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Coordination after gains and losses: Is prospect theory's value function predictive for games?

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Koordination nach Gewinnen und Verlusten: Hält die Wertfunktion der Prospekttheorie für strategische Spiele?

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Abstract

We analyze the effects of prior gain and loss experiences on individuals' behavior in two coordination games: battle of the sexes and simultaneous market entry. We propose subjectively transformed games that integrate elements of prospect theory, aggregation of prior and subsequent payoffs, and social projection. Mathematical predictions of behavior are derived based on equilibrium selection concepts. Males' behavior in our experimental studies is largely consistent with our predictions. However, the behavior of many female respondents appears to be rather consistent with interpreting the initial random lottery outcomes used to manipulate prior experiences as a signal for the players' abilities to compete. This could be related to females' known uneasiness of competing against counterparts that might be male and thus, a generally higher salience of rivalry in our incentivized experiments. Females also chose to play far more mixed strategies than males indicating some uncertainty about what type of behavior is appropriate.

Keywords: Prospect Game Theory, Prior Outcomes, Coordination, Equilibrium Selection, Economic Experiment

Zusammenfassung

Wir präsentieren eine Verhaltensvariante der Spieltheorie, die auf der Wertfunktion der Prospekttheorie, dem Aggregationsprinzip und auf sozialer Projektion beruht. Gleichgewichtsvorhersagen basieren auf einer Anwendung der allgemeinen Gleichgewichtsauswahltheorie von Harsani und Selten. Unsere mathematischen Verhaltensvorhersagen werden mittels zweier Experimente zum battle of the sexes und zum simultanen Markteintritt getestet. Das Verhalten männlicher Probanden stimmt weitgehend mit unseren Vorhersagen überein. Dagegen scheinen weibliche Probanden die Ergebnisse der Zufallszuweisung von Gewinnen und Verlusten als Signale für die Wettbewerbsfähigkeit der Spieler zu interpretieren. Dies könnte damit zusammenhängen, dass Frauen sich in Wettbewerbssituationen, in denen die Mitspieler männlich sein könnten, unwohl fühlen – und einer damit einhergehenden Betonung des „Wettbewerbsaspektes" unserer mit monetären Anreizen ausgestatteten Experimente. Frauen benutzen außerdem wesentlich mehr gemischte Strategien als Männer. Letzteres scheint eine Unsicherheit darüber anzudeuten, welche Verhaltensweisen in unseren Experimenten angemessen sind.

Schlüsselwörter: Prospekt-Spieltheorie, Vorerfahrungen, Koordination, Gleichgewichtsauswahl, ökonomisches Experiment

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1. Introduction

There is ample experimental and field evidence for the large effects of individuals' prior gain and loss experiences on subsequent choices in non-strategic decisions (Bowman 1980, 1982; Fiegenbaum and Thomas 1988; Fiegenbaum 1990; Shefrin and Statman 1985; Weber and Camerer 1998; Thaler and Johnson 1990; Myagkov and Plott 1997; Weber and Zuchel 2005). These behaviors are often argued to be consistent with the convex-concave property of prospect theory's value function (Kahneman and Tversky 1979; Tversky and Kahneman 1992; Wakker amd Tversky 1993), context dependent preferences (Tversky and Simonson 1993; Tversky and Kahneman 1991), and aggregation of prior experiences with future (potential) outcomes (Thaler 1985; Thaler and Johnson 1990).

Interestingly, an explicit mathematical analysis of the effects of individuals' prior gain and loss experiences integrating concepts in line with prospect theory is still missing for behavior in strategic games.. This paper aims at developing a mathematical model based on psychological and game-theoretic concepts that closes that gap for the case of coordination problems and tests the predictions experimentally. Studying symmetric coordination problems such as battle of the sexes (BOS) and simultaneous market entry (ME) is especially interesting. Experimentally, gain and loss experiences have either not been studied in such coordination situations or all players shared the same experience (only for ME: Rapoport et al. 1998). However, individuals' behavior in symmetric situations is hard to predict; often, such predictions are made employing (rule) learning models that are applied to behavior in games with feedback that are played over multiple rounds (see, e.g., Camerer and Ho 1998; Stahl and Haruvy 2002). Prior gain and loss experiences are also realistic – there is no individual decision without 'history' –, they may be an important way to 'break the symmetry', and hence may help individuals to coordinate.

Underlying our mathematical treatment are the following four basic premises:

(1) Prior gain and loss experiences are reflected in a *subjective transformation of payoffs* according to a *reference-dependent value function* (Tversky and Kahneman 1991, 1992; Kahneman and Tversky 1979; for games see also: Shalev 2000; Fehr and Schmidt 1999).

(2) Prior gains and losses and subsequent outcomes may be processed in an *aggregated* form (Thaler and Johnson 1990; Weber and Camerer 1998).

(3) In a strategic game, players presume the same behavioral patterns of others that they would themselves exhibit, i.e. the same reaction to prior outcomes. This is consistent with the in social psychology well-established phenomenon of *social projection* (Allport 1924; Festinger 1954; Orive 1988; Krueger 2000).

(4) Individuals behave consistent with the general equilibrium point selection theory of Harsanyi and Selten (1988), specifically, with the selection criteria of *perfectness* and

risk-dominance. Both assumptions can be motivated theoretically as well as empirically (e.g. Harsanyi 1995a, Selten 1995, Güth 2002, and Cabrales, Garcia-Fontes and Motta 2000).[1]

The experimental studies test our theoretical predictions by implementing prior gain and loss experiences before BOS and ME games. Gain and loss experiences are assigned randomly and with real payments at the beginning of the experiment. Players are then confronted with multiple rounds of the respective game and with all possible gain/neutral/loss experiences of their counterparts, about whom they are informed. Since mixed strategy play has to be expected in coordination games, we explicitly elicit such strategies. Respondents are given the chance to make use of a randomizing device similar to Anderhub, Engelmann and Güth (2002), a procedure referred to as *explicit randomization* in the literature Camerer (2003).

We find that, consistent with our formal analysis, male respondents seem to aggregate prior and subsequent outcomes, seem to play subjectively transformed games, and select pure equilibrium points in situations when the prior experiences of the players are different. Many female respondents, however, behave in a way that is inconsistent with our model. First, whereas both males and females take advantage of the possibility of explicit mixing, females use it twice as often than males. Indeed, females play mixed strategies surprisingly often in asymmetric situations where we expected respondents to play a pure strategy. This might indicate some uncertainty as to what behavior to expect from the others. Second, females only sometimes choose the pure strategies we predicted in those asymmetric situations; but quite often they choose the other one. Overall, females' behavior appears to be consistent with being in conflict with the reasoning proposed by our model and perceiving our incentivized experiments as some sort of a rivalry where the random allocation of prior gains are interpreted in terms of signals for the players' abilities to compete. The latter is somewhat plausible because of females' known uneasiness to 'compete' against counterparts that might be males (Gneezy, Niederle, and Rustichini 2003; Niederle and Vesterlund 2007).

