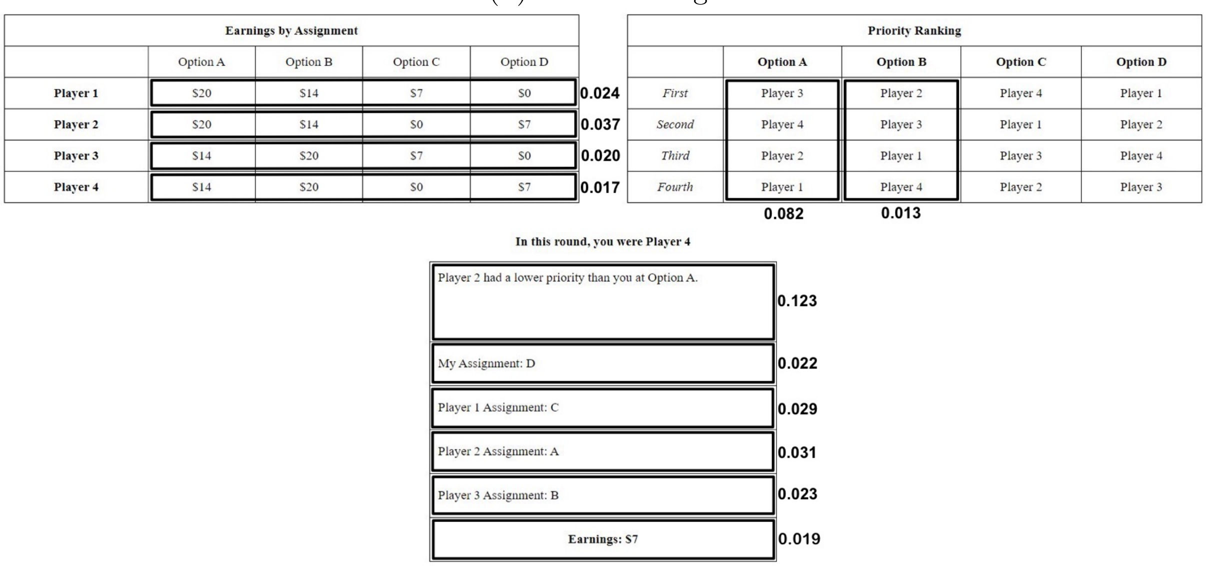
[11] While both players 2 and 3 earn \$20 each, Player 2 is assigned to Player 4's second most preferred school while Player 3 is assigned to Player 4's top choice.

[12] All of the 10 subjects who received this message visually attended to it.

Figure 1: 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

Notes: The proportion of gaze time is averaged for each AOI among participants assigned to the Player 4 role conditional on being assigned to treatment FULL and a two-way cycle forming between players 2 and 3.

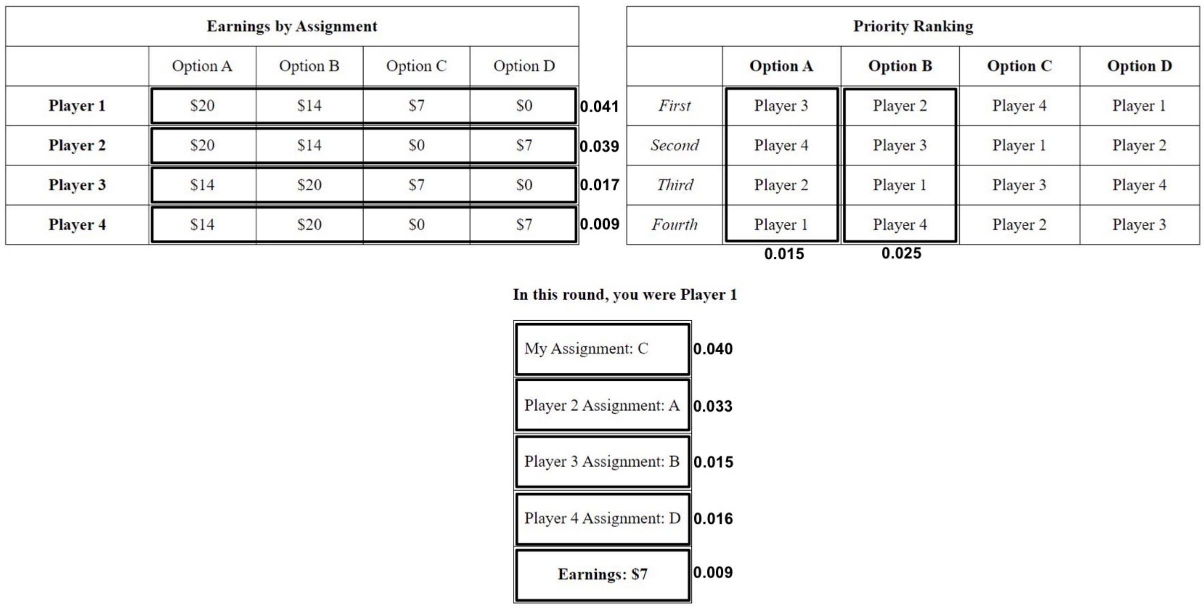
to this information.[13] Within-subject differences in how gaze was dispersed between priorities at options A (justified-envy) and B (unjustified-envy), as well as between assignments of players 2 (justified-envy) and 3 (unjustified-envy) for subjects assigned to treatment FULL, provide support that subjects attend to justified-envy only when they learn about others' assignments and receive a message that accentuates it.

One possibility for why subjects are not more attentive towards justified than unjustified envy in the initial feedback stage in a within-subject comparison could be because Player 4 is more envious towards Player 3 (unjustified-envy) than Player 2 (justified-envy).[14] To address this issue, we exploit a between-subject comparison between players 1 and 4. Specifically, we test whether these subjects pay differential attention to the players who were assigned to their second-best choices in equilibrium. Crucially, Player 4 experiences justified-envy towards the player assigned to his second-best choice (Player 2) whereas Player 1 experiences unjustified envy towards the analogous player (Player 3). Figure 2 depicts areas of interest for the comparison with Player 4 (Figure 1). We examine whether there are differences in visual attendance between players 1 and 4 toward (vi) the assignments of the players assigned to their second-best options, (vii) induced payoffs of the players assigned to their second-best options, and (viii) the priorities at these options. In the initial feedback stage, subjects assigned to the Player 4 role allocate more gaze time towards the assignment of the player assigned to their second-best choice (Player 2, with justified-envy) than Player 1 subjects do towards the assignment of the analogous player (Player 3, without justified-envy), which suggests when holding earnings constant subjects are more attentive to assignments with justified than unjustified envy (rank-sum test, $N = 17$, $p = 0.005$). Comparing players' 1 and 4 gaze allocation towards the assignments of players assigned to their first choice, however, reveals no difference (rank-sum test, $N = 17$, $p = 0.205$). For a subject to fully grasp the presence of justified-envy, he must also observe that he has a higher priority ranking at a more desirable option than a subject assigned to that option. Comparing players' 1 and 4 gaze allocations towards the priorities of their second-best choices reveals no difference (rank-sum test, $N = 17$, $p = 0.695$). Finally, we

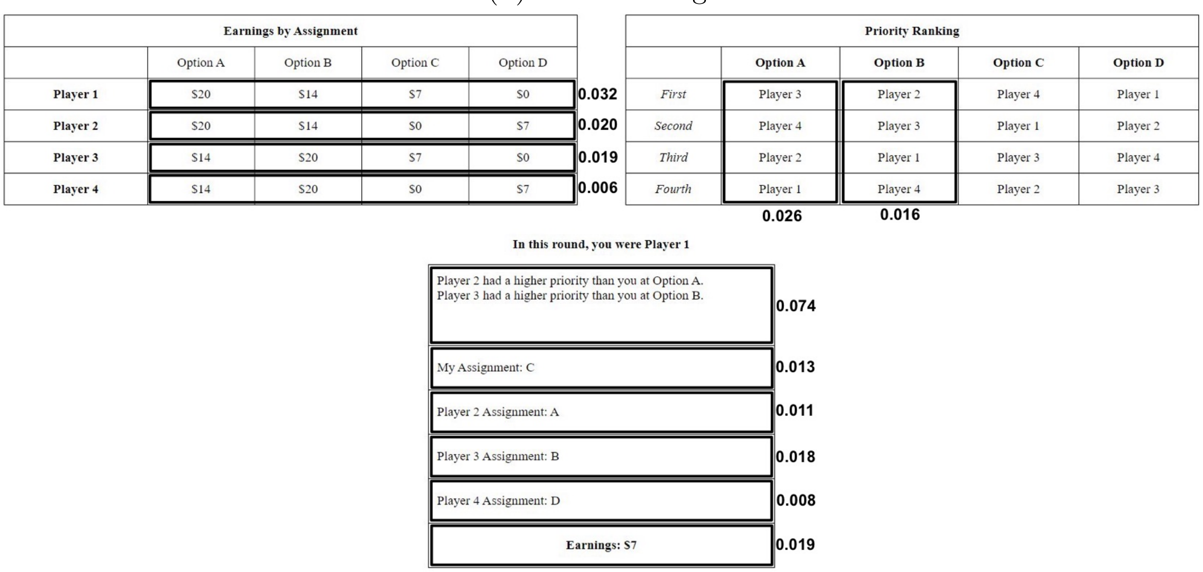
[13]There are no meaningful differences in (iii)-(v) for subjects assigned to treatment PARTIAL in the initial stage when experiencing justified-envy except that these subjects spent more time fixating on the priorities at Option B than Option A (Wilcoxon paired test, $N = 6$, $p = 0.094$) which could be a result of Option B being Player 4's most preferred option. Recall subjects assigned to treatment PARTIAL never learn the assignments of others; therefore, the differences in (i) and (ii) are not applicable to this set of subjects. Similar figures to Figure 1 for subjects assigned to treatment PARTIAL are available upon request. Upon receiving a neutral message that this concludes the feedback stage of the game, these subjects spent more gaze time on their own induced payoff row than the induced payoffs of the other group members (Wilcoxon paired test, $N = 6$, $p = 0.063$).

[14]Recall, in equilibrium, Player 3 is assigned to Player 4's top choice and Player 2 is assigned to Player 4's second-best choice.

Figure 2: 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

Notes: The proportion of gaze time is averaged for each AOI among participants assigned to the Player 1 role conditional on being assigned to treatment FULL and a two-way cycle forming between players 2 and 3.

find no meaningful differences on gaze dwell times between players 1 and 4 towards the induced preferences of players assigned to their second-best choices although this is marginally insignificant (rank-sum test, $N = 17$, $p = 0.118$). The lack of differences in visual gaze towards priorities but not in assignments or induced payoffs of other subjects suggests Player 4 subjects inspected the earnings of other group members more thoroughly than Player 1 subjects. Importantly, these results provide weak evidence that subjects are more attentive to envy with than without justification in the initial feedback stage due to the lack of differential attention at option priorities.

Next, we examine if differences in attentiveness toward option priorities emerge when the presence of justified-envy is accentuated with an explicit message.[15] At this stage, subjects are not differentially attentive toward priorities at their second-best option when experiencing justified rather than unjustified envy (rank-sum test, $N = 17$, $p = 0.138$). Importantly, we noted earlier that at this stage subjects assigned to the Player 4 role visually attended significantly more at the priorities of Option A than Option B which provided evidence that the message geared subjects' attention as intended. For subjects assigned to the Player 1 role, however, the message emphasized envy without justification at both options A and B, and subjects did not allocate their gaze differentially between these options (Wilcoxon paired test, $N = 7$, $p = 0.667$). These data provide evidence that subjects do not actively look for whether they may be prone to justified-envy unless they are directed to such information.

Our two feedback conditions allow us to test if justified envy imposes an emotional toll on subjects both when it can be observed through information about the assignments of others and when subjects are informed only about their own assignment. We interpret emotional arousal captured by GSR as unpleasant feelings whenever a subject is not assigned to her most preferred choice. Subjects may display arousal if assigned to their best choice due to the joy or excitement of higher earnings. Importantly, biometric response literature consistently points out that more negative evaluations of stimuli are associated with increased arousal. We documented support for this phenomenon in our data by testing whether subjects with lower earnings in the school choice game exhibit higher arousal in both TTC and DA as caputred by the GSR magnitude. We focus on equilibrium assignments of TTC to test whether the distributions of arousal vary over time by earnings and type of envy.[16] We reject the hypothesis that subjects are similarly aroused

[15] A subject assigned to a Player 4 role received such a message when a 2-way efficient cycle formed between players 2 and 3 (see Figure 1(b)). A subject assigned to a Player 1 role received a message that highlighted the lack of justified envy (see Figure 2(b)).

[16] Recall that in DA there exist non-truthful strategies that are in the set of equilibrium strategies which can sometimes generate an efficient outcome in this mechanism. The same is not true for TTC, however. In TTC

upon learning their earnings in both feedback conditions in TTC (Kruskal-Wallis functional test, $p < 0.1$, during the first 10 seconds). Subjects exhibit different levels of arousal upon receiving targeted messages in TTC that accentuate (the lack of) justified-envy (Kruskal-Wallis functional test, $p < 0.05$, for extended periods of time in the message stage) but a neutral message that provides no additional information does not differentially impact subjects (Kruskal-Wallis functional test, $p < 0.1$, only during the last 15 seconds).[17] To follow-up and untangle which groups differ, we conduct *post-hoc* Dunn's tests to adjust for multiple pairwise comparisons using a Bonferroni correction.[18] Next, we examine whether envy with and without justification imposes differential arousal on subjects when holding earnings constant.

