Emotions and the Design of Institutions*

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Incomplete and preliminary: January 15, 2017

Abstract

Darwin (1872) already observed that emotions may facilitate communication. Moreover, since they are somewhat in between instinctive and conscious choice, they convey some truthful information about the agent. This mitigates problems with interaction of agents in institutions because it eases incentive compatibility constraints. This note provides just a brief exposition of these simple ideas by reinterpreting work on mechanism design with partial state verifiability by Deneckere and Severinov (2008) in the context of emotions.

Keywords: Emotions, mechanism design, verifiable information, behavioral economics.

JEL-Classifications: C70, C72.

*This note is prepared for the Workshop on "Microfoundations of Expectations: The Role of Emotions in the Anticipation of Aggregate Outcomes of Human Interaction", Max-Planck Institute for the Mathematics in the Sciences, Leipzig, January 17-19, 2017.

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1 Design of Institutions

In this section, I briefly review the basics of the design of institutions; see Mas-Colell, Whinston, and Green (1995, Chapter 23) for a textbook treatment. In economics, institutions refer to markets, allocations mechanisms, voting systems, legal frameworks, organizations etc. Economists not only analyze existing institutions, but also study the design of institutions. The study of design of institutions is called mechanism design. Roughly it can be understood as the "converse" to game theory. In game theory, we take the game as given and aim to find the outcome resulting from optimal behavior. In mechanism design, we take the outcome as given and aim to design a game that when played optimally implements that outcome.

Consider a nonempty finite set $N = \{1, ..., n\}$ of agents. There is a nonempty finite set of states Ω that summarizes everything that is relevant to the situation. Each agent $i \in N$ observes a subset of states according to a possibility correspondence $\Pi_i : \Omega \longrightarrow 2^{\Omega} \setminus \{\emptyset\}$ that for simplicity forms a partition of Ω. For simplicity, we assume that there is a strict positive common prior μ on Ω.

There is a nonempty finite set of allocations, social alternatives, or simply outcome X.

The utility of agent i is given by the utility function $u_i : X \times \Theta \longrightarrow \mathbb{R}$. The space Θ a nonempty finite set of payoff indices. We assume that it has a product structure, $\Theta := \times_{i \in N} \Theta_j$, for some nonempty finite sets Θ_i, $i \in N$. These indices are determined by the state via functions $\tau_i : \Omega \longrightarrow \Theta_i$, for $i \in N$. We let $\tau(\omega) := \prod_{i \in N} \tau_i(\omega)$. We assume that each agents knows one component of payoff relevant information. I.e., for each agent $i \in N$, $\omega' \in \Pi_i(\omega)$ implies $\tau_i(\omega') = \tau_i(\omega)$.

Agents are expected utility maximizers.

The outcome that agents adopt may depend on the agents' preferences. More formally, a social choice function is a mapping $f : \Theta \longrightarrow X$. We are interested in social choice functions that can be implemented in institutions. The formal notion of a institution is a mechanism.

Definition 1 *A mechanism $G = \langle (A_i)_{i \in N}, g \rangle$ consists of a nonempty set of actions A_i each agent i and an outcome function $g : \prod_{i \in N} A_i \longrightarrow X$ that assigns to each profile of strategies an outcome.*

A mechanism summarizes the choices each agent can take and the rules that determine the outcome that emerges from these choices taken by the agents.

Definition 2 *A mechanism G together with the set of states Ω, the prior μ, possibility correspondences Π_i, utility functions u_i, and payoff mapping τ define a* Bayesian game *$\langle N, \Omega, \mu, (\Pi_i)_{i \in N}, (A_i)_{i \in N}, \tau, (\tilde{u}_i)_{i \in N} \rangle$ in which the utility function $\tilde{u}_i : (\times_{i \in N} A_i) \times \Theta \longrightarrow \mathbb{R}$ is* *defined by* $\tilde{u}_i(a_1, ..., a_n, \theta) = u_i(g(a_1, ..., a_n), \theta)$ *for all* $(a_1, ..., a_n) \in \times_{i \in N} A_i$ *and* $\theta \in \Theta$. *We abuse notation and simply write* $u_i(a_1, ..., a_n, \theta)$.