The remainder of the paper is organized as follows. In the next section we introduce the mathematical framework of subjectively transformed games after gain and loss experiences. Sections 3 and 4 theoretically and experimentally analyze the BOS and ME games, respectively. Each of these sections starts with equilibrium predictions based on our formal framework. We then elaborate on the specifics of the experimental designs and report on the findings. In Section 5, we offer a discussion and propose avenues for future research.

1 For the case of incomplete information, see Cabrales, Nagel, and Armenter (2007).

2. Subjective Transformation of Games After Prior Experiences (TAP Games)

In this section we introduce our theoretical framework of subjectively transformed games for the case of prior gain and loss experiences, using standard game theoretic terminology.

Our approach is based on specific assumptions about the processing of prior gain and loss experiences and additional payoffs (Aggregation), the evaluation of such amounts (Transformation), and the assumptions players make on the subjective payoffs of their counterparts (Social Projection). Incorporating these assumptions into the class of normal form games, we are finally able to define a new class: TAP Games.

2.1 Transformation and common knowledge

According to (cumulative) prospect theory (Kahneman and Tversky 1979; Tversky and Kahneman 1992; Wakker and Tversky 1993), individuals' evaluation of monetary payments can be reflected by a reference-dependent value function $v:\mathbb{R}\rightarrow\mathbb{R}$ (Davies and Satchell 2007; Wakker and Zank 2002), where $v(0)=0$ is the reference point and for $\alpha,\lambda>0$:

$$(1)\qquad v(z)=\begin{cases} z^{\alpha}, & \text{if } z\geq 0 \\ -\lambda\cdot(-z)^{\alpha}, & \text{if } z<0 \end{cases}.$$

Estimations of the parameters for a median decision maker led to $\alpha\approx 0.88$ and $\lambda\approx 2.25$ (Tversky and Kahneman 1992). This value function is strictly convex (which implies risk-proneness) in the loss domain (i.e. for $z<0$) and strictly concave (which implies risk-aversion) in the gain domain (i.e. for $z\geq 0$). A $\lambda>1$ implies loss aversion.

For the sake of generality[2], we postulate concave ($v^{concave}$) and convex (v^{convex}) functions (where $v^{concave}(0)=v^{convex}(0)=0$) and a loss aversion parameter λ where $\lambda v(-z)+v(z)<0$ (if $z>0$), for $v\in\{v^{concave},v^{convex}\}$, and v is assumed to be strictly increasing and defined as

$$(2)\qquad v(z)=\begin{cases} v^{concave}(z), & \text{if } z\geq 0; \\ v^{convex}(z)=-\lambda\cdot v^{concave}(-z), & \text{if } z<0. \end{cases}$$

It is an important issue how to ensure common knowledge, a mathematical prerequisite of solving our strategic games, when the assumed parameters are general.[3] In a standard game theoretic treatment, a solution to this problem would require assuming the same parameter

2 The general requirements of our definition reflect the original approach of e.g. Tversky and Kahneman (1992), Kahnemann and Tversky (1984), Wakker and Deneffe (1996), and Abdellaoui (2000), who are more interested in describing "qualitative" risk attitudes than finding an "exact" parameterized mathematical value function.

3 We are grateful for an anonymous referee for pointing out this issue to us. This enabled us to better clarify this contribution of our paper.

values for all respondents; this could, e.g., be implemented by assuming that all players are characterized by roughly those values that Tversky and Kahneman (1992) have reported for a median decision maker (see above).

Our treatment, however, is more subtle. We basically assume that each decision maker plays his or her own *subjective* game. If a decision maker has parameter values of, say, $\alpha \approx 0.72$ and $\lambda \approx 3.10$, he or she assumes the counterparts to have the same values because of *social projection* (for more details, see 2.3) and solves his or her subjective game accordingly. Or in other words, there is no need to think of a game solution as requiring two or three decision makers having *congruent* expectations. It is sufficient to require that the individual decision maker *assumes* the others to be alike.

2.2 Aggregation

If prior gain or loss experiences exist and are taken into account in the evaluation of subsequent payments, we assume that an experience and a payment will be added together. Formally, in the case of aggregation, the evaluation of an experience $e_j \in \mathbb{R}$ with a subsequent payoff $x \in \mathbb{R}$ by an individual j is simply reflected by a transformation $F_{e_j} : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$, where $F_{e_j}(x) := v(e_j + x)$ and v is the value function defined in (2). In the case of no recent experience ($e_j = 0$), in the following also referred to as a "neutral experience," or if the individual segregates the amounts (this means, that the individual "ignores" the experience), this expression is reduced to $F_0(x) = v(x)$.

2.3 Social Projection

We assume that a player will presume her anonymous counterparts to behave in the same way as she would behave if she was in the counterparts' situation. This assumption is consistent with fundamental findings from social psychology. Specifically, whenever individuals come from a similar social group, *social projection* leads to the above similarity presumption of counterparts' attitudes and behavior (Allport 1924, Festinger 1954, Krueger 2000): "When a person reacts to (forms an opinion about) an opinion object, he or she has the tendency to project or attribute that response to others who may or may not be present" (Orive 1988, 953-954).

Applied to the context of a strategic game, when a player in a game with anonymous counterparts forms an opinion about the whole game, she has the tendency to expect the other players to form the same opinion. In our case, each player should expect the same reaction pattern (after gains and losses) from others that she would exhibit herself. Moreover, each player should expect his or her own value function's parameter values to also apply to the counterpart(s) ensuring a special form of 'common' knowledge within each subjective game (see also 2.1).

2.4 TAP Games

Using all of the above assumptions, we are now able to characterize a subjectively transformed game. Let $G = (S_1,...,S_n;U_1,...,U_n)$ be a noncooperative $n-$player coordination game in standard form (i.e. $U_j : S \to \mathbb{R}$ are payoff[4] realizations of a pure strategy vector $s \in S = \times_{j=1}^{n} S_j$, and S_j are strategy sets for player $j = 1,...,n$) and let the players have made recent experiences e_j, then all players $j = 1,...,n$ consider the game $G_{TAP} = (S_1,...,S_n;F_{e_1}(U_1),...,F_{e_n}(U_n))$. G_{TAP} differs from the original game G only in the fact that the objective payoff U_j is replaced by the subjective payoff evaluation of player j: $F_{e_j}(U_j) = v(e_j + U_j)$ for all $j = 1,...,n$. In other words, all players *i* take the recent experiences e_j of player *j* into account but transform the payoff according to the value function v, defined in (2). Each player also assumes the counterpart(s) to be described by the same parameter values that apply to her. The abbreviation TAP results from the fact that our approach is based on the concepts of payoff *T*ransformation with respect to *A*ggregation and on social *P*rojection.

Game-theoretic solutions for TAP games may be different from solutions of untransformed (normative) games. However, the following statements[5] are very easy to verify and therefore will be stated without (complete) proofs: First, since payoff transformations according to F_{e_j} are real numbers again, and the 'common' knowledge requirement about (subjective) payoffs will be satisfied by the social projection hypothesis (all players *i* "know" their own F_{e_i} and the F_{e_j} of all the other players *j*), it follows e.g. from Theorem 1 in Nash, (1951):

LEMMA 1: A game G_{TAP} has (at least) one equilibrium point in mixed strategies.