The variation in experiencing justified versus unjustified envy in our data when holding earnings constant is generated exclusively from subjects assigned to their third-best and fourth-best options. We consider equilibrium assignments in TTC for our main analysis since through these assignments the presence (or absence) of justified-envy is exogenously generated for comparison between players 1 and 4 who both earn \$7 each. Instances where subjects assigned to roles of players 1 and 4 earned \$0 each occured because at least one of these two players failed to report an equilibrium strategy that can be described as reporting the third-best choice ahead of the fourth. For this reason, interpreting the effect of justified-envy resulting from these assignments is difficult.[19] Figure 3 shows changes in emotional arousal from the onset of the initial feedback stage captured by GSR averaged across subjects over time who were assigned to different feedback conditions. These figures include observations from the TTC mechanism for players 1 and 4 when an efficient two-way cycle formed between players 2 and 3.[20] We note that when equilibrium assignments occured in treatment FULL, subjects who experienced justified-envy are, on average, more aroused during the initial feedback stage than subjects who experienced envy without justification. We conduct a functional Dunn's test to examine if there are statistical differences between these groups over time.[21] We do not find meaningful differences between subjects who experienced envy with and

non-truthful equilibrium strategies always lead to an efficient outcome.

[17]We show support in the Appendix through dynamic analyses that subjects with lower earnings exhibit higher arousal in both mechanisms which is consistent with more negative evaluations of stimuli triggering a greater response.

[18]Dunn's tests make an adjustment by accounting for the ranks of the data potentially changing if they are re-ranked in a pairwise fashion. We conduct functional rank-sum tests in the DA mechanism comparing subjects with differential earnings that are obtained through truthful revelation (all of these subjects experience unjustified envy).

[19]For example, a Player 1 or 4 subject who reported an equilibrium strategy but earned \$0 in the school choice game may be more negatively impacted because of recognizing that other subjects failed to report equilibrium strategies. Additionally, subjects who failed to report an equilibrium strategy might not be affected given their confusion.

[20]When such a cycle does not form between players 2 and 3, Player 4 experiences envy that is not justified. We keep the allocations of players 2 and 3 fixed for a clean comparison of envy with and without justification between players 4 and 1, respectively.

[21]Since GSR data were collected at 128 Hz, we conducted 3840 such non-parametric tests for the initial feedback

without justification at this stage (Dunn's test, $p > 0.1$ at all times).[22] When turning to equilibrium assignments in treatment PARTIAL, we can see that subjects who experienced envy with and without justification have similar arousal levels throughout the initial feedback stage.[23] Next, we examine arousal differences at the second feedback stage where these subjects were presented with the same feedback information as in the previous stage but received an additional message that accentuated justified-envy or highlighted the lack thereof in treatment FULL.[24] Figure 4 shows changes in emotional arousal from the onset of this stage for both feedback conditions. In our main feedback condition where we provide subjects with information about others' assignments, we note statistically significant differences in arousal between subjects who experience envy with and without justification shortly after these subjects receive respective messages. As seen in Figure 4, subjects who experience justified-envy show sustained and greater arousal than subjects whose envy is not justified, and these differences persist during the first 15 seconds following stimulus onset (Dunn's test, $p < 0.05$, except in the interval between 8-10 seconds).[25] While the latter show a slow, steady decline in arousal, the former exhibit relatively increased, sustained arousal for the entirety of the feedback stimulus. We do not find statistically significant differences for these analogous groups in treatment PARTIAL in the first 15 seconds following stimulus onset. Subjects who experienced envy without justification showcase higher arousal during the last 10 seconds which could be due to Player 1 subjects inspecting their unfavorable priority rankings at Options A and B. Importantly, these differences later in the stage are not emerging due to additional information which is the case in treatment FULL.

Biometric response data from the feedback stage suggest subjects attend to justified-envy only when they are directed to this information. Furthermore, holding earnings constant, justified (relative to unjustified) envy appears to impose an emotional toll on subjects only when it is made salient through an explicit message. These data provide evidence that while subjects may not be actively seeking information about whether they may be prone to justified-envy which is purported to be a fairness criterion in the context of school choice, subjects are negatively affected by such information when it is accentuated via messages.

stage which lasted 30 seconds.

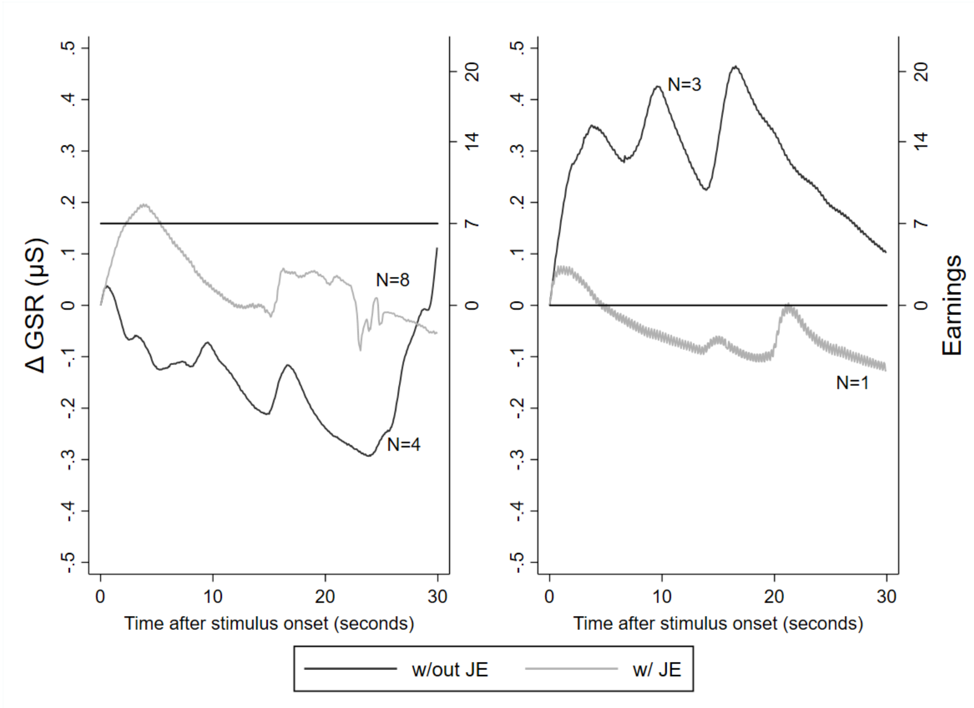
[22] p-values range between 0.10-0.15 for intervals between 4-6 seconds and between 18-22 seconds following stimulus onset.

[23] We identified signal spikes through thorough visual inspection likely resulting from participant movement for one of the 4 subjects who experienced justified-envy in this condition. We fitted a spline for this subject by smoothing the signal based on observations in the last second to exclude the artefact and recover the signal.

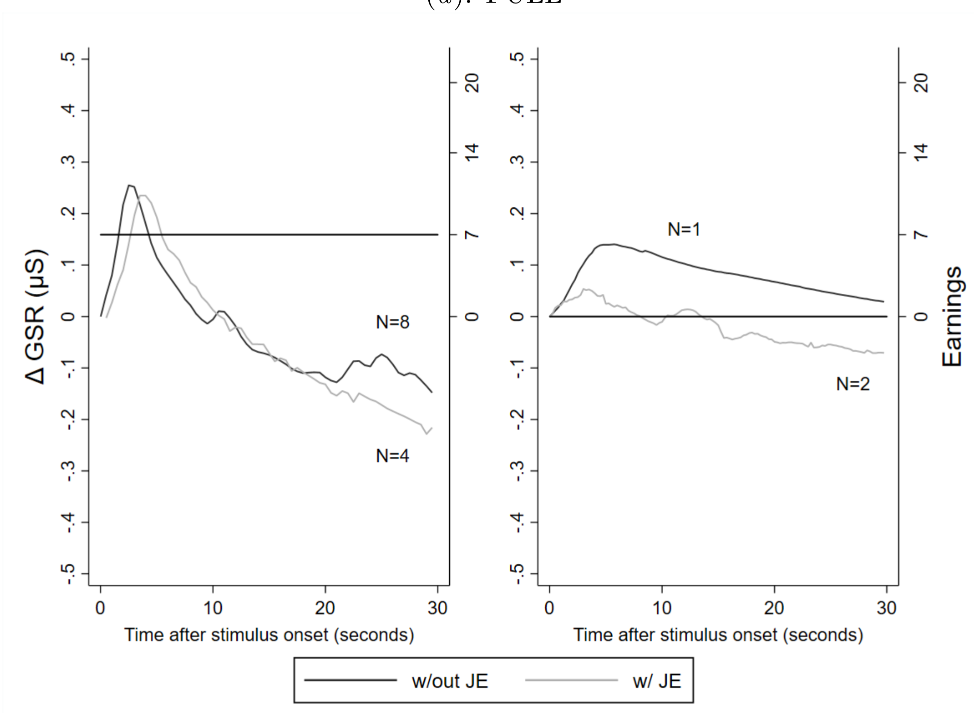
[24] Subjects in treatment PARTIAL received a neutral message saying "This concludes the stage of this game."

[25] Similar figures can be found in the Appendix using a 0.10 significance threshold for these subjects.

Figure 3: Skin Conductance (Results Stage)



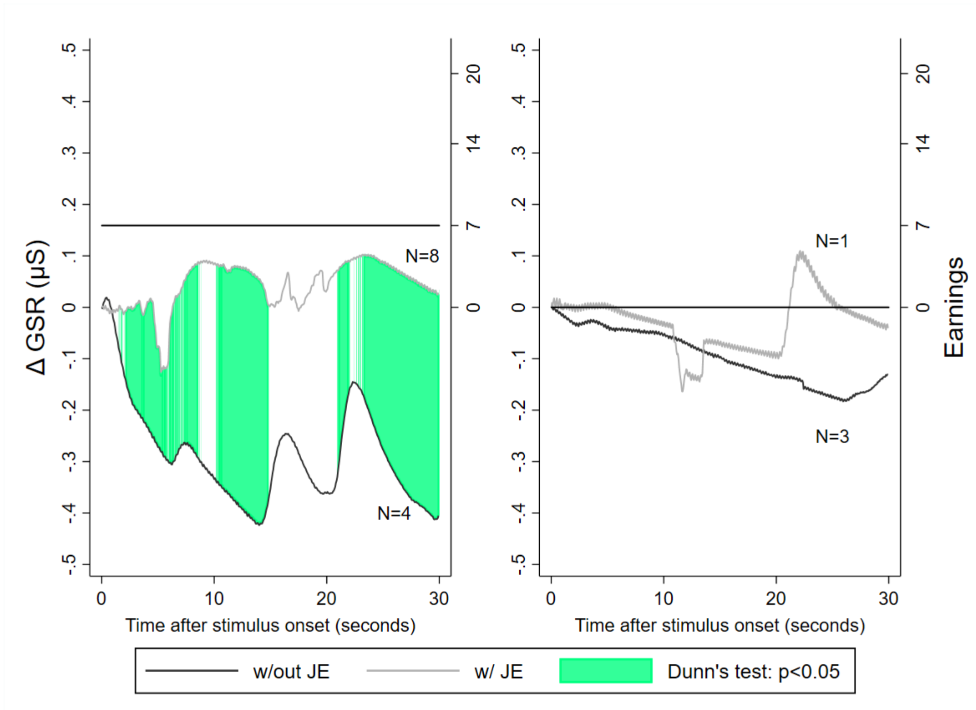
(*a*): FULL



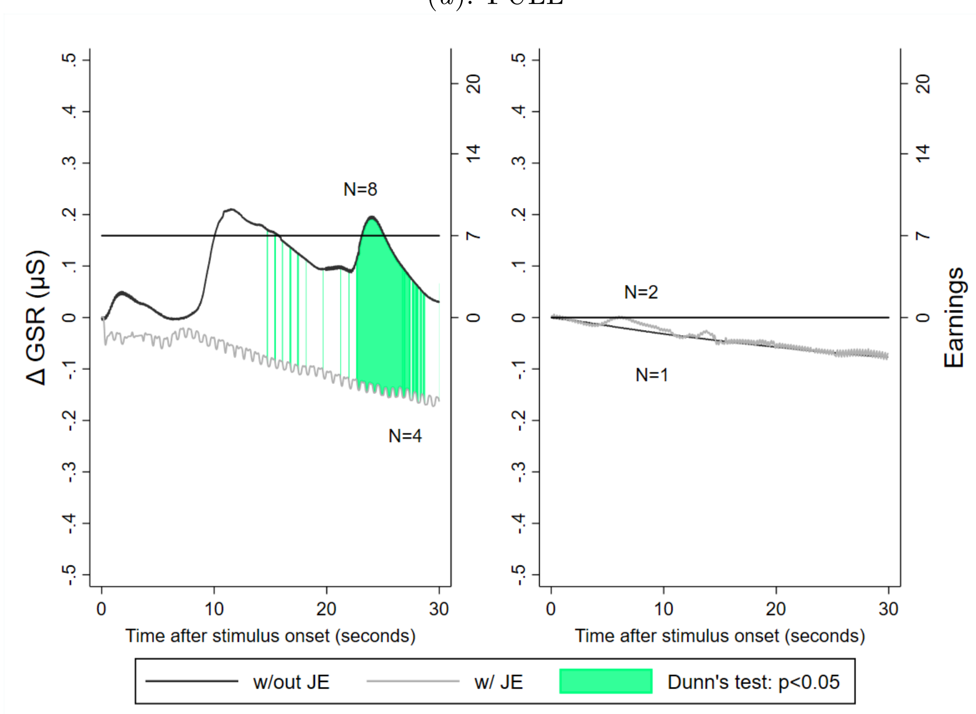
(*b*): PARTIAL

Notes: mean change in skin conductance averaged across subjects over time in the initial feedback stage conditional on a two-way cycle forming between players 2 and 3. Subjects assigned to treatment PARTIAL never learn the assignments of others. Horizontal lines denote earnings in the one-shot school choice game.

Figure 4: Skin Conductance (Message Stage)



(*a*): FULL



(*b*): PARTIAL

Notes: mean change in skin conductance averaged across subjects over time in the message stage conditional on a two-way cycle forming between players 2 and 3. Subjects assigned to treatment PARTIAL never learn the assignments of others. Shaded regions denote significance at the 0.05 level based on functional Dunn's tests. Subjects assigned to treatment FULL received a message designed to accentuate justified-envy or highlight the lack thereof, and subjects assigned to treatment PARTIAL received a neutral message saying "This concludes the stage of this game." Horizontal lines denote earnings in the one-shot school choice game.