A strategy of player i in a Bayesian game is a map $\sigma^i : \Omega \longrightarrow A_i$ such that for all $\omega, \omega' \in \Omega$ with $\omega' \in \Pi_i(\omega)$, we have $\sigma^i(\omega') = \sigma^i(\omega)$. That is, the strategy of player i is adapted to her information.

For simplicity, we focus on Bayesian Nash equilibrium. A profile of strategies $\sigma = (\sigma_i)_{i \in N}$ is a Bayesian Nash equilibrium of the Bayesian game $\langle N, \Omega, \mu, (\Pi_i)_{i \in N}, (A_i)_{i \in N}, \tau, (u_i)_{i \in N} \rangle$ if $(\sigma^i(\omega))_{i \in N, \omega \in \Omega}$ is a Nash equilibrium of the strategic game defined as follows:

(i) The set of players is $\{(i, \Pi_i(\omega)) \mid i \in N, \omega \in \Omega\}$.

For each player (i, ω),

(ii) the set of actions is A_i,

(iii) the utility function of player $(i, \Pi_i(\omega))$ is the expected utility function

$$U_{(i, \Pi_i(\omega))}(\sigma) := \sum_{\omega' \in \Omega} u_i(\sigma(\omega'), \tau(\omega')) \cdot \mu\left(\{\omega'\} \mid \Pi_i(\omega)\right)$$

Definition 3 *A mechanism* $G = \langle (A_i)_{i \in N}, g \rangle$ *implements a social choice function* f *in Bayesian Nash equilibrium if there is a strategy profile* σ *that is a Bayesian Nash equilibrium of the Bayesian game induced by the mechanism such that* $g(\sigma(\omega)) = f(\tau(\omega))$ *for all* $\omega \in \Omega$. *A social choice function* f *is Bayesian implementable if there exists a mechanism* G *that implements it in Bayesian Nash equilibrium.*

Denote by $\mathcal{P}_i := \{\Pi_i(\omega) \mid \omega \in \Omega\}$ the partition of Ω formed by player i's possibility correspondence.

Remark 1 *From the Revelation Principle we know that a social choice function* f *is Bayesian implementable if and only if there exists a "direct" mechanism* $G = \langle (\mathcal{P}_i)_{i \in N}, g \rangle$ *that implements* f *in Bayes Nash equilibrium. In such a direct mechanism, player* i*'s set of actions are reports of her information sets, for every players* $i \in N$. *Moreover, for all* $\omega \in \Omega$ *we have* $g(P_1, ..., P_n) = f(\tau(\omega))$ *where* $P_i = \Pi_i(\omega)$ *for all* $i \in N$.

The significance of the revelation principle is that we do not need to search over all games but can restrict ourselves without loss of generality to "truthtelling" or "direct" mechanisms in which agents report their information. The downside is that the mechanism often appear a bit abstract and may not resemble institutions in the real world.

If f is Bayesian implementable, then it should be measurable with respect to each of the players' information partition. Hence it must be measurable with respect to the join of the players' information partition. We abuse notation and write $f(P_i, \Pi_{-i}(\omega))$ or similar.

Remark 2 *A social choice function f is Bayesian implementable if for all $i \in N$ and all $\omega \in \Omega$,*

$$\sum_{\omega' \in \Omega} u_i(f\left(\Pi_i(\omega), \Pi_{-i}(\omega')\right), \tau(\omega')) \cdot \mu\left(\{\omega'\} \mid \Pi_i(\omega)\right) \geq \sum_{\omega' \in \Omega} u_i(f\left(P_i, \Pi_{-i}(\omega')\right), \tau(\omega')) \cdot \mu\left(\{\omega'\} \mid \Pi_i(\omega)\right)$$

for all $P_i \in \mathcal{P}_i$.