Second, since payoff-transformations F_{e_j} in TAP Games are monotone increasing in *x*, it follows:

LEMMA 2: The strategy vector $\tilde{s} \in S$ is a pure strategy equilibrium of the game G, if and only if, it is a pure strategy equilibrium of the game G_{TAP}.

LEMMA 3: A pure strategy equilibrium $\tilde{s}^1 \in S$ payoff-dominates a pure strategy equilibrium $\tilde{s}^2 \in S$ in the game G, if and only if, $\tilde{s}^1 \in S$ payoff-dominates $\tilde{s}^2 \in S$ in the game G_{TAP}.

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4 Payments received during or at the end of a game are called payoffs.

5 For (formal) definitions of the respective terms see for instance Harsanyi and Selten (1988).

In general, for a game with multiple pure strategy equilibria a number of so-called equilibrium point selection theories exist (Harsanyi and Selten 1988, Güth 1992, Harsanyi 1995a, Harsanyi 1995b, Selten 1995 and Güth 2002), that all try to suggest final solutions for such a game. Common to all these theories is the requirement to apply a solution procedure only on a subset of equilibrium points that are called *perfect* (Selten 1975).

Further selection criteria are *risk-dominance* and *payoff-dominance* (Harsanyi and Selten 1988). We will experimentally test the TAP approach for games with multiple pure strategy equilibria. In our games, no pure strategy equilibrium payoff-dominates another, and it hence follows from LEMMA 2 and LEMMA 3 that payoff-dominance (Harsanyi and Selten 1988) cannot become the relevant selection criterion[6]. Instead, according to the general equilibrium point selection theory of Harsanyi and Selten (1988), we have to analyze our games with respect to risk-dominance. APPENDIX D provides two simple examples to illustrate the intention of perfectness and risk-dominance[7], and shortly discusses methods to elicit game-playing behavior if mixed strategies are the (theoretical) solution of a game.

3. Analysis of Battle Of The Sexes

The standard BOS for two players i and j is defined as $BOS = \left(S_i, S_j, U_i, U_j\right)$ where

(3) $$S_i = \left\{s_i^i, s_i^j\right\} \text{ and } S_j = \left\{s_j^i, s_j^j\right\},$$

and payoffs for $0 < x < y$:

(4) $$U_i(s) = \begin{cases} y, \text{ if } s = (s_i^i, s_j^i); \\ x, \text{ if } s = (s_i^j, s_j^j); \\ 0, \quad \text{else}; \end{cases} \text{ and } U_j(s) = \begin{cases} y, \text{ if } s = (s_i^j, s_j^j); \\ x, \text{ if } s = (s_i^i, s_j^i); \\ 0, \quad \text{else}; \end{cases},$$

and, normatively, the only unique solution for this game is mixing among the pure perfect strategy equilibria $\tilde{s}^i = (s_i^i, s_j^i)$ and $\tilde{s}^j = (s_i^j, s_j^j)$. Let p_i denote the probability of playing s_i^i for player *i*, and let p_j denote the probability of playing s_j^j for player *j*. Then the mixed strategy equilibrium points are given by $\tilde{p}^i = (\tilde{p}_i, 1 - \tilde{p}_j)$ and $\tilde{p}^j = (1 - \tilde{p}_i, \tilde{p}_j)$, where $\tilde{p}_i = \dfrac{y}{y + x} = \tilde{p}_j$.

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[6] This fact also prevents the discussion, whether risk- or payoff-dominance has the priority within equilibrium selection theory. Whereas Harsanyi and Selten´s 1988 approach focusses on payoff dominance, modern theories (Harsanyi 1995a, Harsanyi 1995b, Selten 1995 and Güth 2002) see in risk-dominance the more important criterion.

[7] For formal definitions see e.g. Harsanyi and Selten (1988).

3.1 Equilibrium Forecasts for the TAP Game

For $i, j \in \{G, N, L\}$, where G identifies a player with a gain experience e_G, N identifies a player with a "neutral" – in the sense of zero prior outcomes – experience $e_N = 0$, and L identifies a player with a loss experience e_L, the respective TAP BOS has to be rewritten by

$$(5) \qquad BOS_{TAP} = \left(S_i, S_j; F_{e_i}(U_i), F_{e_j}(U_j)\right),$$

where the subjective payoff is defined by

$$(6) \qquad F_{e_i}\left(U_i(s)\right) = \begin{cases} v(e_i + y), \text{ if } s = (s_i^i, s_j^i); \\ v(e_i + x), \text{ if } s = (s_i^j, s_j^j); \\ v(e_i), \qquad \text{else}; \end{cases} \text{ and } F_{e_j}\left(U_j(s)\right) = \begin{cases} v(e_j + y), \text{ if } s = (s_i^j, s_j^j); \\ v(e_j + x), \text{ if } s = (s_i^i, s_j^i); \\ v(e_j), \qquad \text{else}. \end{cases}$$

According to LEMMA 2, the pure strategy equilibria are again $\tilde{s}^i = (s_i^i, s_j^i)$ and $\tilde{s}^j = (s_i^j, s_j^j)$, which are both perfect, and according to LEMMA 3 there is no payoff-dominance relationship between $\tilde{s}^i$ and $\tilde{s}^j$. Additionally, one can derive a complete mixed strategy equilibrium and a *T*ransformed *M*ixed *N*ash *E*quilibrium (TMNE). For the probability $\tilde{p}_i$ of player i for $\tilde{s}^i$ and for the probability $\tilde{p}_j$ of player j for $\tilde{s}^j$ this is characterized by:

$$(7) \qquad \tilde{p}_i = \frac{v(e_j + y) - v(e_j)}{v(e_j + y) + v(e_j + x) - 2v(e_j)} \text{ and } \tilde{p}_j = \frac{v(e_i + y) - v(e_i)}{v(e_i + y) + v(e_i + x) - 2v(e_i)}.$$

REMARK 1. Note, that (7) implies a difference between a mixed Nash equilibrium according to the standard BOS and the mixed Nash equilibrium for the transformation via prospect theory's value function (with or without aggregation).

Let (i, j) be a player combination (player i with a prior experience e_i interacts with player j with a prior experience e_j). Consider the case that both players have the same experience $i = j \in \{G, N, L\}$. Here, BOS_{TAP} is symmetrical, and neither $\tilde{s}^i$ risk dominates $\tilde{s}^j$ nor the other way around. Therefore, it follows from Harsanyi and Selten (1988):

PROPOSITION 1: Let the player combinations (G, G), (N, N), and (L, L) be given. According to the criterion of risk-dominance the complete mixed equilibrium according to (7) will be selected.

Now, for BOS_{TAP}, we fix $|e_L| = e_G = y$. For asymmetric player combinations it holds:

PROPOSITION 2: Let the player combinations (L, G) and (L, N) be given. According to the criterion of risk-dominance the pure strategy equilibrium $\tilde{s}^L$ will be selected.

PROOF: See Appendix B.