Result 3 *Subjects self-report differential attribution to ability depending on the payoffs. Subjects attribute more weight to ability (mechanism) when they earn high (low) payoffs.*

At the end of the school choice game we asked subjects to report to what extent their ability affected their assignment versus to what extent the mechanism was responsible for their assignment. The question was presented on a 7-point slider scale with the extremes corresponding to the mechanism and a subject's own ability (Appendix, Survey Question 3). The slider position was originally placed in the middle and the question strongly prompted subjects to pick a side by "moving the slider accordingly." Subjects could submit their answer without moving the slider and therefore not pick a side. Out of 184 subjects, 24 of them did not attribute more weight to their ability or the mechanisms. Subjects could move the slider as many times as they wished and could return to the original middle position after moving the slider before submitting their answers.

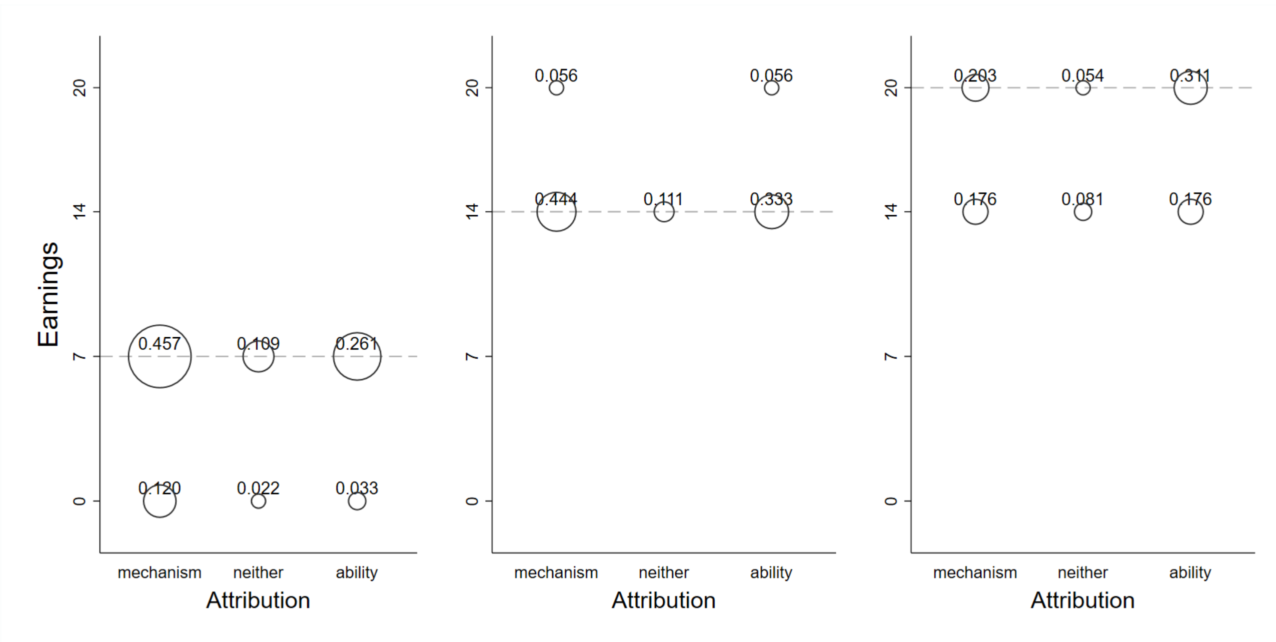
Figure 5 shows the attribution of school choice game earnings conditional on equilibrium payoffs under truthful revelation. Subjects attribute their assignment to the mechanisms significantly more frequently than to their own ability when they earn low equilibrium payoffs (χ^2 p-value=0.027). Subjects do not attribute their assignment to their ability significantly more frequently than to the mechanisms when they earn high equilibrium payoffs (χ^2 p-value=0.405). These results are consistent with a self-serving bias which suggest subjects attribute their assignment to their own ability when favorable outcomes materialize and otherwise attribute unfavorable outcomes to factors outside of their control.

Table 7 provides regression results of subjects attribution of more weight to their ability on payoffs. The dependent variable takes a value of 1 if a subject attributes more weight to his ability than the mechanism, and a value of 0 if a subject attributes more weight to the mechanism than his ability.[26] We examine if ability differences and feedback about others' assignments cause differential attribution for the school choice game earnings. We classify subjects into one of two ability types based on whether their Raven Progressive Matrices (RPM) task score is above or below the median. Figure 6 reports the distribution of the RPM task scores. Ties are broken by the time used to complete the task where faster subjects (with the same score) are assigned to be high ability.[27]

[26]We drop 24 out of 184 subjects who do not attribute more weight to their ability or the mechanisms. Not attributing more weight to own ability or the mechanisms is not correlated with earnings from the school choice game. 12.5%, 13%, 16.7% and 9.1% of subjects do not attribute more weight to the mechanisms or their ability when they earn \$0, \$7, \$14 and \$20, respectively.

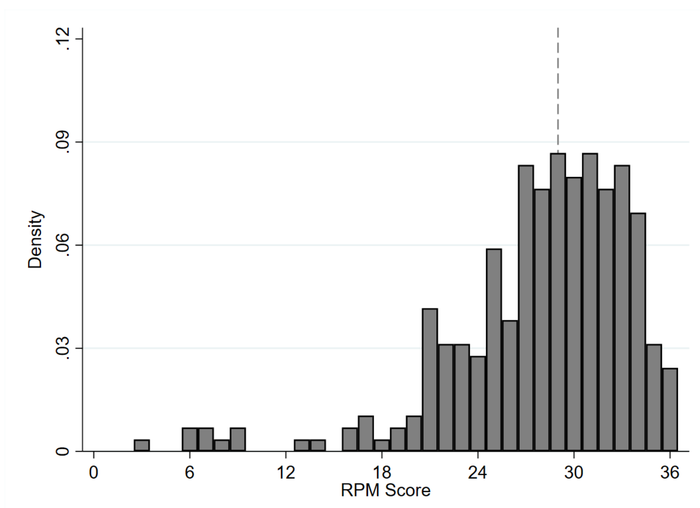
[27]25 subjects had an RPM score of 29. The median subject in time used to complete the task was randomly categorized as *low ability*. None of the results are affected if this subject is categorized as *high ability*.

Figure 5: The Attribution of School Choice Game Earnings



Notes: observations pooled from the DA and TTC mechanisms. Low equilibrium payoffs are $7 in both mechanisms. High equilibrium payoffs under dominant strategy play are $14 in DA, and $20 in TTC. Dotted lines denote these equilibrium payoffs.

Figure 6: Distribution of RPM Scores



Notes: distribution of the number of correct answers in the RPM task. The dotted line denotes the sample median.

Lastly, we examine if experiencing justified-envy is predictive of attributing more weight to the mechanisms than ability. We report regression results in Table 7. The first specification confirms that subjects are more likely to attribute higher earnings in the school game to their ability and lower earnings to the mechanisms after controlling for randomly assigned player roles, ability differences and whether subjects observed others' allocations in the feedback stage (p=0.081). This model also provides evidence that *high ability* subjects attribute school choice game earnings more often to the mechanisms (p=0.090), which implies *high ability* subjects recognize equilibrium assignments are pre-determined given the complete information setting. In specification (2), we find evidence that subjects attribute higher earnings in the school choice game to their ability after controlling for justified-envy (p=0.079) with the magnitude of the effect remaining practically unchanged compared to specification (1). In this specification too, *high ability* subjects attribute their school choice game earnings more frequently to the mechanisms (p=0.083). After controlling for earnings, randomly assigned feedback conditions, player roles and ability differences in specification (2), we do not find evidence that experiencing justified-envy affects the likelihood of attributing earnings to outside factors, i.e. mechanisms (p=0.529). Lastly in model (3), we examine if experiencing justified-envy in a setting where it can be internalized through feedback about others' assignments is associated with a differential attribution compared to when subjects do not have information about the assignments of other group members. We do not find evidence that experiencing justified-envy in treatment FULL is associated with attributing school choice game earnings more frequently to the mechanisms than in an informational feedback setting where subjects cannot presumably infer they may be experiencing justified-envy (p=0.275). In this specification too, the effects of differential earnings and ability differences on the attribution of outcomes persist with similar magnitudes.

Table 7: Attribution and School Choice Game Earnings

	$ability_w > mechanism_w$		
	(1)	(2)	(3)
Type2	0.021	0.017	0.027
	(0.189)	(0.190)	(0.190)
Type3	0.025	0.022	0.034
	(0.187)	(0.187)	(0.187)
Type4	0.161	0.111	0.101
	(0.109)	(0.134)	(0.134)
Earnings	0.024*	0.024*	0.023*
	(0.014)	(0.014)	(0.014)
High	-0.132*	-0.136*	-0.136*
	(0.078)	(0.078)	(0.078)
FULL	0.003	-0.007	-0.040
	(0.077)	(0.079)	(0.084)
Justified-envy		0.098	-0.062
		(0.156)	(0.214)
FULL x Justified-envy			0.267
			(0.244)
Constant	0.178	0.184	0.209*
	(0.123)	(0.124)	(0.126)
Observations	160	160	160
R-squared	0.085	0.087	0.095

Notes: observations pooled from DA and TTC.
***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

Result 4 *Subjects with above-median scores on the Raven's Progressive Matrices task are more likely to report truthfully in strategy-proof mechanisms. However, not all strategy-proof mechanisms level-the-playing-field.*

We now examine strategies and outcomes of *high ability* and *low ability* subjects. In the strategy-proof mechanisms, *low ability* subjects fail to report dominant strategies more frequently compared to their *high ability* counterparts. In DA, *low ability* subjects report preferences truthfully significantly less often than *high ability* subjects (two-sided t-test, $p = 0.049$). In TTC, it appears *low ability* subjects do not report preferences truthfully less frequently than *high ability* types (two-sided t-test, $p = 0.258$).

Table 8 provides regression results of dominant strategy play of *high* and *low ability* subjects.[28] *High ability* subjects report preferences truthfully significantly more often than *low ability* subjects in both DA ($p = 0.086$) and TTC ($p = 0.043$) after controlling for player roles and feedback

[28]While reporting truthfully is a weakly dominant strategy in DA and TTC, there are other non-truthful strategies that are in the set of equilibrium strategies. In our set-up, for both DA and TTC, equilibrium strategies for players 2 and 3 can be summarized by reporting truthfully the top two choices. In both mechanisms, equilibrium strategies for players 1 and 4 involve reporting their third preferred choice ahead of their fourth. Such strategy profiles make Player 4 bossy in DA since this role dictates whether players 2 and 3 obtain their top or second choice. Hence, equilibrium strategies in DA can sometimes generate efficient outcomes and not eliminate justified-envy.

Table 8: Effect of Ability on Strategy Choice

	(1) DA-Truth	(2) TTC-Truth
Type2	0.267	0.112
	(0.229)	(0.104)
Type3	0.464	0.257*
	(0.381)	(0.125)
Type4	0.066	-0.165
	(0.233)	(0.107)
High	0.225*	0.077**
	(0.099)	(0.035)
FULL	-0.051	-0.150*
	(0.335)	(0.080)
Constant	0.192	0.566***
	(0.424)	(0.107)
Observations	36	148
R-squared	0.233	0.133

Notes: *High* is a dummy for high ability subjects (i.e., above median RPM). Standard errors in parentheses and clustered at the session-level. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

condition. While it might be expected that subjects who had information about others' assignments in the practice rounds may learn to report preferences more in line with theoretical predictions, we do not find this to be the case. Surprisingly, when subjects receive information about the assignments of others in the feedback stage of the practice rounds, they become less likely to report truthfully in both DA and TTC. Importantly, in the practice rounds, subjects may simply play random strategies to explore or learn how their strategies map into assignments. As mentioned earlier, there are other non-truthful strategies that are in the set of equilibrium strategies for both of these mechanisms.

We now examine outcome differences between ability types in the two strategy-proof mechanisms. *High ability* subjects outperform *low ability* ones under DA and TTC in terms of average earnings relative to equilibrium payoffs.[29] Differences in earnings relative to equilibrium between *high* and *low ability* types are not significant in DA (two-sided t-test, $p = 0.1264$), but the difference is significant in TTC (two-sided t-test$p = 0.054$). Besides ability, differences in earnings depend on a number of random factors such as the randomly assigned player role, feedback setting from practice rounds and importantly on the number of group members that are *high ability.* In TTC, for example, *high ability* types are more likely to report preferences truthfully and therefore provide a

[29] *High ability* subjects on average earn $1.4 more relative to equilibrium payoffs than their *low ability* counterparts in DA. Meanwhile in TTC, *high ability* subjects earn $0.91 more than their *low ability* counterparts. See Figure B2 in the Appendix for differences in all mechanisms.

positive externality to other subjects since in equilibrium efficient exchanges can occur with truthful revelation. The success of the TTC algorithm thus hinges on one's own and others' ability to recognize its strategy-proofness. In equilibrium in TTC, two two-way cycles form through truthful revelation but other possible strategies too. Table 9 provides a regression framework to examine the differences in earnings between ability types controlling for type and feedback assignment, and the number of high ability subjects in one's group excluding self. After controlling for random factors, the magnitude of the effect favoring *high ability* types in DA drops from \$1.40 to about \$0.80 suggesting DA levels the playing field. In both specifications (1) and (2) the dummy coefficient for *high ability* is not significant. This finding lends support to that of Basteck and Mantovani (2018) that the strategy-proof DA mechanism levels the playing field.[30] Specifications (3) and (4) show that after controlling for random factors the difference in earnings favoring *high ability* types persists in TTC. This is simply a result of *high ability* types having a higher propensity to report preferences truthfully. Types 2 and 3 earn significantly less relative to equilibrium compared to Types 1 and 4 because at least one of Types 2 or 3 does not report their most preferred choice first, thus preventing the formation of an efficient 2-way cycle. In equilibrium in TTC it is sufficient that low equilibrium payoff types report their third most preferred option ahead of their fourth. Coefficients on types suggest that failures to report equilibrium strategies occur more frequently from the top than the bottom. Importantly, efficiency gains cannot materialize for a subject who truthfully reveals preferences if she is matched with one who fails to recognize TTC's incentive compatibility. The coefficient on *GroupHigh* in specification (4) is positive and is evidence that *high ability* types create positive externalities since they are more likely to report preferences truthfully thus allowing for efficient multi-way cycles to actualize ($p = 0.130$).