Economists are usually interested in particular social choice functions that satisfy certain desirable properties such as ex post efficiency, budget balance (when transfers are involved), and participation constraints. We define these properties in turn.

Definition 4 (Ex post efficiency) *The social choice function f is ex post efficient if there doesn't exist a state $\omega \in \Omega$ for which there is an outcome $x \in X$ such that $u_i(x, \tau(\omega)) \geq u_i(f(\tau(\omega)), \tau(\omega))$ for all $i \in N$ and $u_i(x, \tau(\omega)) > u_i(f(\tau(\omega)), \tau(\omega))$ for some i.*

Consider now a context in which outcomes do not only consist of an allocation of physical goods but also on monetary transfers. A social choice function satisfies ex post *budget balance* if the sum of transfers over all agents add up to zero in every state.

Consider now a context in which each agent has an outside option when not participating in the mechanism. A mechanism satisfies the *interim participant constraint* if each agent expects a weakly larger expected utility from participating in the mechanism than her outside option.

2 Emotions

Now let each state and action also determine the (interim) emotions of each agent i. (We take these emotions to arise after a state occurred and the agent decided which action take but before the uncertainty or the outcome is resolved.) Consider a psychological classification system with m different categories of emotions. For each category $j = 1, ..., m$, the emotions can take values in a set E_j. The space of all emotions is given by the set of profiles $E := \times_{j=1}^{m} E_j$. We draw on Darwin's old idea that emotions help to communicate (Darwin, 1972). Moreover, since they are somewhat involuntary and somewhat between instinctive and conscious choice, they convey some truthful information about the agent. The emotions of an agent may not be perfectly observable by the mechanism designer or other agents. The observability of emotions of agent i is modelled by the "mood" correspondence $M_i : \Omega \times A_i \longrightarrow 2^E \setminus \{\emptyset\}$. We assume that the mood correspondence is measurable with respect to the agent's partition since otherwise she could use her mood to discriminate among states in her possibility set. That is, for every player $i \in N$, state $\omega \in \Omega$, and action $a_i \in A_i$, if $\omega' \in \Pi_i(\omega)$ then $M_i(\omega', a_i) = M_i(\omega, a_i)$.

Given a 'mood' of player i, $E' \subseteq E$, and her action a_i, the inverse image $(M_i(a_i))^{-1}(E')$ is the set of states consistent with such a mood of player i when player i takes action a_i.

Denote by $\mathcal{P}_i(E', a_i) = \{\Pi_i(\omega) \mid \omega \in (M_i(a_i))^{-1}(E')\}$ be the set of members of the partition induced by player i's possibility correspondence and the observation of player i's mood E' and her action a_i. Note that for all $i \in N$, $a_i \in A_i$, $E' \subseteq E$, $\mathcal{P}_i(E, a_i) \subseteq \mathcal{P}_i$.

Observing player i's mood, E', is now a partial proof of her type. Her type (i.e., possibility set) must be an element of $\mathcal{P}_i(E', a_i)$ when she takes action a_i.

3 Example of Bilateral Trade with Blushing Traders

In one of the most fundamental results of mechanism design, Myerson and Satterthwaite (1983) showed that a social choice function that is ex-post efficient and budget balanced is not Bayesian implementable in a mechanism satisfying interim participation constraints. We show by example how emotions can overcome this impossibility. This example is essentially due to Deneckere and Severinov (2008), who study mechanism design with partial state verifiability. In our context, partial state verifiability is due to emotions.