To derive a prediction for the player combination (G,N) and to be able to compute boundaries $p_{\min}$ and $p^{\max}$ for $\tilde{p}_{i,j} \in \left(p_{\min}, p^{\max}\right)$ of (7), it is necessarry to specify the value function defined in (2). This will be done applying the behavioral assumptions in section 2 with a minimum loss in generality. In the following, we use the class of exponential functions[8]:

$$(8) \qquad v(z) = \begin{cases} -(e^{-\alpha z} - 1), & \text{if } z \geq 0; \\ \lambda \cdot (e^{\alpha z} - 1), & \text{if } z < 0. \end{cases}$$

where $\alpha \in (0, +\infty)$ is assumed to be individual specific.

PROPOSITION 3: Let the player combinations (G,N) be given and v be defined as in (8). According to the criterion of risk-dominance the complete mixed equilibrium according to (7) will be selected.

PROOF: Implementing exponential transformations according to (8) and recalculating the Nash-products, then both Nash-products are equal. According to Harsanyi and Selten (1988), the equilibrium in complete mixed strategies has to be selected.

Q.E.D.

REMARK 2. The insertion of (8) into (7) leads to the possibility to compute limits for $\alpha \to 0$ and $\alpha \to \infty$ for the symmetric player combinations and for player combination (G,N), which forms the base for later analyses.

3.2 Experimental Implementation

The BOS experiment was conducted using the software Z-Tree (Fischbacher 1999, 2001) and carried out in an experimental laboratory in a large European city mostly with economics and management students ($n = 168$, 63 female and 105 male respondents). The students were recruited at different universities in a major European city using flyers, posters, and class room announcements. A minimum of six, a maximum of twelve students participated in an experimental session. Everyone received an upfront compensation of EUR 11 (approximately USD 15) for the duration of about one hour. A simple and transparent random device, a bingo cage with twelve numbered balls, was used to put the students in experimental conditions by creating prior outcome experiences. For each student, a ball was drawn without replacement. If a number ranging from one to four was drawn, the respective student incurred a loss of

8 First, there is evidence for a good approximation of outcome evaluation according to prospect theory by an exponential value function (Currim and Sarin 1989; Smidts 1997, and Beetsma and Schotman 2001). But it is shown by Zank (2001), that an exponential value function also satisfies the requirements of axiomatic (cumulative) prospect theory. Second, in section 3.3 and 4.3 we compare the results with alternative approaches with respect to the curvature of v. For these comparisons it is necessary to consider value functions that are concave in the loss and convex in the gain domain, but stem from the same class. Obviously (only) exponential functions can satisfy this requirement. For a very general approach modeling reference dependencies see also Bleichrodt 2007.

EUR 9, if a number ranging from five to eight was drawn, the student neither lost nor earned anything, and if a number ranging from nine to twelve was drawn, the student incurred a gain of EUR 9 (i.e., $e_L = -9$, $e_G = 9$ and $e_N = 0$). Respondents were told that the gain or loss would be added to or subtracted from their experimental account determining their total payoff at the end of the experiments. This was done to keep the experience salient over the course of the entire experiment.

Participants were then informed that they would play a game with one opponent who was randomly selected out of all subjects by the computer and reselected each round. Learning was not possible since feedback about the outcome of previous rounds was not provided throughout the experiment (random rematching without feedback). In order to have the respondents play all different player-type combinations at least once, each respondent had to play multiple rounds. In each round, the player was informed about the "type" of his opponent (i.e. initial payoff experience). The subjects were informed that one of the rounds played will be randomly selected by the computer for each participant and represents the basis for their final payout from the experiment. The outcomes in the BOS were specified with $x = 3$ and $y = 9$. No comprehension tests were carried out because of the relative simplicity of the task. No experimental currency but the actual EUR amounts were used in the experimental instructions.

To be able to analyze the behavior and to test our model, respondents were allowed to state mixed strategies. Specifically, they had to determine the number of A (strategy 1) and B (strategy 2) balls in a 100-ball urn; the computer picked one of the strategies randomly, and the probabilities for this random draw were directly derived from the number of A's and B's in the urn. Each of our 168 respondents played twelve rounds. Each game consisted of two players and $168 \cdot 12 \cdot 0.5 = 1008$ games were played resulting in 2016 measured decisions. The average session lasted 60 minutes. This included the first ten minutes during which the experiment was explained both verbally and on the screen. On average, twenty minutes were spent with responding to questions after the experiment.

3.3 Experimental Findings

Since there is empirical evidence for differences in the behavior of females and males in a variety of decision situations (e.g. Byrnes, Miller and Schafer 1999; Eckel and Grossman 2002; Eckel and Grossman 2005; Fehr-Duda, de Gennaro, and Schubert 2006), and because we quickly became aware of pronounced gender differences also in our two experiments and games, we report our findings by gender.

The focus of our report lays in the investigation of subjects' strategy choices. If one assumes that there exists a theory *A* and a theory *B*, and there are choice events E_A and E_B identifying these (alternative) theories, then a common procedure to verify one of both theories is (e.g. in an experiment) to count the number of E_A- and E_B-choices, and to test these numbers against a uniform distribution (e.g. Camerer 1989; Battalio, Kagel, and Jiranyakul 1990). If for one of the theories the number of choices is significantly greater, the respective theory is recognized as being verified (and the respective other theory is recognized as falsified). Taking under consideration that the number of choice events for *A* may differ from the number of choice events for *B*, we analyze our dataset in this spirit.

In Tables 1 and 4 the forecasts resulting from the concept of risk-dominance and based on the TAP approach are stated in percent with respect to the strategy choices. If risk-dominance selects a pure strategy equilibrium corresponding with a 0% or 100% choice of the respective strategy, the case is marked with "RD^{TAP}". Thereby, the percentage for a strategy choice is given from the perspective of playing the strategy of player *i* for the equilibrium $\tilde{s}^i$, $i \in \{G, N, L\}$ (see also section 3.1.). For instance, for the combination (L, G) and the situation "*L vs. G*" and according to PROPOSITION 2, the loser (*L*) has to play the strategy s_L^L for the equilibrium $\tilde{s}^L$ with 100%. For the combination (L, G) and the situation "*G vs. L*" and according to PROPOSITION 2, the winner (*G*) has to play the strategy s_G^G for the equilibrium $\tilde{s}^G$ with 0%. In other words, the players have to coordinate in the pure equilibrium, which will be "preferred" by the loser. For the combination (L, N) and the situation "*L vs. N*" and according to PROPOSITION 2, the loser (*L*) has to play the strategy s_L^L for the equilibrium $\tilde{s}^L$ with 100%. For the combination (L, N) and the situation "*N vs. L*" and according to PROPOSITION 2, the neutral (*N*) has to play the strategy s_N^N for the equilibrium $\tilde{s}^N$ with 0%. Also, here the players have to coordinate in the pure equilibrium, which will be "preferred" by the loser.