[30]In the Appendix we lend further support to their findings by examining propensities of ability types to play equilibrium strategies in IA.

Table 9: Earnings and Cognitive Ability

	Earnings relative to equilibrium			
	DA		TTC	
	(1)	(2)	(3)	(4)
Type2	1.940	2.176	-1.487*	-1.457*
	(1.211)	(1.336)	(0.726)	(0.730)
Type3	1.849	2.158	-1.396*	-1.416*
	(1.092)	(1.318)	(0.747)	(0.741)
Type4	-0.264	-0.030	0.114	0.077
	(0.391)	(0.646)	(0.102)	(0.082)
FULL	-0.297	-0.034	-0.456	-0.417
	(0.416)	(0.765)	(0.427)	(0.445)
High	0.823	0.796	0.964**	0.818*
	(0.993)	(0.852)	(0.432)	(0.391)
GroupHigh		0.639		0.445
		(0.977)		(0.280)
Constant	-1.566	-2.785	-1.433**	-2.048**
	(1.386)	(2.591)	(0.603)	(0.854)
Observations	36	36	148	148
R-squared	0.195	0.234	0.099	0.120

Notes: *High* is a dummy for high ability subjects (i.e., above median RPM score). *GroupHigh* $\in \{0, 1, 2, 3\}$ is the number of high ability subjects in one's group excluding self. Standard errors in parentheses and clustered at the session-level. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

5 Discussion

In this paper, we propose a novel way to examine welfare properties under mechanism design: through involuntarily provided biometric feedback. Specifically, we look at whether subjects exhibit more discontentment in the form of increased galvanic skin response in the presence of envy with and without justification. The preference profiles that underlie the theoretical framework of our design are specifically chosen so that two out of four subjects will not attain their first or second-choice school. Both subjects will envy the other two subjects that received their first (or second) choice. Only in the TTC, will one player profile 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 allocations of others are observed and whether we emphasize this particular type of (justified) envy.

We initially document the perceived importance of envy, or more precisely disadvantageous inequality, through increased arousal as captured by dynamic galvanic skin response and magnitude. We then follow through by noting the negative welfare effects of justifiable envy. Our results suggest that justified-envy is a sound fairness criterion and situations of priority violation may be perceived as an obvious conflict with the very role of priorities which is in line with the views of some theorists and school board administrators. 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 are negatively affected by this information. One way to alleviate this concern is to implement a mechanism from a set of strategy-proof mechanisms and evaluate the efficiency-equity trade-off when choosing between them. For our experimental game, moving from the DA to the TTC mechanism under dominant strategy play presents a Pareto-improvement where players 2 and 3 are assigned to strictly better schools and players 1 and 4 are assigned to the same schools.

At the same time, we note confirmation of theoretical predictions (Result 1), an extrapolation of a well-known psychological result, the self-attribution bias, in our data (Result 3), and similar results to past studies (Result 4). To reaffirm that biometric measures can have a place in mechanism design and specifically school choice, our appendix looks at eye-tracking under the Boston (IA) mechanism. Our results unite two findings in literature: the use of eye-tracking to detect level-k strategies (e.g., Wang et al., 2010), and the use of level-k and sophistication in reporting non-truthful strategies under the non-strategy-proof Boston mechanism (Zhang, 2021).

References

Abdulkadiroğlu, A., Pathak, P. A., Roth, A. E., and Sönmez, T. (2005). The boston public school match. *American Economic Review*, 95(2):368–371.

Abdulkadiroğlu, A. and Sönmez, T. (2003). School choice: A mechanism design approach. *American economic review*, 93(3):729–747.

Basteck, C. and Mantovani, M. (2018). Cognitive ability and games of school choice. *Games and economic behavior*, 109:156–183.

Bó, I. and Hakimov, R. (2020). Iterative versus standard deferred acceptance: Experimental evidence. *The Economic Journal*, 130(626):356–392.

Burks, S. V., Carpenter, J. P., Goette, L., and Rustichini, A. (2009). Cognitive skills affect economic preferences, strategic behavior, and job attachment. *Proceedings of the National Academy of Sciences*, 106(19):7745–7750.

Calsamiglia, C., Haeringer, G., and Klijn, F. (2010). Constrained school choice: An experimental study. *American Economic Review*, 100(4):1860–74.

Carpenter, P. A., Just, M. A., and Shell, P. (1990). What one intelligence test measures: a theoretical account of the processing in the raven progressive matrices test. *Psychological review*, 97(3):404.

Cason, T. N. and Plott, C. R. (2014). Misconceptions and game form recognition: Challenges to theories of revealed preference and framing. *Journal of Political Economy*, 122(6):1235–1270.

Charness, G., Rustichini, A., and Van de Ven, J. (2018). Self-confidence and strategic behavior. *Experimental Economics*, 21(1):72–98.

Chen, Y., Jiang, M., Kesten, O., Robin, S., and Zhu, M. (2018). Matching in the large: An experimental study. *Games and Economic Behavior*, 110:295–317.

Chen, Y. and Kesten, O. (2019). Chinese college admissions and school choice reforms: An experimental study. *Games and Economic Behavior*, 115:83–100.

Chen, Y., Liang, Y., Sönmez, T., et al. (2016). School choice under complete information: An experimental study. *Journal of Mechanism and Institution Design*, 1(1):45–82.

Chen, Y. and Sönmez, T. (2006). School choice: an experimental study. *Journal of Economic theory*, 127(1):202–231.

Costa-Gomes, M., Crawford, V. P., and Broseta, B. (2001). Cognition and behavior in normal-form games: An experimental study. *Econometrica*, 69(5):1193–1235.

Devetag, G., Di Guida, S., and Polonio, L. (2016). An eye-tracking study of feature-based choice in one-shot games. *Experimental Economics*, 19(1):177–201.

Ding, T. and Schotter, A. (2019). Learning and mechanism design: An experimental test of school matching mechanisms with intergenerational advice. *The Economic Journal*, 129(623):2779–2804.

Dur, U., Hammond, R. G., and Morrill, T. (2018). Identifying the harm of manipulable school-choice mechanisms. *American Economic Journal: Economic Policy*, 10(1):187–213.

Ekman, P., Levenson, R. W., and Friesen, W. V. (1983). Autonomic nervous system activity distinguishes among emotions. *science*, 221(4616):1208–1210.

Featherstone, C. R. and Niederle, M. (2016). Boston versus deferred acceptance in an interim setting: An experimental investigation. *Games and Economic Behavior*, 100:353–375.

Fischbacher, U., Hausfeld, J., and Renerte, B. (2022). Strategic incentives undermine gaze as a signal of prosocial motives. *Games and Economic Behavior*, 136:63–91.

Gatti, E., Calzolari, E., Maggioni, E., and Obrist, M. (2018). Emotional ratings and skin conductance response to visual, auditory and haptic stimuli. *Scientific data*, 5(1):1–12.

Gill, D. and Prowse, V. (2016). Cognitive ability, character skills, and learning to play equilibrium: A level-k analysis. *Journal of Political Economy*, 124(6):1619–1676.

Gong, B. and Liang, Y. (2020). A dynamic matching mechanism for college admissions: Theory and experiment. Technical report, Working paper.

Gray, J. R. and Thompson, P. M. (2004). Neurobiology of intelligence: science and ethics. *Nature Reviews Neuroscience*, 5(6):471–482.

Griffin, M. G., Resick, P. A., and Galovski, T. E. (2012). Does physiologic response to loud tones change following cognitive–behavioral treatment for posttraumatic stress disorder? *Journal of traumatic stress*, 25(1):25–32.

Guillen, P. and Hakimov, R. (2018). The effectiveness of top-down advice in strategy-proof mechanisms: A field experiment. *European Economic Review*, 101:505–511.

Haag, A., Goronzy, S., Schaich, P., and Williams, J. (2004). Emotion recognition using bio-sensors: First steps towards an automatic system. In *Tutorial and research workshop on affective dialogue systems*, pages 36–48. Springer.

Jiang, T., Potters, J., and Funaki, Y. (2016). Eye-tracking social preferences. *Journal of Behavioral Decision Making*, 29(2-3):157–168.

Joffily, M., Masclet, D., Noussair, C. N., and Villeval, M. C. (2014). Emotions, sanctions, and cooperation. *Southern Economic Journal*, 80(4):1002–1027.

Jones, C. M. and Troen, T. (2007). Biometric valence and arousal recognition. In *Proceedings of the 19th Australasian conference on computer-human interaction: Entertaining user interfaces*, pages 191–194.

Jones, E. E. and Davis, K. E. (1965). From acts to dispositions the attribution process in person perception. In *Advances in experimental social psychology*, volume 2, pages 219–266. Elsevier.

Kassas, B. and Palma, M. A. (2019). Self-serving biases in social norm compliance. *Journal of Economic Behavior & Organization*, 159:388–408.

Klijn, F., Pais, J., and Vorsatz, M. (2013). Preference intensities and risk aversion in school choice: A laboratory experiment. *Experimental Economics*, 16:1–22.

Klijn, F., Pais, J., and Vorsatz, M. (2019). Static versus dynamic deferred acceptance in school choice: Theory and experiment. *Games and Economic Behavior*, 113:147–163.

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. *Biological psychology*, 84(3):394–421.

Lang, P. J. (2014). Emotion's response patterns: The brain and the autonomic nervous system. *Emotion Review*, 6(2):93–99.

Morrill, T. (2013). An alternative characterization of top trading cycles. *Economic Theory*, 54:181–197.

Morrill, T. (2015a). Making just school assignments. *Games and Economic Behavior*, 92:18–27.

Morrill, T. (2015b). Two simple variations of top trading cycles. *Economic Theory*, 60(1):123–140.

Pais, J. and Pintér, Á. (2008). School choice and information: An experimental study on matching mechanisms. *Games and Economic Behavior*, 64(1):303–328.

Pathak, P. A. and Sönmez, T. (2013). School admissions reform in chicago and england: Comparing mechanisms by their vulnerability to manipulation. *American Economic Review*, 103(1):80–106.

Polonio, L., Di Guida, S., and Coricelli, G. (2015). Strategic sophistication and attention in games: An eye-tracking study. *Games and Economic Behavior*, 94:80–96.

Posner, J., Russell, J. A., and Peterson, B. S. (2005). The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development and psychopathology*, 17(3):715–734.

Proto, E., Rustichini, A., and Sofianos, A. (2014). Higher intelligence groups have higher cooperation rates in the repeated prisoner's dilemma. *Available at SSRN 2505361*.

Raven, J. (2000). The raven's progressive matrices: change and stability over culture and time. *Cognitive psychology*, 41(1):1–48.

Russell, J. A. (1980). A circumplex model of affect. *Journal of personality and social psychology*, 39(6):1161.

Sinha, R., Lovallo, W. R., and Parsons, O. A. (1992). Cardiovascular differentiation of emotions. *Psychosomatic Medicine*, 54(4):422–435.

Sirois, S. and Brisson, J. (2014). Pupillometry. *Wiley Interdisciplinary Reviews: Cognitive Science*, 5(6):679–692.

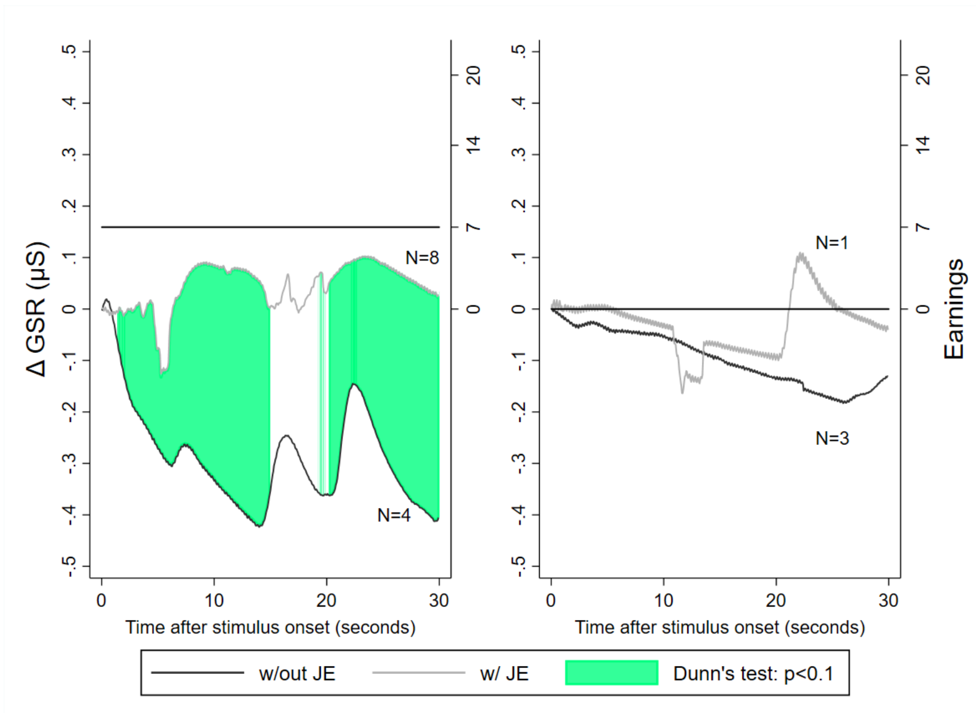
Stephenson, D. (2022). Assignment feedback in school choice mechanisms. *Experimental Economics*, pages 1–25.