We consider a bilateral trade setting with a single good and a buyer and a seller. We denote by $x = 1$ the trade outcome and by $x = 0$ the no-trade outcome. The buyer's value for the good can take ℓ possible values denoted by

$$0 < \theta_b^1 < \theta_b^2 < ... < \theta_b^\ell.$$

The seller's cost can take ℓ possible values denoted by

$$0 < \theta_s^1 < \theta_s^2 < ... < \theta_s^\ell.$$

We assume that

$$\theta_b^{j-1} \leq \theta_s^{j-1} < \theta_b^j \leq \theta_s^j$$

for all $j > 1$. If agents trade, the buyer pays a price p to the seller. The profit of a buyer with value θ_b^j is $u_b(1, \theta_b^j, p) = \theta_b^j - p$. The profit of a seller with cost θ_s^j is $u_s(1, \theta_s^j, p) = p - \theta_s^j$. For any agent i, the profit from no-trade is normalized to zero, $u_i(0, \theta_i, p) = 0$ for all θ_i and p.

We assume each trader knows her value or cost, respectively, but not the other's parameter. I.e., $\omega' \in \Pi_i(\omega)$ if and only if $\tau_i(\omega') = \tau_i(\omega)$. Thus, instead letting traders report their possibility set, we can let traders report their payoff type. For all $\theta_{-i}^j \in \Theta_{-i}$ and $\omega \in \Omega$, there exists $\omega' \in \Pi_i(\omega)$ such that $\tau_{-i}(\omega') = \theta_{-i}^j$.

For simplicity, we consider just one kind of emotion; let's call it content and discontent. Moreover, we assume that when an agent is discontent, then she blushes. In the context of the example, we assume that traders can lie about their value or costs by at most one grid point without blushing (denoted by b). Agent i's mood observability correspondence is a function, $M_i : \Omega \times \Theta_i \longrightarrow \{b, \neg b\}$, defined by

$$M_i(\omega, \theta_i) = \begin{cases} \neg b & \text{if } \theta_i \in \{\theta_i^{j-1}, \theta_i^j, \theta_i^{j+1}\} \text{ with } \theta_i^j = \tau_i(\omega) \\ \neg b & \text{if } \theta_i \in \{\theta_i^1, \theta_i^2\} \text{ with } \theta_i^1 = \tau_i(\omega) \\ \neg b & \text{if } \theta_i \in \{\theta_i^{\ell-1}, \theta_i^\ell\} \text{ with } \theta_i^\ell = \tau_i(\omega) \\ b & \text{otherwise.} \end{cases}$$

That is, if at state ω agent i reports θ_i then she blushes unless she reports within one grid point of her true payoff type $\tau_i(\omega)$.

We claim that there exists a Bayesian incentive compatible, ex-post efficient, budget balanced mechanism that satisfies interim participation constraints. Transfer the good from the seller to the buyer if and only if the reports θ_b^j and θ_s^k are such that $j > k$ and both agents do not blush at a price $p(\theta_b^j, \theta_s^k) \in [\theta_b^j, \theta_s^k]$ that shall be nondecreasing in both reports θ_b and θ_s.

Ex post efficiency and budget balance are obvious.

For Bayesian incentive compatibility, by a result by Deneckere and Severinov (2008) it is enough to check that payoff type θ_i^2 does not want to report θ_i^1 and payoff type $\theta_i^{\ell-1}$ does not want to report θ_i^ℓ, for $i = b, s$. Type θ_b^1 never gets to trade. Hence θ_b^2 has no incentive to report θ_b^1. Type $\theta_b^{\ell-1}$ has no incentive to report θ_b^ℓ as she cannot profit from trading with $\theta_s^{\ell-1}$. Moreover, type θ_b^ℓ would trade at a weakly higher price with any θ_s^j with $j < \ell - 1$. Similarly, type $\theta_s^{\ell-1}$ has no incentive to report θ_s^ℓ as such a seller never trades. Moreover, type θ_s^2 has no incentive to report θ_s^1 as she cannot profit from trading with θ_b^1 and would trade as a weakly lower price with any θ_b^j for $j > 1$.