For the symmetric combinations (Table 4) and (G, N) we have (analytically or numerically) derived the respective limits based on exponential value functions (see section 3.1.) and depending on the specific payoffs in the experiment: $x = 3$, $e_L = -9$, and $e_G = y = 9$. Those predictions fall into the interval[9] [51%,99%] and are presented as the *T*ransformed *M*ixed *N*ash *E*quilibrium (TMNE). (Here, people had to mix between 51% and 99%.) Additionally, for the sake of comparison, the *S*ymmetric *M*ixed *N*ash *E*quilibrium (SMNE), i.e. the standard Nash equilibrium with untransformed payoff functions, is presented: It coincides with 75%.

[9] It depends on the slope of the value function (concave versus convex) whether mixing takes place in the interval [51%,74%] or the interval [76%,99%]. For instance, for the combination (G, N) the insertation according to REMARK 2 gives the possibility to derive limits depending on the cases "$\alpha \to 0$" and "$\alpha \to \infty$" using the specific payoffs from the game $x = 3$ and $y = 9$. We obtain for the equilibrium probabilities:

$$\tilde{p}^G \in \left(\frac{1-e^{-\alpha y}}{2-e^{-\alpha y}-e^{-\alpha x}}, \frac{1-e^{-\alpha x}}{2-e^{-\alpha y}-e^{-\alpha x}} \right) \text{ and } \tilde{p}^N \in \left(\frac{1-e^{-\alpha x}}{2-e^{-\alpha y}-e^{-\alpha x}}, \frac{1-e^{-\alpha y}}{2-e^{-\alpha y}-e^{-\alpha x}} \right).$$

Now, limit analyses for the cases "$\alpha \to 0$" and "$\alpha \to \infty$" reveal that either both players have to mix within [51%,74%] or both players have to mix within [76%,99%]. (Note, that we still assume that both players are characterized by the same α.) Similar results will be found analysing symmetric combinations. Therefore, for simplicity and keeping the results in mind, we leave out an exact differentiation and identification and refer to all scores on the interval [51%,99%] as „mixing."

In the following we want to investigate, whether real strategy choices correspond with the predictions for $\tilde{p}_i$ and $\tilde{p}_j$ (the probabilities for earning the higher payoff in the game).

Due to the specific predictions for asymmetric combinations we split the full length of the interval $[0\%,100\%]$ into the subsets

(9) $\{0\%\} \cup [1\%,50\%] \cup [51\%,74\%] \cup \{75\%\} \cup [76\%,99\%] \cup \{100\%\}$,

and for symmetric combinations into the subsets

(10) $\{[0\%,50\%] \cup \{100\%\}\} \cup [51\%,74\%] \cup \{75\%\} \cup [76\%,99\%]$.

For the presentation of the results we used the following measure: We analyze strategy choices for a specific subset or interval I with length l_I. If strategy choices were equally distributed, the measured number of choices m_I in I would be equal to the expected number of choices $n_I \cdot P_I$, where n_I is the total number of choices in a specific player combination and $P_I = \frac{l_I}{101}$ is the probability that one choice falls into I. Therefore, we define for an interval I (which corresponds with the respective cases from Table 1) the measure $r_I = \frac{m_I}{n_I \cdot P_I}$, which is the ratio between the observed number of choices and the expected number of choices. In the case of a uniform distribution of choices, r_I would be equal to one. Furthermore, $r_I > 1$ supports the underlying case in the corresponding interval. If $r_I < 1$, there are less choices than there would be if strategies were equally distributed and the respective case has no support. Additionally, for each case (i.e. *L vs. G*, *G vs. L* etc.) we tested the empirical distribution of strategy choices $\left[\frac{m_1}{n_1},\ldots,\frac{m_k}{n_k}\right]$ against the distribution $\left[\frac{l_1}{101},\ldots,\frac{l_k}{101}\right]$ ($k \in \{6,4\}$) implied by a uniform distribution about the entire interval [0%,100%] by running χ^2-analyses. These tests are significant[10] at a $p < 0.01$-level. This means that some intervals will be more often empirically frequented than implied by a uniform distribution about the entire interval [0%,100%], and some subsets will be less often empirically frequented than implied by a uniform distribution about the entire interval [0%,100%].

Ratios identifying the cases from Tables 1 and 4 are presented in Tables 2 – 3 and 5 – 6. The respective maxima of r_I are printed in bold, and if the maxima coincide with a specific prediction the maxima are highlighted with a grey shadow. For instance, for *L vs. G* in Table 3 the number $r_I = 48.45$ reflects the fact that about 48 times more strategy choices coincide with losers' pure strategy selection (100% for $\tilde{s}^L$) than were expected, assuming a uniform

[10] In the case where no strategy choice coincides with a specific subset, the χ^2-test cannot be applied (see Hope 1968; Patefield 1981). However, particulary in this case, the null hypothesis of an expectation based on a uniform distribution has to be rejected.

distribution about the entire interval [0%,100%]. Here, the prediction based on TAP receives the highest support.

For all asymmetric situations containing one loser, the behavior of male players is consistent with predictions "RD^{TAP}" (Tables 1 and 3). Females' behavior is only consistent with predictions "RD^{TAP}" in (L,G) and (L,N) (Tables 1 and 2).

Additionally, we analytically checked predictions[11] (resulting from an equilibrium point selection based on risk-dominance) according to alternative hypotheses of player behavior. In detail, we assumed different value functions of the following forms: A value function, representing risk proneness in the loss as well as in the gain domain:

$$(11) \qquad v(z) = \begin{cases} v^{convex}(z), & \text{if } z \geq 0; \\ \lambda \cdot v^{convex}(z), & \text{if } z < 0. \end{cases}$$

A value function, representing risk aversion in the loss as well as in the gain domain:

$$(12) \qquad v(z) = \begin{cases} v^{concave}(z), & \text{if } z \geq 0; \\ \lambda \cdot v^{concave}(z), & \text{if } z < 0. \end{cases}$$

A value function, representing a converse curvature compared to the value function, defined in (2):

$$(13) \qquad v(z) = \begin{cases} v^{convex}(z), & \text{if } z \geq 0; \\ v^{concave}(z) = -\lambda \cdot v^{convex}(-z), & \text{if } z < 0. \end{cases}$$

We further distinguished with respect to loss aversion and loss proneness.

For (11) and (12) and exponential transformations according to (8), the result of the analyses (for all player combinations) is the TMNE, and selection hypotheses based on risk proneness and risk aversion in the loss as well as in the gain domain have to be rejected.

For (13) and loss aversion, the forecast is opposite to the prediction of PROPOSITION 2: In combination (L,G) and according to the criterion of risk-dominance, the pure strategy equilibrium $\tilde{s}^G$ will be selected. In combination (L,N) and according to the criterion of risk-dominance the pure strategy equilibrium $\tilde{s}^N$ will be selected. We find tendencies for such a prediction in the behavior of females (see Table 2).

In the symmetric combinations and (L,G) the behavior does not coincide with the prediction according to the TMNE. Therefore it has to be rejected. Instead, the behavior of females, and in (N,N) for males, supports a forecast according to the SMNE (Tables 5 and 6).

[11] The extensive analyses are available from the authors upon request.