Wang, J. T.-y., Spezio, M., and Camerer, C. F. (2010). Pinocchio's pupil: using eyetracking and pupil dilation to understand truth telling and deception in sender-receiver games. *American economic review*, 100(3):984–1007.

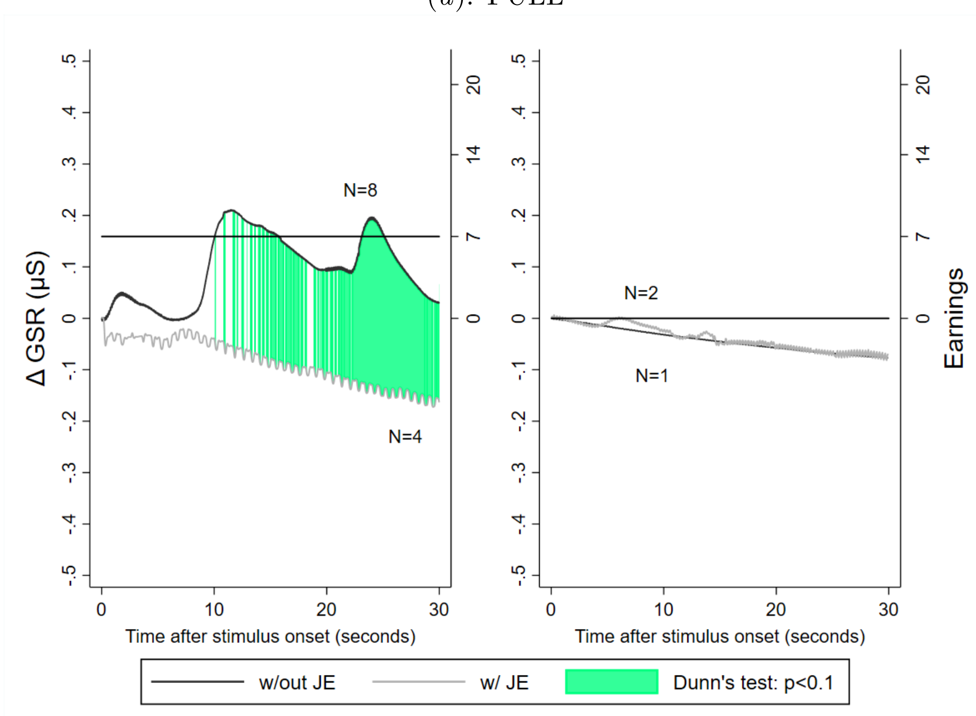
Zhang, J. (2021). Level-k reasoning in school choice. *Games and Economic Behavior*, 128:1–17.

A Envy and Arousal in Strategy-Proof Mechanisms

Figure A1: Skin Conductance (TTC, Message Stage)



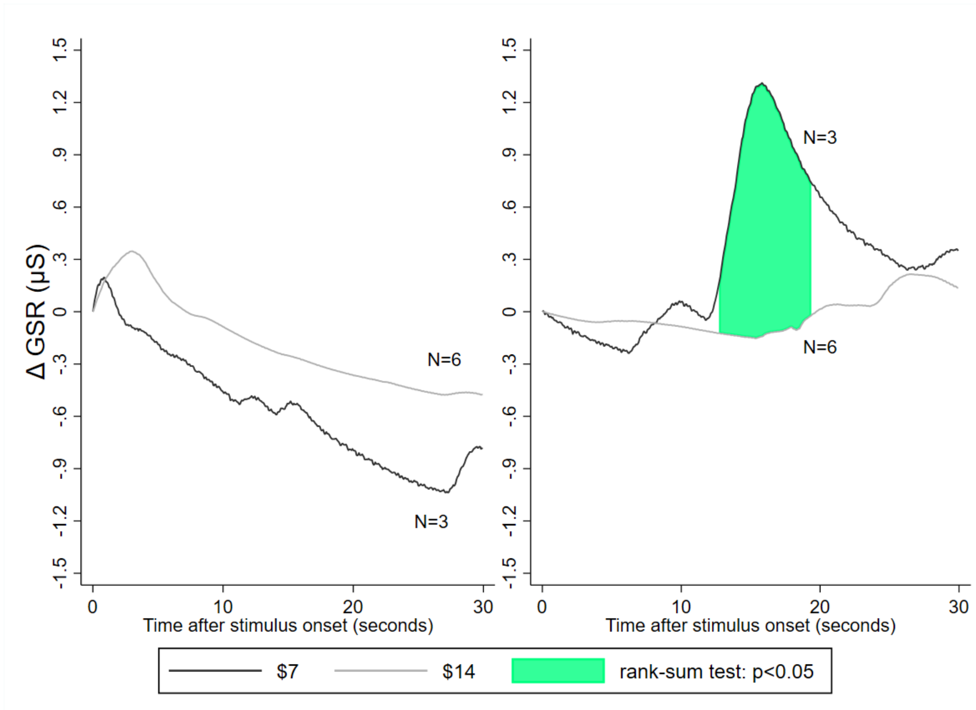
(*a*): FULL



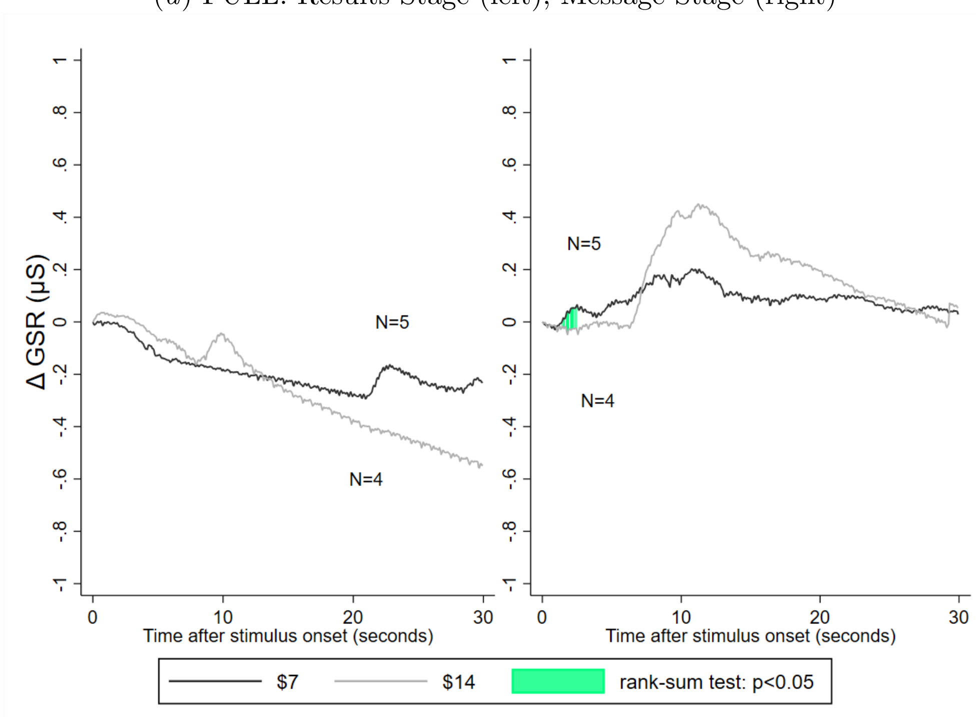
(*b*): PARTIAL

Notes: mean change in skin conductance averaged across subjects over time in the message stage conditional on a two-way cycle forming between players 2 and 3. Subjects assigned to treatment PARTIAL never learn the assignments of others. Shaded regions denote significance at the 0.1 level based on functional Dunn's tests. Subjects assigned to treatment FULL received a message designed to accentuate justified-envy or highlight the lack thereof, and subjects assigned to treatment PARTIAL received a neutral message saying "This concludes the stage of this game." Horizontal lines denote earnings in the one-shot school choice game.

Figure A2: Skin Conductance (DA)



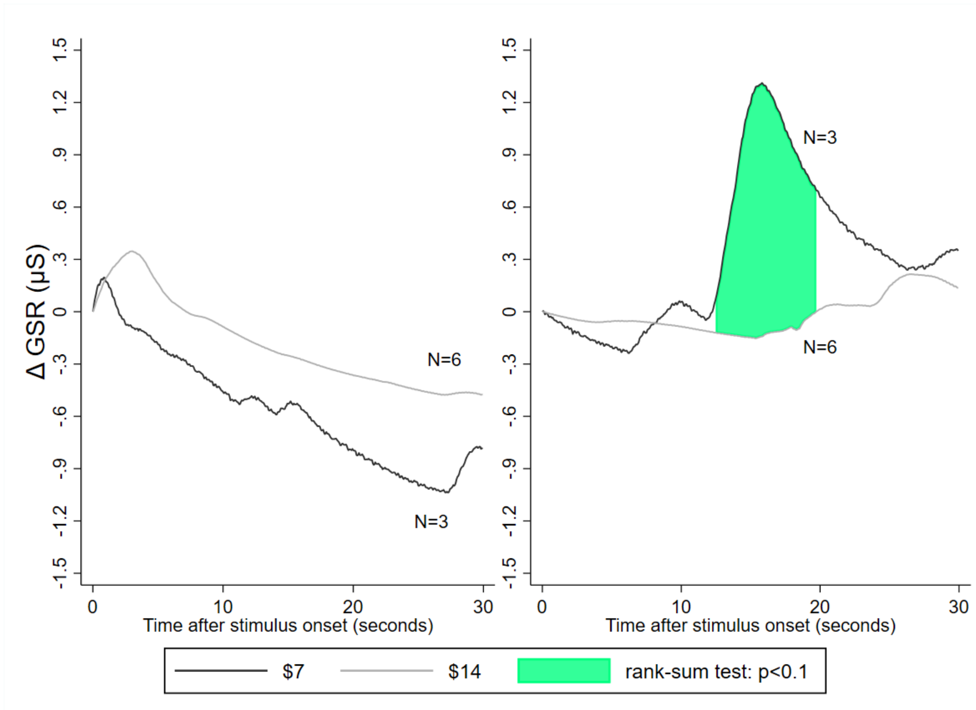
(*a*) FULL: Results Stage (left), Message Stage (right)



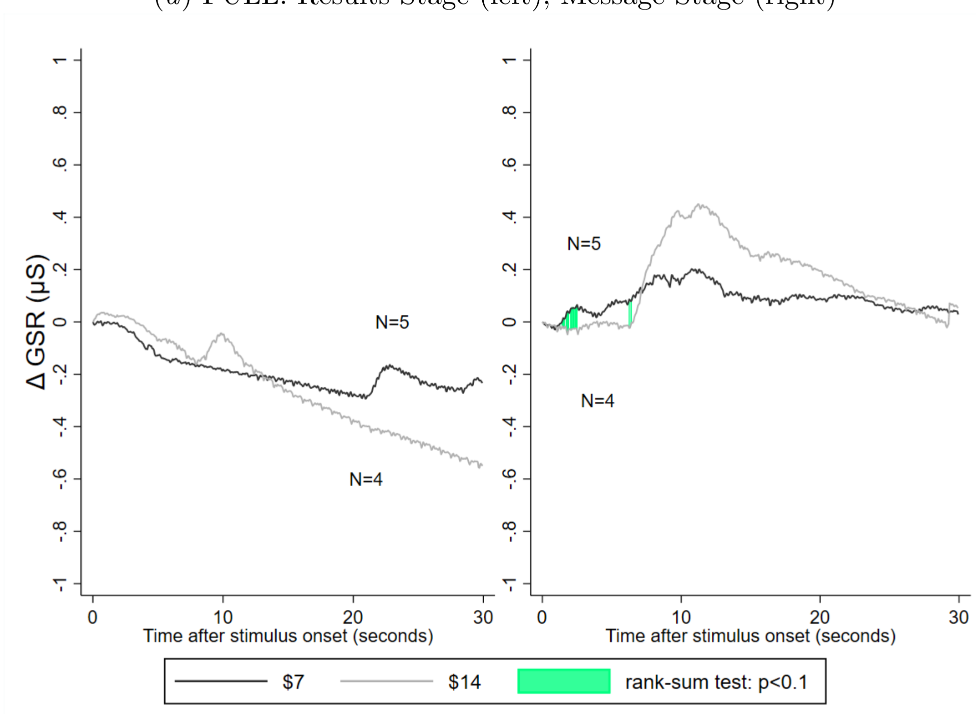
(*b*) PARTIAL: Results Stage (left), Message Stage (right)

Notes: mean change in skin conductance averaged across subjects over time conditional on assignments that are reached through truthful revelation. Subjects assigned to treatment PARTIAL never learn the assignments of others. Shaded regions denote significance at the 0.05 level based on functional rank-sum tests.