Finally, for participation constraints, note that any type prefers to participate in the mechanism. Types θ_b^1 and θ_s^ℓ never get to trade. So they are not worse off by participating in the mechanism. For all other types, (ex post) profits from participating in the mechanism are weakly positive.

4 Open Issues

1. How to go beyond Deneckere and Severinov (2008)?

2. Which emotions are better observable than others?

3. Which emotions are less easy to fake?

4. Which emotions are correlated with which consequentialist preferences?

5. How about uncertainty about the "fakeability" of an agent's emotion?

6. Why this inelegant formalization with possibility sets and beliefs? Replace by type spaces (not just payoff types of course)?

7. How about emotions about allocations? Are they "summarized" already in consequentialist preferences or should the domain of utility functions be extended? How about "psychological mechanisms" akin to psychological games? How to think about welfare in such a setting?

8. How about emotions about mechanisms?

9. ...

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Empathy for Disappointment and Elation in a Simple Experimental Game*

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Incomplete: January 11, 2017

Abstract

We present a simple experimental design to allows the experimenter to reveal the presence of a player's empathy for another player's disappointment or elation.

Keywords: Empathy, emotions, disappointment, elation, emotional perspective taking, social preferences, behavioral economics.

JEL-Classifications: C70, C72.

*Burkhard acknowledges the hospitality of the WZB during which the work was conceived.

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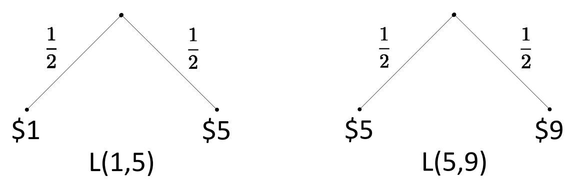
1 Introduction

Consider the following two lotteries. Lottery $L(1,5)$ features two outcomes, \$1 and \$5, with equal probability. Lottery $L(5,9)$ has two outcomes, \$5 and \$9, also with equal probability. Consider two players, one who plays lottery $L(1,5)$ and draws \$5 and one who players lottery $L(5,9)$ and draws \$5. In terms of material payoffs, both players are equally good off. Yet, the player receiving \$5 in lottery $L(5,9)$ may be upset or disappointed because he "lost" while the player receiving \$5 in lottery $L(1,5)$ may feel joy or elation because he got "lucky" and "won". Somehow the lottery $L(5,9)$ creates a higher aspiration or expectation than lottery $L(1,5)$ such that the "loosing" amount \$5 in $L(5,9)$ creates a disappointment while the "winning" amount \$5 in $L(1,5)$ creates eleation even though the amounts are the same.

Figure 1: Lotteries.



Now consider an observer who is endowed with an lump sum of \$10 and who can decide whether and how much of it to transfer to the player she observes. If the observer is capable of feeling empathy for the player, then she may transfer some non-zero amount to the player drawing \$5 in lottery $L(5,9)$ to mitigate him feeling disappointed about "loosing" the lottery. In contrast, she may not transfer that much to a player drawing \$5 in lottery $L(1,5)$ because he won already. We take empathy here to mean the ability to "share in the affect of others" (e.g., Singer, 2006).

At a first glance, the discussion above seem to capture in a straightforward way our intuition about how empathy might work in such a setting. Yet, there are issues. For instance, the discussion focused on empathy to "loosing" the lottery. But there may be also empathic responses to "joy" or elation. Perry et al. (2012) observe empathic responses to joy although they argue that some of the neural correlates for empathic responses to joy differ from the neural correlates for empathic responses to distress. Anyway, if there are empathic responses to joy, then giving a higher transfer may create more joy in the player and consequently a larger empathic response by the observer. This may apply to drawing \$5 in both lotteries.