Summarizing, we find that whenever the prediction according to "RD^{TAP}" implies a pure strategy choice, this forecast is valid for male losers as well as winners. For females only losers act according to "RD^{TAP}", whereas winners behave according to risk-dominance in connection with TAP but with a value function that is concave in the loss and convex in the gain domain.

If the prediction implies mixing according to the TMNE, this forecast has to be fully rejected for females. For them, playing according to the SMNE (consistent with being unaffected by prior gain or loss experiences) has to be accepted for symmetric combinations. With males, however, actual behavior comes close to the prediction: When randomizing between 76% and 99% is predicted (for G *vs*. N and for N *vs*. G), the pure strategy (100%) equilibrium is played instead. Altogether our predictions nearly perfectly hold for male respondents. However, female respondents' behavior deviates in various ways. The overall behavioral pattern of females in the asymmetric situations exhibits one simple characteristic, however: Females have a tendency to play their preferred equilibrium, regardless of whether this is predicted by our theory or not.

Table 1: Equilibrium forecasts for assym. combinations in the game BOS_{TAP}

	0%	1%-50%	51%-74%	75%	76%-99%	100%
L vs. G				SMNE		RD^{TAP}
G vs. L	RD^{TAP}					
L vs. N						RD^{TAP}
N vs. L	RD^{TAP}					
G vs. N			TMNE		TMNE	
N vs. G			TMNE		TMNE	

Table 2: Ratios r_I for asymm. combinations in the game BOS_{TAP}, female

	0%	1%-50%	51%-74%	75%	76%-99%	100%
L vs. G	2.66	0.74	1.11	5.32	0.72	**11.96**
G vs. L	11.11	0.48	1.14	4.04	0.80	**15.15**
L vs. N	3.84	0.82	0.91	6.39	0.75	**10.23**
N vs. L	13.37	0.83	0.12	2.97	0.56	**26.74**
G vs. N	3.12	0.50	1.17	10.41	0.69	**17.70**
N vs. G	4.75	0.48	0.89	7.13	0.69	**27.33**

Table 3: Ratios r_I for assymm. combinations in the game BOS_{TAP}, male

	0%	1%-50%	51%-74%	75%	76%-99%	100%
L vs. G	4.78	0.35	0.97	2.73	0.17	**48.45**
G vs. L	**33.40**	0.72	0.34	1.63	0.34	13.85
L vs. N	6.27	0.42	0.58	4.88	0.70	**38.31**
N vs. L	**36.90**	0.54	0.51	1.29	0.49	11.65
G vs. N	8.75	0.87	0.56	0.00	0.36	**26.24**
N vs. G	5.81	0.20	0.36	5.81	0.94	**47.69**

Table 4: Equilibrium forecasts for symm. combinations in the game BOS_{TAP}

	1%-50% 100%	51%-74%	75%	76%-99%
G vs. G		TMNE		TMNE
N vs. N		TMNE	SMNE	TMNE
L vs. L		TMNE		TMNE

Table 5: Ratios r_I for symm. combinations in the game BOS_{TAP}, female

	1%-50% 100%	51%-74%	75%	76%-99%
G vs. G	0.94	0.97	**5.55**	0.97
N vs. N	1.23	0.48	**10.45**	0.63
L vs. L	0.96	0.69	**2.77**	1.33

Table 6: Ratios r_I for symm. combinations in the game BOS_{TAP}, male

	1%-50% 100%	51%-74%	75%	76%-99%
G vs. G	**1.61**	0.47	0.76	0.22
N vs. N	1.40	0.22	**3.69**	0.80
L vs. L	1.53	0.17	8.03	0.39

4. Analysis of Simultaneous Market Entry

In a three player simultaneous market entry game each player $l \in \{i, j, k\} \in \{G, N, L\}$ has the same strategy set $S_l = \{0,1\} = \left\{s_l^0, s_l^1\right\}$, where "1" stands for "entering the market" and "0" stands for "staying out." For the vector $s = (s_i, s_j, s_k)$ of pure strategy combinations and $z > 0$ the payoff is defined as

$$U_l = \begin{cases} z(2 - m(s)), & \text{if } s_l = 1 \\ 0, & \text{if } s_l = 0 \end{cases}, \quad (14)$$

where the number of players who actually enter the market is defined as $m(s) = s_i + s_j + s_k$.

4.1 Equilibrium Forecasts

For $i, j, k \in \{G, N, L\}$, the respective TAP ME can be written by

$$(15) \qquad ME_{TAP} = \left(S_i, S_j, S_k; F_{e_i}(U_i), F_{e_j}(U_j), F_{e_k}(U_k)\right),$$

where for $l \in \{i, j, k\}$

$$(16) \qquad F_{e_l}\left(U_l(s)\right) = \begin{cases} v\left(z(2 - m(s)) + e_l\right), & \text{if } s_l = 1; \\ v(e_l), & \text{if } s_l = 0. \end{cases}$$

This is equivalent to

$$(17) \qquad u_l := F_{e_l}\left(U_l(s)\right) = \begin{cases} v\left(z(2 - m(s)) + e_l\right) - v(e_l), & \text{if } s_l = 1; \\ 0, & \text{if } s_l = 0. \end{cases}$$

If we choose $e_L = -z$, $e_N = 0$, and $e_G = z$, it is (in connection with LEMMA 2) easy to verify that games with a payoff defined by (16) as well as games with a payoff defined by (14) have the same structure of equilibrium points: Three pure strategy equilibria in which one player enters the market and two players stay out (denoted by $\tilde{s}^l$, $l \in \{i, j, k\}$, where the l'th player enters), three pure strategy equilibria in which two players enter the market and one player stays out (denoted by $\tilde{s}^{-l}$, $l \in \{i, j, k\}$, where the l'th player stays out), one equilibrium in complete mixed strategies (denoted by $\tilde{p}$, the probability for entering the market), and a continuum of equilibria in which one player enters the market, one player stays out, and one player plays mixed strategies: For a standard equilibrium analysis see e.g. Duffy and Hopkins (2005).

To receive equilibrium forecasts, we apply the general equilibrium point selection theory of Harsanyi and Selten (1988). The application of this theory requires the consideration of a so-called ε*-perturbed form* of ME_{TAP} denoted with ME_{TAP}^{ε}. An ε-perturbed game has to be *irreducible* (for a definition see Harsanyi and Selten 1988): One can easily verify that the game ME_{TAP}^{ε} is irreducible because it is not decomposable, does not contain inferior strategies, and does not contain duplicate or semiduplicate strategies.

Given an irreducible game, the further application of Harsanyi and Selten's theory (1988, p. 222) requires the analysis of special substructures of the game, called *primitive formations*. In the case of the considered ME game, primitive formations are identical with strict equilibrium points of ME_{TAP}^{ε}, or in other words with perfect equilibria of the game ME_{TAP}. If there is only one strict equilibrium in ME_{TAP}^{ε}, this point coincides with the solution. This will be the case in the asymmetric player combinations (L,G,G), (L,L,G), (L,L,N), and (L,N,N).