Figure A3: Skin Conductance (DA)



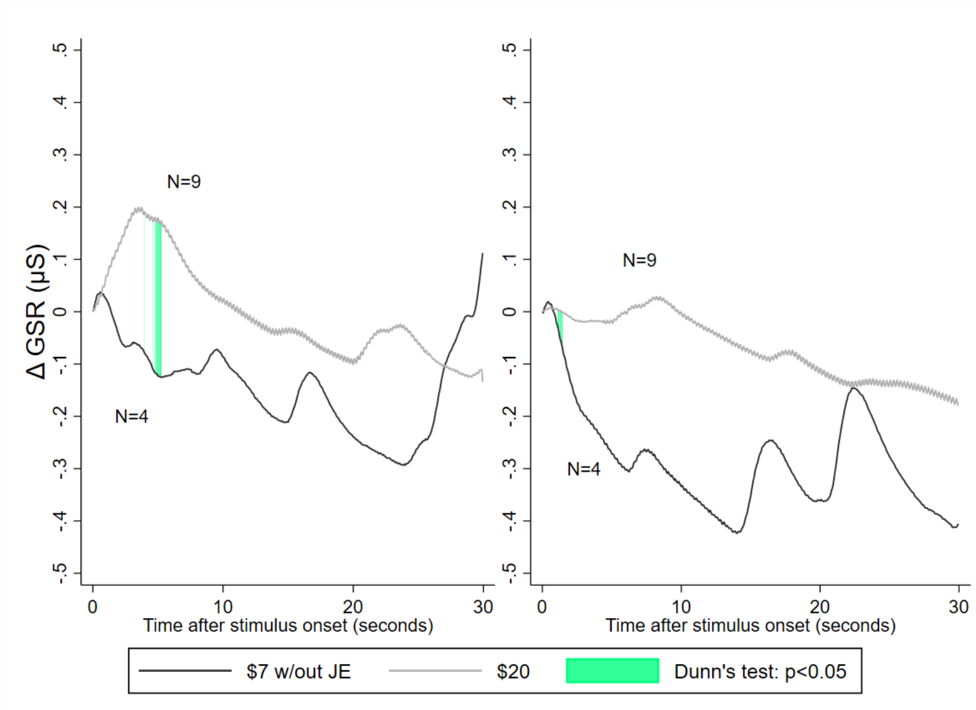
(*a*) FULL: Results Stage (left), Message Stage (right)



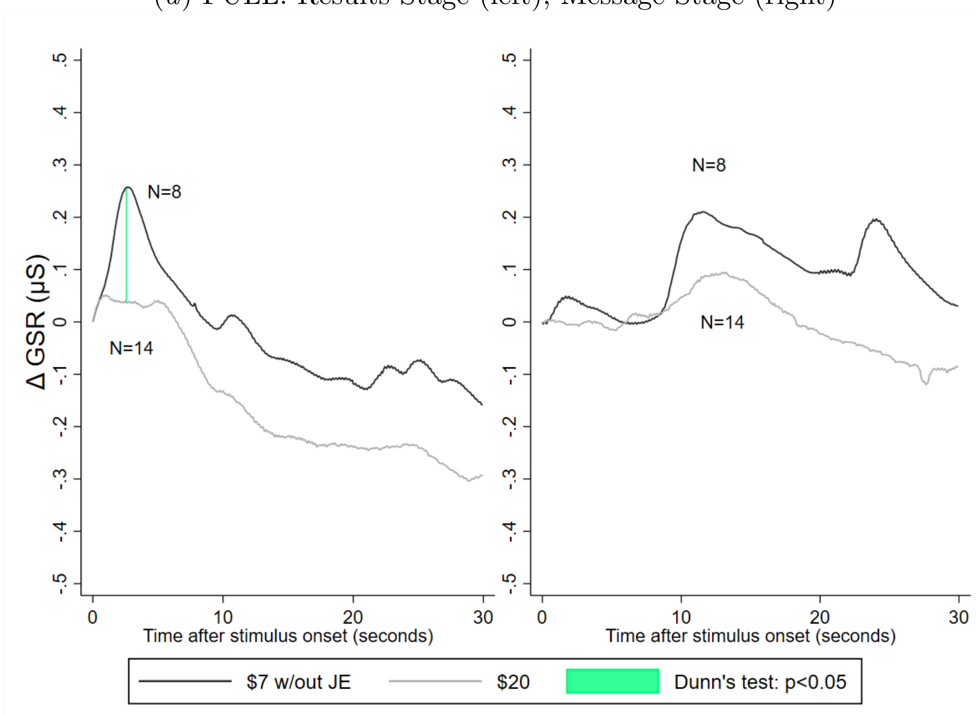
(*b*) PARTIAL: Results Stage (left), Message Stage (right)

Notes: mean change in skin conductance averaged across subjects over time conditional on assignments that are reached through truthful revelation. Subjects assigned to treatment PARTIAL never learn the assignments of others. Shaded regions denote significance at the 0.1 level based on functional rank-sum tests.

Figure A4: Skin Conductance (TTC)



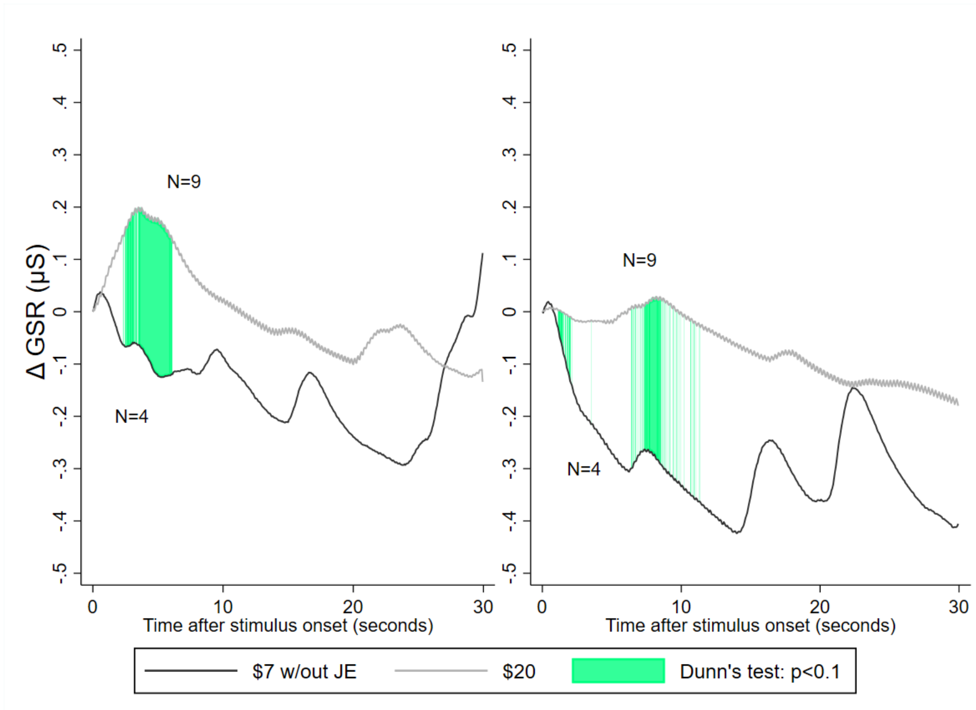
(a) FULL: Results Stage (left), Message Stage (right)



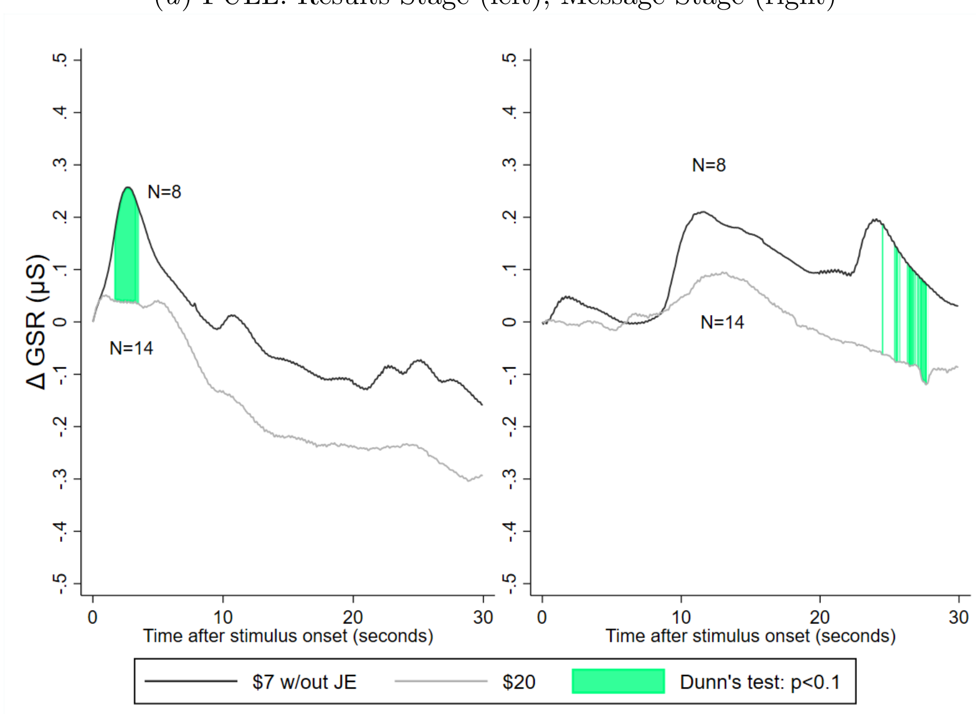
(b) PARTIAL: Results Stage (left), Message Stage (right)

Notes: mean change in skin conductance averaged across subjects over time conditional on equilibrium assignments. Subjects assigned to treatment PARTIAL never learn the assignments of others. Shaded regions denote significance at the 0.05 level based on functional Dunn's tests.

Figure A5: Skin Conductance (TTC)



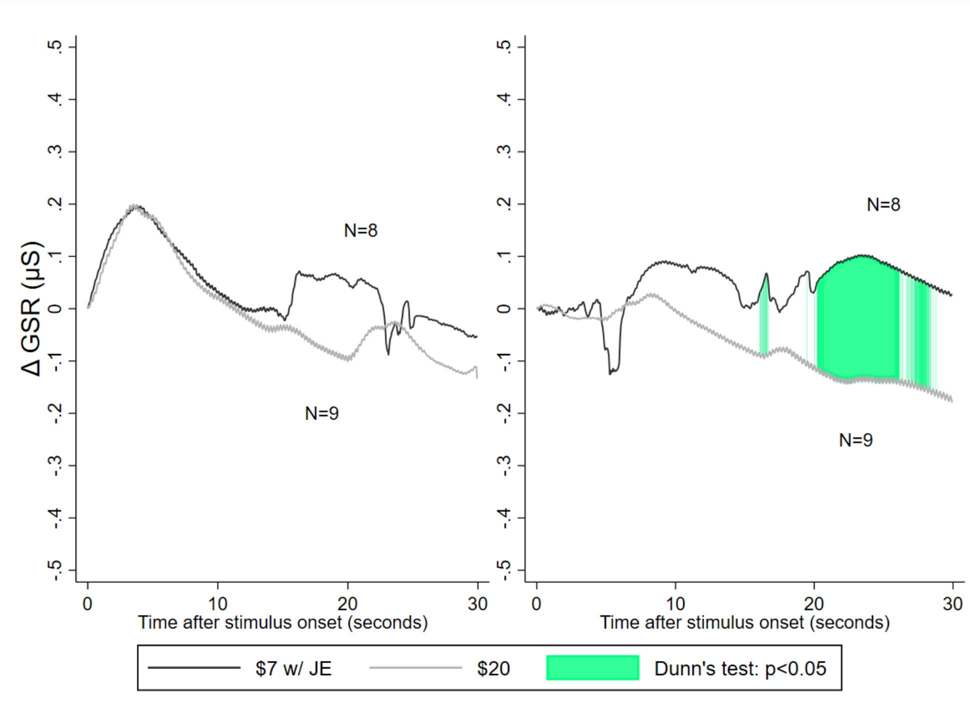
(*a*) FULL: Results Stage (left), Message Stage (right)



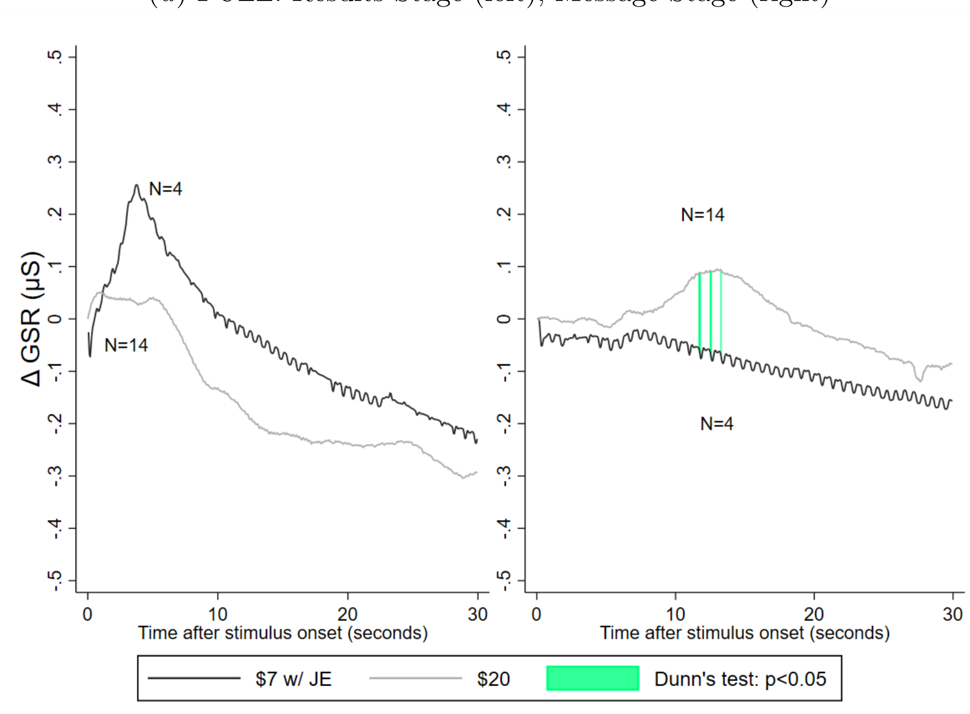
(*b*) PARTIAL: Results Stage (left), Message Stage (right)

Notes: mean change in skin conductance averaged across subjects over time conditional on equilibrium assignments. Subjects assigned to treatment PARTIAL never learn the assignments of others. Shaded regions denote significance at the 0.05 level based on functional Dunn's tests.