2 A Simple Model

There are two players, player 1 and player 2. Player 1 is passive. He has no choices to make but collects a payoff. The game proceeds in three stages:

Stage 1: Nature plays out player 1's lottery. As outlined in the Introduction, we consider two different lotteries (see Figure 1). Lottery $L(1,5)$ pays either \$1 or \$5 with equal probability. The lottery $L(5,9)$ pays either \$5 or \$9 with equal probability. We denote by L any lottery and by denote by x the amount of money received by player 2 from the lottery. Note that the expected values are given by

$$\mathbb{E}[L] = \begin{cases} 3 & \text{if } L = L(1,5) \\ 7 & \text{if } L = L(5,9) \end{cases}$$

Stage 2: Player 1 receives a lumpsum of \$10 and decides how much to transfer to player 2. We denote the transfer by $y \in \{\$0, \$1, \$2, ..., \$10\}$. The transfer is deducted from the payment of \$10 that player 1 receives upfront.

Stage 3: The game ends. All players collect their payoffs. The utility function of player 1 when facing lottery L is given below.

$$\begin{aligned} u_1(x,y,L) &= x + y + \min\{x + y - \mathbb{E}[L], 0\} + \max\{x + y - \mathbb{E}[L], 0\} \\ &= 2 \cdot (x+y) - \mathbb{E}[L] \end{aligned} \quad (1)$$

The first term, $x + y$, is player 1's material payoff. It consists of the payout from the lottery as well as the payment received from player 2. The second term can be interpreted as the disappointment induced by losing the lottery. The term $\min\{x + y - \mathbb{E}[L], 0\}$ is negative or zero. The magnitude is depends on the difference between the payout from the lottery and the expected payment from the lottery mitigated by any payment received from player 2. The third term, $\max\{x + y - \mathbb{E}[L]\}$, can be interpreted as the elation felt by player 1 from winning the lottery. This term is positive or zero.

It is important that the transfer from player 1 to player 2 if any comes as a surprise to player 2. Otherwise, player 2 may also form prior expectations about player 1's transfer and consequently may experience disappointment or elation with respect to the transfer. Moreover, if the transfer is not anticipated by player 2, then it is reasonable to assume that any payment received from player 1 positively affects player 1 and mitigates his disappointment.

The utility function of player 2 is a version of the disappointment-elation model proposed in Loomes and Sugden (1986) (see also Bell, 1985, for a closely related model). They consider a utility function that takes the sum of the outcome of the lottery and a term that measures disappointment or elation from the outcome via a monotone function of the difference between the realized outcome and the expected outcome. The second and third term of function (1) together is analogous to their disappointment-elation function. The difference is that they only consider differentiable disappointment-elation functions and do not consider the mitigation of disappointment by transfers from another player.

The utility function of player 2 is

$$u_2(x, y, L, d, j) \quad = \quad 10 - y + d \cdot \min\{x + y - \mathbb{E}[L], 0\} + j \cdot \max\{x + y - \mathbb{E}[L], 0\}. \qquad (2)$$

The first term, $10 - y$, represents player 2's material payoff. The second term, $d \cdot \min\{x + y - \mathbb{E}[L], 0\}$, represents player 2's empathy with player 1's disappointment from losing the lottery. The parameter d may be interpreted as player 2's level of empathy for disappointment of player 1. The third term, $j \cdot \max\{x + y - \mathbb{E}[L], 0\}$, represents player 2' empathy with player 1's elation emanating from winning the lottery. The parameter j may be interpreted as player 2's level of empathy for joy/elation of player 1.

Any $d > 0$ represents a player 2 who displays some degree of empathy for disappointment of player 1 (analogous for $j > 0$). Yet, we are interested in "substantial" levels of empathy that even outweigh the importance that player 2 attaches to his own substantial payout from the experiment. Given our simple model, we can define substantial levels of empathy for disappointment and eleation, respectively, as follows:

Definition 1 *Player 2 has substantial empathy for disappointment if $d > 1$. Player 2 has substantial empathy for elation if $j > 1$.*

We are interested in player 2's behavior after observing that player 1 receives a payoff of \$ 5 as this behavior can be used to reveal information about player 2's empathy for disappointment and elation, respectively.