If there is more than one strict equilibrium, according to the definition in Harsanyi and Selten (1988, p. 223), one has to check pairwise the *dominance relationships* between such points. Since the criterion of payoff-dominance in ME_{TAP}^{ε} is irrelevant for all possible player combinations, only the criterion of risk-dominance defined according to Harsanyi and Selten (1988, p. 223) has to be considered. The respective tool in Harsanyi and Selten's theory (1988) is the *logarithmic tracing procedure*, which has to be applied to the set of strict equilibria. According to Theorem 4.13.1 (Harsanyi and Selten 1988, p. 173), this procedure is always feasible, well defined, and its outcome is always unique. Since the number of players is greater than two, the application of the logarithmic tracing procedure requires the multinomial equations to be analytically solved (see (4.13.5) – (4.13.7) in Harsanyi and Selten 1988, p. 167-168). This is impossible, particularly for a function defined in (2). However, in the player combinations (G,N,N) and (G,G,N) only two solution candidates remain. If the set of risk-undominated equilibria contains more than one element, a substitution step that applies the tracing procedure using a special prior distribution, the centroid, is required. Fortunately, we do not have to apply the tracing procedure directly. Due to Theorem 4.13.1 (Harsanyi and Selten 1988, p. 173), the logarithmic tracing procedure always selects a *unique* risk-undominated equilibrium. Based on the argument of uniqueness we can solve all cases for the symmetric player combinations in terms of the TMNE.

Now, we determine the unique TMNE of the game ME_{TAP}:

PROPOSITION 3: Let $e_L = -z$, $e_N = 0$ and $e_G = z$. The transformed mixed Nash equilibrium strategy of player j in the game ME_{TAP} is given by

(18) $$\tilde{p}_j = \left[1 + \sqrt{\frac{u_i(-z)u_k(-z)u_j(z)}{-u_i(z)u_k(z)u_j(-z)}}\right]^{-1}, \text{ where}$$

(19) $$u_l(-z) = v(-z+e_l) - v(e_l) \text{ and } u_l(z) = v(z+e_l) - v(e_l), \text{ for } l \in \{i,j,k\}.$$

PROOF: See Appendix C.

REMARK 2. Again, we obtain a difference between the mixed Nash equilibrium according to the standard game ME and the mixed Nash equilibrium for the transformation via prospect theory's value function (with or without aggregation).

PROPOSITION 4: Let the player combinations (G,G,G), (N,N,N), and (L,L,L) be given. According to the criterion of risk-dominance the complete mixed equilibrium according to (18) will be selected.

PROOF: See Appendix C.

PROPOSITION 5: Let the player combinations (L,j,k) (and (L,L,k)) for $j,k \in \{G,N\}$ be given. In the game ME_{TAP} only the equilibrium point $\tilde{s}^L$ ($\tilde{s}^{-l}$, $l \in \{G,N\}$) is perfect, and therefore will be selected.

PROOF: See Appendix C.

PROPOSITION 6: Let the player combination (G,N,N) (and (G,G,N)) be given. According to the equilibrium point selection theory of Harsanyi and Selten in the game ME_{TAP} either $\tilde{s}^G$ ($\tilde{s}^N$) or the transformed mixed Nash equilibrium will be selected.

PROOF: See Appendix C.

According to the computation of limits in the forecast for equilibrium play in the game BOS_{TAP} we insert (8) into (17). Now it is possible to derive predictions for the symmetric combinations and (G,N,N) and (G,G,N).

4.2 Experimental Implementation

The ME experiment was conducted using the software Z-Tree (Fischbacher 1999, 2001) and carried out in an experimental laboratory at the same university mostly with economics and management students. The recruiting procedure was the same as with BOS. We conducted 13 sessions; nine students participated in each of them, resulting in a total of $n = 117$ participants (51 female, 66 male). Each received an upfront compensation of EUR 14 (approximately USD 19).

A transparent bingo cage with nine numbered balls was used in the same way as in the BOS to put the students in different experimental conditions based on prior outcome experiences. For each student a ball was drawn without replacement. If a number ranging from one to three was drawn, the respective student incurred a loss of EUR 6. If a number ranging from four to six was drawn, the student neither lost nor earned anything. If a number ranging from seven to nine was drawn, the student incurred a gain of EUR 6. Like in the BOS, these amounts were not directly paid out or collected. Subjects repeatedly played a market entry game with $z = 6$. All other features were identical to the BOS experiment (i.e. random rematching without feedback), but the instructions were adapted to the different game. The nine respondents in 13 sessions each played 29 rounds leading to a total of 3393 decisions. The mean duration of a session was again approximately one hour of which the first ten minutes were spent explaining the experiment (both verbally and on the screen). About ten minutes were spent with answering questions after the experiment. No comprehension tests were carried out because of the straightforward tasks. No artificial experimental currency but the actual EUR amounts were used in the experimental instructions.

4.3 Experimental Findings

According to the analyses of the BOS game, in Tables 7 and 9 the forecasts resulting from the TAP approach are stated with respect to the strategy choices in percent.

If perfectness selects a pure strategy equilibrium, corresponding to a 0% or 100% choice of the respective strategy, the case is marked with "$\mathrm{P}^{\mathrm{TAP}}$"; if risk-dominance selects a pure equilibrium, it is marked with "$\mathrm{RD}^{\mathrm{TAP}}$". Thereby, the percentage for a strategy choice is given from the perspective of playing the strategy of player *i* for market entry. For instance, for the combination (G, L, L) and the situation "*G vs. LL*" and according to PROPOSITION 5 the winner (G) has to play the strategy for market entry with 0%, and in the situation "*L vs. GL*" and according to PROPOSITION 5 the loser (L) has to play the strategy for market entry with 100%. In other words, the losers should enter the market and the winner stays out.

For the symmetric combinations (Table 10) and (G,N,N) and (G,G,N) we have (analytically) derived respective limits based on exponential value functions (see section 3.1.), depending on the specific amounts of the experiment: $z = 6$, $e_L = -6$, and $e_G = 6$.

Those predictions lie in the interval $[1\%,99\%]$ and are again presented as the transformed mixed Nash equilibrium (TMNE) (here, people had to mix between 51% and 99%). Additionally, as an alternative, the symmetric mixed Nash equilibrium (SMNE) is presented: it coincides with 50%.

Due to the specific predictions for asymmetric and symmetric combinations we split the full length of the interval $[0\%,100\%]$ into the subsets

$$\{0\%\} \cup [1\%,49\%] \cup \{50\%\} \cup [51\%,99\%] \cup \{100\%\}. \tag{20}$$

Similar to the BOS-study, we tested the empirical distribution of strategy choices against the expected distribution of strategy choices assuming a uniform distribution about [0%,100%] by running χ^2-analyses. These tests are again significant at a $p < 0.01$-level.

Again, ratios identifying the cases from Tables 7 and 10 are presented in Tables 8 – 9 and 11 – 12. The respective maxima of r_I are printed in bold, and if the maxima coincide with a specific prediction the maxima are highlighted with a grey shadow.

For all asymmetric situations, the behavior of male players is consistent with predictions "$\mathrm{P}^{\mathrm{TAP}}$" (Tables 7 – 8). Females' behavior is only partly consistent with predictions "$\mathrm{P}^{\mathrm{TAP}}$":

See (G,N,G) and (N,G,G) in Tables 7 and 9. Moreover, there are strong tendencies for playing the SMNE.