Figure A6: Skin Conductance (TTC)



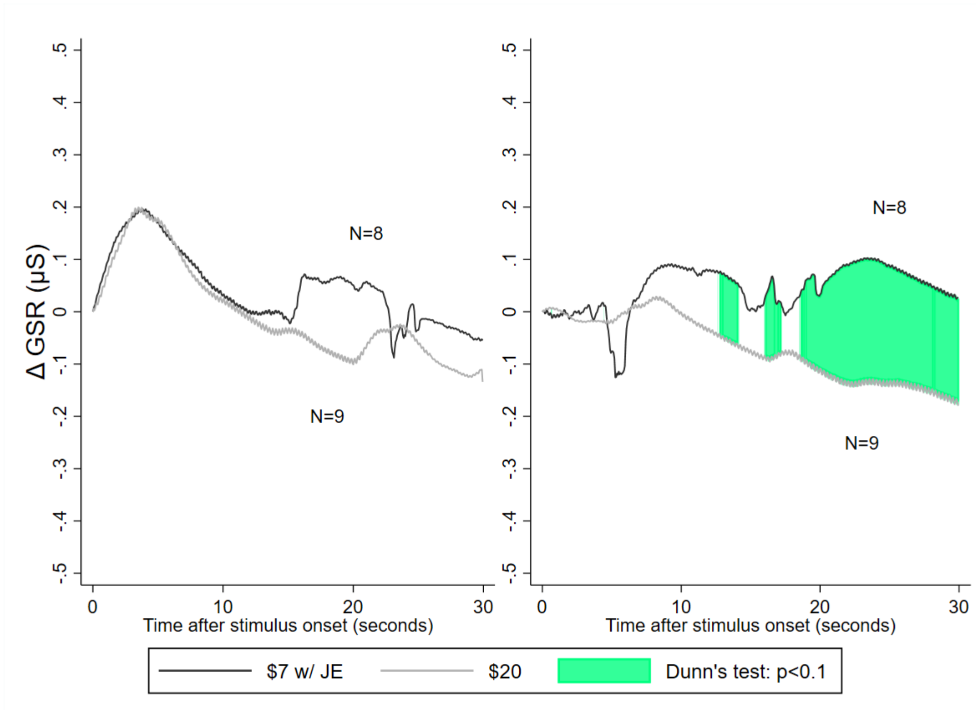
(*a*) FULL: Results Stage (left), Message Stage (right)



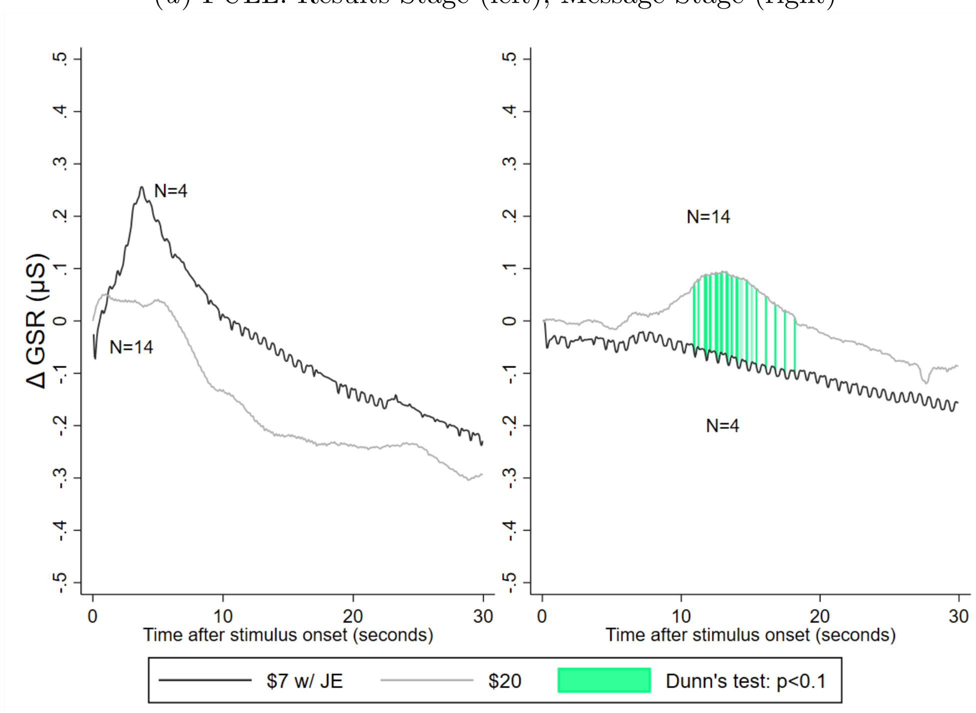
(*b*) PARTIAL: Results Stage (left), Message Stage (right)

Notes: mean change in skin conductance averaged across subjects over time conditional on equilibrium assignments. Subjects assigned to treatment PARTIAL never learn the assignments of others. Shaded regions denote significance at the 0.05 level based on functional Dunn's tests.

Figure A7: Skin Conductance (TTC)



(*a*) FULL: Results Stage (left), Message Stage (right)



(*b*) PARTIAL: Results Stage (left), Message Stage (right)

Notes: mean change in skin conductance averaged across subjects over time conditional on equilibrium assignments. Subjects assigned to treatment PARTIAL never learn the assignments of others. Shaded regions denote significance at the 0.05 level based on functional Dunn's tests.

B The Boston (aka Immediate Acceptance, IA) Mechanism

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

Round 1: Each school considers all students who rank it first. If the number of applicants is lower than the school capacity, all applicants are admitted. If the number of applicants is greater than the school capacity, seats are assigned according to the priority order of applicants at that school until there are no seats left.

Round 2: Applicants that were rejected in Round 1 are considered for the school they ranked second. If the number of applicants is lower than the remaining school capacity, all applicants are admitted. If the number of applicants is greater than the remaining school capacity, seats are assigned according to the priority order of applicants at that school until there are no seats left.

Generally, in Round ($k \geq 3$): Applicants that were rejected in Round $k-1$ are considered for the school they ranked k^{th}. If the number of applicants is lower than the remaining school capacity, all applicants are admitted. If the number of applicants is greater than the remaining school capacity, seats are assigned according to the priority order of applicants at that school until there are no seats left. The process terminates after any round k where either every student is assigned a seat at some school, or the only students who remain unassigned have listed no more than k choices.

To obtain equilibrium assignments in IA, we use the level-k framework proposed by Zhang (2021). At the first level, applicants report preferences truthfully; thereafter incentives emerge to mis-report preferences as subjects employ a *Skip-the-Previously-Most-Preferred* strategy:

Level 0: All players report preferences truthfully. Players 1 and 4 are left unassigned.

Level 1: Players 1 and 4 apply to their next most preferred option. Player 4 is assigned to Option A which in turn leaves Player 2 unassigned. Player 1 applies to Option B but has a lower priority than its current assignment, namely Player 3. Players 1 and 2 are left unassigned.

Level 2: Players 1 and 2 apply to their next most preferred option. Player 1 applies to Option C and since she is the only applicant, she is assigned to it. Player 2 applies to Option B and since she has a higher priority than its current assignment (Player 3), Player 2 is assigned to it. Player 3 is left unassigned.

Level 3: Player 3 applies to her next most preferred option. Player 3 applies to Option A and since she has a higher priority than its current assignment (Player 4), Player 3 is assigned to it. This leaves Player 4 unassigned.

Level 4: Player 4 applies to her next most preferred option. Player 4 applies to Option D and since she is the only applicant, she is assigned to it.

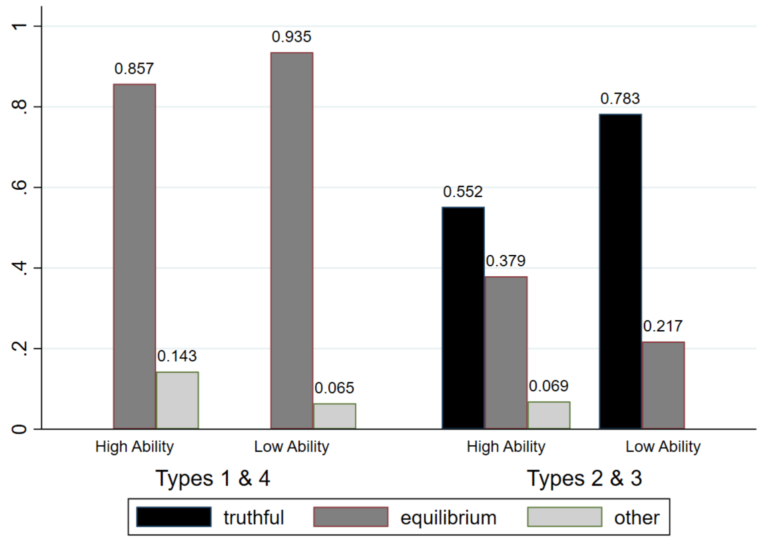
Note that in equilibrium in IA, players 2 and 3 employ a *Skip-the-Top* strategy and report their second-most preferred option as their first choice. Meanwhile for players 1 and 4 it is sufficient that they report their third-most preferred option ahead of their least preferred option. Importantly this set of reports eliminates justified-envy in IA.

B.1 Heterogeneity Among High and Low Ability Subjects

Payoffs earned in the school choice game depend to a large extent on the strategies employed by other subjects in the session. Given our information setting, equilibrium predictions for IA are such that player types 2 and 3 use the *Skip-the-Top* strategy meaning they report their second most preferred option first. Equilibrium strategies for types 2 and 3 can be summarized by the first choice in the ranking report. Types 1 and 4 report their third most preferred option ahead of their fourth most preferred option with no other restrictions on the rest of the ranking report. Figure B1 shows the distribution of strategies used by *high* and *low ability* subjects in IA. The equilibrium reporting rates of *high* and *low ability* subjects do not substantially differ in cases when they are assigned to Types 1 and 4 in IA (two-sided t-test, $p = 0.357$). For types 2 and 3, however, *high ability* subjects are about twice more likely to report equilibrium strategies than *low-ability* subjects (two-sided t-test, $p = 0.217$). The truth-telling rate of *high ability* subjects is significantly lower than that of *low ability* subjects when they are assigned to types 2 and 3 (two-sided t-test, $p = 0.085$). *High ability* subjects seem to better recognize incentives for deviating from truth-telling and adjust their strategy by playing *Skip-the-Top*. Our results are consistent with those in Basteck and Mantovani (2018) and they also find that *high ability* subjects are about twice more likely to use the *Skip-the-Top* strategy.

We run an ordinary least squares regression to examine the robustness of the finding that *high* and *low ability* subjects have different propensities for using different strategies in IA. We report the results in Table B1 which are largely consistent with those from Figure B1. *Low ability* subjects are 26.9 probability points more likely to report preferences truthfully in IA ($p = 0.068$) when the truthful strategy is not in the set of equilibrium strategies. *High ability* subjects are not more likely to report equilibrium strategies in IA. Types 2 and 3 are significantly less likely to report equilibrium strategies compared to types 1 and 4 largely because the truthful strategy is not in

Figure B1: Distribution of strategies in IA



Notes: The truthful strategy is in the set of equilibrium strategies for Types 1 & 4. Equilibrium strategies for Types 2 & 3 are analogous to Skip-the-Top.

the set of equilibrium strategies for types 2 and 3. While it might be expected that subjects with information about others' assignments in the feedback stage may learn to report preferences more in line with theoretical predictions, we do not find this to be the case. When subjects receive information about the assignments of others in the feedback stage of practice rounds, they become less likely to report equilibrium strategies in IA ($p = 0.040$).

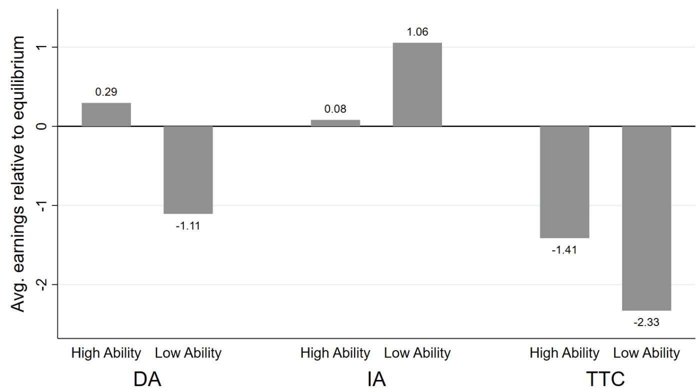
Table B1: Effect of Ability on Strategy Choice

	(1) Truth	(2) Equilibrium
Type2	-0.205	-0.515***
	(0.124)	(0.137)
Type3		-0.769***
		(0.072)
Type4		-0.063
		(0.069)
High	-0.269*	0.058
	(0.136)	(0.085)
FULL	0.173	-0.140**
	(0.101)	(0.062)
Constant	0.823***	0.948***
	(0.095)	(0.085)
Observations	52	104
R-squared	0.127	0.424

Notes: Specification (1) examines ability differences in truth-telling only for types 2 & 3. Specifications (2) includes all types and the truthful strategy is in the set of equilibrium strategies for types 1 & 4. Standard errors in parentheses and clustered at the session-level. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

Average earnings relative to equilibrium payoffs by ability type in the one-shot school choice game are shown in Figure B2. *Low ability* subjects do not significantly outperform *high ability* ones in IA (two-sided t-test, $p = 0.411$). Besides ability, differences in earnings depend on a number of random factors such as the assigned type, feedback setting from practice rounds and on the number of group members that are *high ability.* In IA, *high ability* types may create negative externalities since they play equilibrium strategies more frequently and therefore do not allow others to capitalize on their mistakes or alternatively *high ability* types may be able to better predict when others are more likely to make mistakes.

Figure B2: Low and high ability subjects' earnings relative to equilibrium payoffs



Notes: average earnings difference relative to equilibrium payoffs for low and high ability subjects (i.e. top and bottom half of the distribution of the RPM task scores).