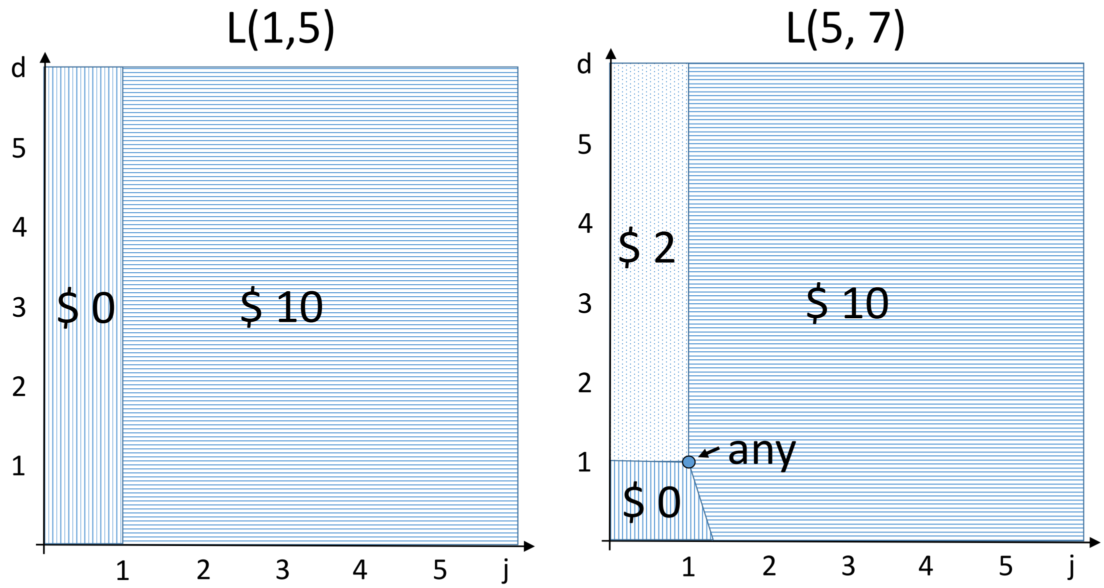
Proposition 1 *The relationship between player 2's empathy for disappointment and elation and player 2's individually optimal transfers to player 1 upon observing the realization of \$ 5 is characterized in Figure 2 for lotteries $L(5, 9)$ and $L(1, 5)$, respectively.*

The proof is straightforward and relegated to the appendix.

3 Experimental Design

Participants arrive in the lab. They are randomly assigned to the role of player 1 or player 2 with an even split of participants. Each of the two groups is taken to a separate room. In each room, all players are numbered consecutively. This numbering will be used to match players of

Figure 2: Characterization of Optimal Transfers upon Realization of \$ 5



different rooms so that participant n in one room will be matched anonymously with participant n in the other room without them knowing who exactly is their counterpart.

In the room of players 1, every player receives an envelope with ten \$1 bills, so \$10 altogether. All players are instructed that each participant in room of players 2 will play lottery. The treatments differ by lotteries. In treatment 1-5, the lottery is $L(1, 5)$. In treatment 5-9, the lottery is $L(5, 9)$.

A phineas cage is prepared in the room with players 2. It contains an equal number of red versus blue balls and will be used to play out lotteries. Moreover in both rooms, a computer with Skype is prepared (without tone). The idea is to transmit the lottery draws from the phineas cage done in front of players 1 to the room containing players 2 in such a way that players 2 do not see the players they are match with but nevertheless get to know the lottery draw of their counterpart. E.g., participant n of players 1 observes by Skype the draw from the lottery of the corresponding player 2. This draw is also recorded by the experimenter. Immediately after watching the lottery draw, player 1 is asked to decide whether and how much to transfer money from her envelope to her counter part. This amount is put privately (so that other players 1 do not know how much is put into the envelope and no "norm" is created) in an envelope with the number of the participant on it, recorded by the experimenter, and given to the participant with the same number in the room of players 1.