We examine the robustness of the difference in earnings in IA between ability types with an ordinary least squares regression that controls for type and feedback assignments, and the number of high ability subjects in one's group excluding self in Table B2. After controlling for type and feedback assignments in specification (1), the magnitude of the effect drops from \$0.98 to \$0.57 ($p = 0.570$) in IA. After controlling for the number of other group members that are *high ability* type, the magnitude of the effect further drops to \$0.25 ($p = 0.825$). These results suggest that there are no meaningful differences in earnings between *high* and *low ability* subjects in IA. The coefficient of *GroupHigh* in specification (2) supports the idea that *high ability* subjects create negative externalities in IA since they play equilibrium strategies more frequently and therefore do not allow others to capitalize on their mistakes or alternatively they are able to predict better when others are prone to making mistakes ($p = 0.315$). The result that *high ability* subjects play equilibrium strategies more frequently was evident in Figure B1 for player types 2 and 3. We also find that they earn relatively more compared to *low ability* subjects when assigned to player roles

1 and 4 which suggests *high ability* subjects better predict when others are more likely to make mistakes. Lastly, *low ability* subjects encounter on average 1.11 *high ability* group members meanwhile *high ability* types encounter 1.8 *high ability* group members and this difference is significant ($p = 0.001$). After accounting for these random factors and the fact that *low ability* subjects have a higher propensity to report preferences truthfully, there are no meaningful differences in earnings relative to equilibrium between *low* and *high ability* subjects in IA.

Table B2: Earnings and Cognitive Ability

	Earnings relative to equilibrium	
	(1)	(2)
Type2	-1.532	-1.589
	(1.655)	(1.625)
Type3	-1.369	-1.513
	(2.676)	(2.646)
Type4	1.921	1.956
	(2.055)	(2.036)
FULL	-1.495	-1.467
	(1.113)	(1.169)
High	-0.577	-0.246
	(0.990)	(1.093)
GroupHigh		-0.446
		(0.428)
Constant	1.856	2.367
	(1.671)	(1.563)
Observations	104	104
R-squared	0.077	0.082

Notes: *GroupHigh* $\in \{0, 1, 2, 3\}$ is the number of high ability subjects in one's group excluding self. Standard errors in parentheses and clustered at the session-level. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

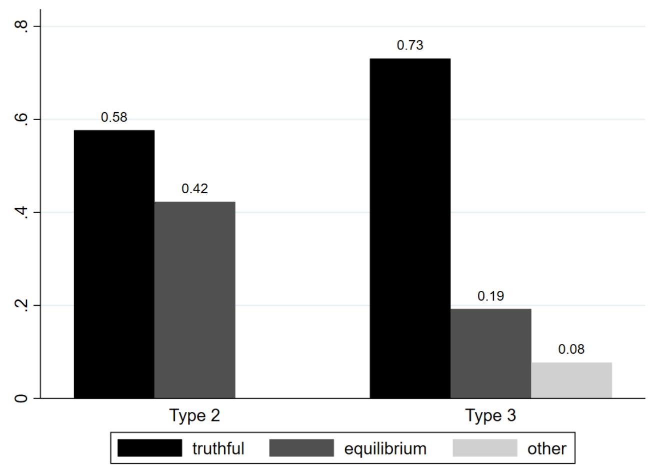
C Level-K and Truth-Telling in the Boston (IA) Mechanism

Studying a complete information structure allows us to pinpoint systemic failures in strategizing in the manipulable IA mechanism. In this mechanism while an applicant may have a general idea on what are the most sought out schools, one may know very little about the priority orderings of schools other than their own. For this reason it may become less obvious on how to optimally report preferences in the field. There are two strategies that can be characterized as *sophisticated* in IA: *Skip-the-Middle* and *Skip-the-Top*. The *Skip-the-Middle* strategy is described as truthfully revealing one's most preferred school and reporting the third best school as the second choice. This strategy becomes especially obvious when there is high demand for one's two most preferred schools. With this strategy, in the event one is not accepted at her most preferred school, by the time she applies to her second best school all seats might have filled up by the end of the first round of acceptances. Therefore it might be optimal to report the third best school as second in the ranking report. The *Skip-the-Top* strategy can be described as not reporting the most preferred school first and instead reporting a school in which one is certain has priority over other applicants. This strategy becomes especially relevant if one has priority over others at the second best school. In the event one reports their most preferred school first and is not assigned to it due to an unfavorable lottery draw, it is possible that by the end of the first round of acceptances there are no seats left at the second best school. To avoid this scenario it may be optimal to *Skip-the-Top* and report the second-best school as the first choice. In the complete information setting we study, it becomes obvious what are optimal manipulative strategies that deviate from one's true preferences. Assuming an initial level of naivete as in Zhang (2021) in which subjects report preferences truthfully, incentives arise to best-respond by mis-reporting truthful preferences until all players report equilibrium strategies. Of the two player roles that earn high equilibrium payoffs, a subject assigned the role of Player 3 needs to exhibit a higher level of thinking than Player 2. Based on the description of levels in section B, it is necessary that Player 3 exhibits level-3 thinking for reporting an equilibrium strategy meanwhile it suffices for Player 2 to be a level-2 thinker. These implications lead to our next prediction that subjects assigned to the role of Player 3 fail to report equilibrium strategies more frequently than subjects assigned to the role of Player 2.

Prediction 6 *In IA, subjects assigned the role of Player 2 are more likely to report equilibrium strategies than those assigned to the role of Player 3 (Zhang 2021).*

Figure B1 and results from Table B1 confirm that player types 2 and 3 are significantly less likely to report equilibrium strategies compared to types 1 and 4 in IA. Equilibrium strategies for types 1 and 4 can be summarized as reporting the third best option ahead of the fourth with no restrictions on the rest of the report. The truthful strategy for these types is in the set of equilibrium strategies. Meanwhile for types 2 and 3 equilibrium strategies can be summarized by the first choice in the ranking report in which they both *Skip-the-Top* and report their second-best option first with no impositions on the rest of the rank-choice report. The *level-k* theory in the context of school choice proposed by Zhang (2021) accommodates these results as one only needs to be a level-0 thinker to report equilibrium strategies if assigned to the role of types 1 or 4. On the other hand, one needs to be higher than a level-0 thinker to report equilibrium strategies if assigned to the role of types 2 or 3. Further, assuming that higher level thinkers are less frequently observed in the population we should expect subjects assigned to the role of type 2 to report equilibrium strategies more frequently than those assigned to the role of type 3. This is because a subject assigned the role of type 2 only needs to be a level-2 thinker to report an equilibrium strategy whereas a subject assigned to a type 3 role needs to be a level-3 thinker. Figure C1 lends strong support to this prediction as type 2 subjects are 23 probability points more likely to *Skip-the-Top* than type 3 subjects (two-sided t-test, $p = 0.074$).[31]

Figure C1: Distribution of strategies for Types 2 & 3 in IA



C.1 Systemic Failures in Strategizing in the Boston Mechanism: Evidence from Eye-Tracking Data

Heatmaps in Figure C2 depict fixation duration across different areas of the reporting stage averaged among subjects assigned to different roles in the manipulable IA mechanism. We examine failures to report equilibrium strategies of player types 2 and 3 since equilibrium strategies entail not reporting truthfully for these two roles. Subjects assigned to the role of Player 2 on average fixate more on Player 4's priority ordering at Option A than subjects assigned to the role of Player 3. This prompts a Player 2 type to report Option B as the most preferred option (level-2) after observing that Player 4 submits Option A as the first choice. On the other hand, subjects assigned to the role of Player 3 generally fail to understand that Player 4 reporting Option A as the first choice (level-1) prompts Player 2 to report Option B as the first choice (level-2) and therefore precluding Player 3 from Option B. At level-3, Player 3 submits Option A as the first choice. We examine

[31]We provide further evidence from eye-tracking data on systemic failures of player types 2 and 3 in reporting equilibrium strategies which are in accordance with level-k reasoning in the next section.

fixations that are longer than 100 milliseconds since this duration has been shown to be an accurate threshold to discriminate between meaningful visual attention and passing moments (Manor and Gordon, 2003). The average fixation count on Player 4's priority at Option A of subjects assigned to the role of Player 2 is 7.83 and of those assigned to the role of Player 3 is 4.29 (two-sided t-test; $p = 0.148$). This result captures origins of systemic failures of subjects assigned to the Player 3 role in failing to report equilibrium strategies more often than subjects assigned to the role of Player 2.

Figure C2: Heatmaps

(a): Player 2.

(b): Player 3.

Another bias that emerges from these heatmaps is that subjects assigned to player roles 2 and 3 reference the row corresponding to their payoffs most frequently in a manipulable mechanism where they have incentives to not report truthfully in equilibrium. The proportion of time spent by players looking at different Areas of Interest (AOI) is reported in Figure C3 for the IA mechanism. We evaluate possible statistical differences in the mean percentage of time spent by participants toward their own and their counterparts' payoffs. Results show that players spent significantly more time fixating on their own payoffs compared to the payoffs of the other players (Wilcoxon paired test, $N = 39$, $p = 0.001$). These results are in accordance with those obtained in previous studies that have used mouse-tracking and eye-tracking techniques (Costa-Gomes et al., 2001; Wang et al., 2010; Polonio et al., 2015; Devetag et al., 2016).

Figure C3: The bold rectangles represent the AOIs (not visible to the subjects) and the numbers in bold correspond to the proportion of gaze time of each AOI averaged among participants assigned to respective player roles.

Earnings by Assignment					
	Option A	Option B	Option C	Option D	
Player 1	$20	$14	$7	$0	**0.049**
Player 2	$20	$14	$0	$7	**0.094**
Player 3	$14	$20	$7	$0	**0.053**
Player 4	$14	$20	$0	$7	**0.028**

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4 **0.023**	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3

(a): Player 2.

Earnings by Assignment					
	Option A	Option B	Option C	Option D	
Player 1	$20	$14	$7	$0	**0.053**
Player 2	$20	$14	$0	$7	**0.067**
Player 3	$14	$20	$7	$0	**0.082**
Player 4	$14	$20	$0	$7	**0.034**

Priority Ranking				
	Option A	**Option B**	**Option C**	**Option D**
First	Player 3	Player 2	Player 4	Player 1
Second	Player 4 **0.017**	Player 3	Player 1	Player 2
Third	Player 2	Player 1	Player 3	Player 4
Fourth	Player 1	Player 4	Player 2	Player 3

(b): Player 3.

SUPPLEMENTAL MATERIALS

DA Instructions

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.

\- \- \-

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.

IA Instructions

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 assigned to it. If more than 1 player is considered for the same option, the option is assigned to the player with the highest priority rank.

Step 2: Players that are not assigned to an option after Step 1 are considered for the option they ranked second. If only 1 player is considered for that option and that option is not yet assigned, the player is assigned to it. If more than 1 player is considered for the same option and that option is not yet assigned, the option is assigned to the player with the highest priority rank.

Step 3: Players that are not assigned to an option after Step 2 are considered for the option they ranked third. If only 1 player is considered for that option and that option is not yet assigned, the player is assigned to it. If more than 1 player is considered for the same option and that option is not yet assigned, the option is assigned to the player with the highest priority rank.

Step 4: If a player has not been assigned to an option after Step 3, he/she is assigned to the option ranked fourth in his/her ranking report.

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

TTC Instructions

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

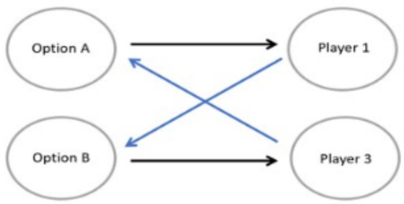
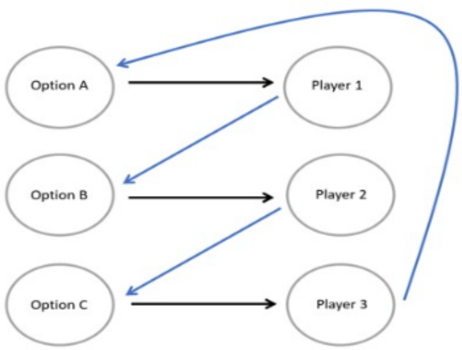


Figure 1c: 3-way cycle



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

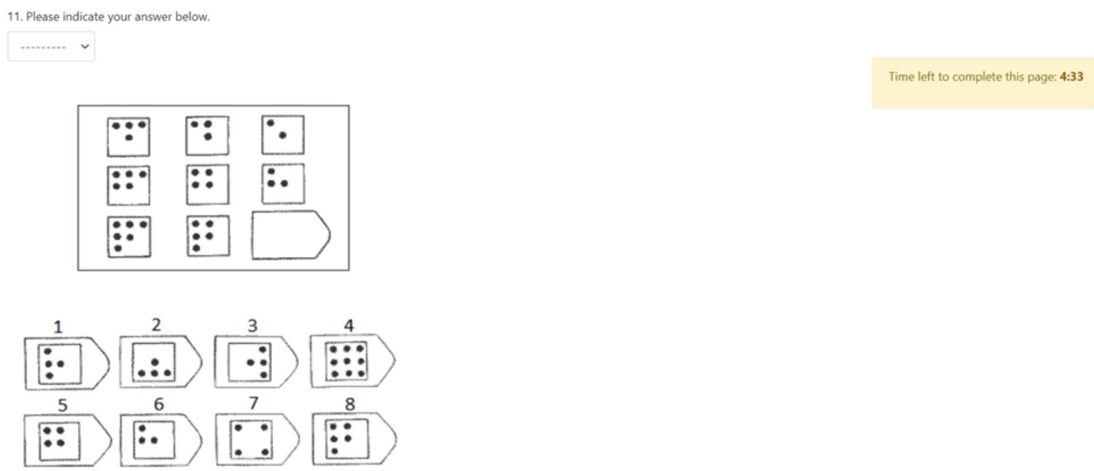
3. To what extent do you think your ability affected your assignment versus to what extent do you think the computer was responsible for your assignment? Please indicate your answer by moving the slider accordingly.

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

Screenshot of a Puzzle from the Raven Progressive Matrices (RPM) Task



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

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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

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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

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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

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