Participants in the room of players 2 are called to watch the lottery draw for their counterpart one by one without watching lottery draws of previous or further participants. Their empathy if any shall be focuses just on their anonymous counterpart.

Prior to eventually receiving a transfer, participants in the room of player 1 are not made aware that they might receive a transfer. This is to avoid expectation formation about the transfer.

The experimental design allows for a between-subject design of transfers depending on the treatment. The hypotheses are informed by the behavioral characterization of substantial empathy towards disappointment and elation in the previous section.

Hypothesis 1 *There is substantial empathy for disappointment but much less empathy to elation. I.e., upon observing a draw $5, the transfer amounts are significantly smaller in treatment 1-5 than in treatment 5-9. Moreover, the transfers in treatment 5-9 are bounded away from $10.*

4 Results

5 Discussion

A Proof of Proposition 1

Let $L = L(5, 9)$ and $x = 5$. Then

$$\begin{aligned} u_2(5, y, L, d, j) &= 10 - y + d \cdot \min\{5 + y - 7, 0\} + j \cdot \max\{5 + y - 7, 0\} \\ &= 10 - y + d \cdot \min\{y - 2, 0\} + j \cdot \max\{y - 2, 0\} \end{aligned}$$

If $y \geq 2$, then

$$\begin{aligned} u_2(5, y, L, d, j) &= 10 - y + j \cdot \max\{y - 2, 0\} \\ &= 10 - y + j \cdot (y - 2) \\ &= 10 - 2 \cdot j + (j - 1) \cdot y \end{aligned}$$

Thus, given $y \geq 2$, the optimal y is \$ 10 if $j > 1$. In this case,

$$u_2(5, 10, L, d, j) = 8 \cdot j.$$

If $j \leq 1$ and $y \geq 2$, then the optimal y is \$ 2. In this case,

$$u_2(5, 2, L, d, j) = 8.$$

If $y \leq 2$, then

$$u_2(5, y, L, d, j) = 10 - y + d \cdot \min\{y - 2, 0\}$$

$$
\begin{aligned}
&= 10 - y + d \cdot (y-2) \\
&= 10 - 2 \cdot d + (d-1) \cdot y
\end{aligned}
$$

Thus, given $y \leq 2$, the optimal y is \$ 2 if $d > 1$. In this case,

$$u_2(5, 2, L, d, j) \;=\; 8.$$

If $d \leq 1$ and $y \leq 2$, then the optimal y is \$ 0. In this case,

$$u_2(5, 0, L, d, j) \;=\; 10 - 2 \cdot d.$$

If $d \leq 1$ and $j > 1$, then a transfer of \$ 10 is preferred to a transfer of \$ 0 if and only if

$$
\begin{aligned}
8 \cdot j &\geq 10 - 2 \cdot d \\
4 \cdot j &\geq 5 - d.
\end{aligned}
$$

Note that if $d = 1 = j$, then any transfer is optimal.

Now, let $L = L(1, 5)$ and $x = 5$. Then

$$
\begin{aligned}
u_2(5, y, L, d, j) &= 10 - y + d \cdot \min\{5 + y - 3, 0\} + j \cdot \max\{5 + y - 3, 0\} \\
&= 10 - y + d \cdot \min\{y + 2, 0\} + j \cdot \max\{y + 2, 0\} \\
&= 10 - y + j \cdot \max\{2 + y, 0\} \\
&= 10 - y + j \cdot (2 + y)
\end{aligned}
$$

$$10 + (j-1) \cdot y + 2 \cdot j$$

If $j < 1$, then the optimal transfer is \$ 0. If $j \geq 1$, then the optimal transfer is \$ 10. This completes the characterization. □

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