We additionally analyzed predictions[12] (resulting from an equilibrium point selection based on perfectness and risk-dominance) according to alternative hypotheses of player behavior. We derived predictions for equilibrium selection for value functions according to (11) – (13) (see section 3.3), and for loss aversion as well as loss proneness. According to perfectness in combinations of (G,L,L) and (G,N,L), the pure strategy equilibrium $\tilde{s}^{G}$ will be selected, and in combinations of (L,N,L), (L,G,G), and (L,G,N), the pure strategy equilibrium $\tilde{s}^{-L}$ will be selected. Therefore, in these combinations females' behavior (Table 9) coincides with a value function that is concave in the loss and convex in the gain domain.

In the symmetric combinations, except in (N,N,N) for females, there are no tendencies for playing the SMNE as well as TMNE.

Summarizing the results, we find that the predictions according to "P^{TAP}" are validated for males. For females there are some tendencies to behave according to perfectness in connection with TAP but with a value function that is concave in the loss and convex in the gain domain. For females and asymmetric combinations, mixing according to the SMNE seems also to be a good predictor. In symmetric combinations the hypothesis that males as well as females play according to the TMNE or SMNE has to be rejected.

[12] The extensive analyses are available from the authors upon request.

Table 7: Equilibrium forecasts for assym. combinations in the game ME_{TAP}

<table>
<tr><th></th><th>0%</th><th>1%-49%</th><th>50%</th><th>51%-99%</th><th>100%</th></tr>
<tr><td>*G vs. LL*</td><td>P^{TAP}</td><td></td><td rowspan="15">SMNE</td><td></td><td></td></tr>
<tr><td>*G vs. NL*</td><td>P^{TAP}</td><td></td><td></td><td></td></tr>
<tr><td>*G vs. GL*</td><td>P^{TAP}</td><td></td><td></td><td></td></tr>
<tr><td>*G vs. NG*</td><td>RD^{TAP}</td><td>TMNE</td><td>TMNE</td><td></td></tr>
<tr><td>*G vs. NN*</td><td></td><td>TMNE</td><td>TMNE</td><td>RD^{TAP}</td></tr>
<tr><td>*N vs. LL*</td><td>P^{TAP}</td><td></td><td></td><td></td></tr>
<tr><td>*N vs. NL*</td><td>P^{TAP}</td><td></td><td></td><td></td></tr>
<tr><td>*N vs. GL*</td><td>P^{TAP}</td><td></td><td></td><td></td></tr>
<tr><td>*N vs. NG*</td><td>RD^{TAP}</td><td>TMNE</td><td>TMNE</td><td></td></tr>
<tr><td>*N vs. GG*</td><td></td><td>TMNE</td><td>TMNE</td><td>RD^{TAP}</td></tr>
<tr><td>*L vs. NL*</td><td></td><td></td><td></td><td>P^{TAP}</td></tr>
<tr><td>*L vs. GL*</td><td></td><td></td><td></td><td>P^{TAP}</td></tr>
<tr><td>*L vs. NG*</td><td></td><td></td><td></td><td>P^{TAP}</td></tr>
<tr><td>*L vs. GG*</td><td></td><td></td><td></td><td>P^{TAP}</td></tr>
<tr><td>*L vs. GN*</td><td></td><td></td><td></td><td>P^{TAP}</td></tr>
</table>

Table 8: Ratios r_I for asymm. combinations in the game ME_{TAP}, male

	0%	1%-49%	50%	51%-99%	100%
G vs. LL	**39.98**	0.18	0.00	0.56	23.15
G vs. NL	**28.76**	0.63	5.61	0.46	14.03
G vs. GL	**30.64**	0.58	14.75	0.39	9.08
G vs. NG	**25.25**	0.81	6.31	0.37	10.52
G vs. NN	**37.88**	0.61	16.83	0.13	10.52
N vs. LL	**37.63**	0.42	5.94	0.40	17.82
N vs. NL	**32.68**	0.52	5.94	0.55	9.90
N vs. GL	**41.58**	0.52	14.52	0.26	5.94
N vs. NG	**33.67**	0.65	7.92	0.24	10.89
N vs. GG	**13.68**	0.29	11.88	0.12	**13.86**
L vs. NL	9.95	0.38	14.54	0.50	**37.49**
L vs. GL	6.12	0.30	22.19	0.31	**42.85**
L vs. NG	7.14	0.28	10.20	0.54	**41.32**
L vs. GG	8.56	0.27	0.00	0.49	**53.07**
L vs. GN	6.12	0.34	10.71	0.56	**41.32**

Table 9: Ratios r_I for asymm. combinations in the game ME_{TAP}, female

	0%	1%-49%	50%	51%-99%	100%
G vs. LL	13.86	0.38	13.86	0,53	**33.67**
G vs. NL	13.20	0.48	7.92	0.77	**19.80**
G vs. GL	24.97	0.40	**28.37**	0.46	6.81
G vs. NG	**27.73**	1.00	6.93	0.20	6.93
G vs. NN	**21.78**	0.65	17.82	0.36	11.88
N vs. LL	4.81	0.38	**19.24**	0.93	16.63
N vs. NL	6.01	0.74	**19.24**	0.64	8.42
N vs. GL	6.41	0.74	**28.86**	0.43	8.02
N vs. NG	9.62	0.78	**15.63**	0.52	14.43
N vs. GG	9.62	1.14	4.81	0.20	**19.24**
L vs. NL	**13.47**	0.32	8.42	1.03	8.42
L vs. GL	0.00	0.32	**28.62**	1.03	3.37
L vs. NG	11.22	0.78	**13.47**	0.62	2.24
L vs. GG	**29.93**	0.47	3.74	0.69	3.74
L vs. GN	**16.83**	0.58	10.10	0.69	6.73

Table 10: Equilibrium forecasts for symm. combinations in the game ME_{TAP}

	0%	1%-49%	50%	51%-99%	100%
G vs. GG		TMNE		TMNE	
N vs. NN		TMNE	SMNE	TMNE	
L vs. LL		TMNE		TMNE	

Table 11: Ratios r_I for symm. combinations in the game ME_{TAP}, male

	0%	1%-49%	50%	51%-99%	100%
G vs. GG	**31.56**	0.49	0.00	0.32	**31.56**
N vs. NN	**35.56**	0.54	11.88	0.42	2.97
L vs. LL	22.95	0.36	11.48	0.37	**32.14**

Table 12: Ratios r_I for symm. combinations in the game ME_{TAP}, female

	0%	1%-49%	50%	51%-99%	100%
G vs. GG	**38.62**	0.82	5.94	0.18	14.85
N vs. NN	3.61	0.63	**28.86**	0.52	14.43
L vs. LL	10.10	0.32	10.10	0.93	**15.15**

5. Discussion and Implications

The long discussion section will be concerned with the main question whether prospect theory's value function generalizes to games (5.1.), with the behavioral differences we observed between female and male respondents (5.2.), the prior evidence on mixed strategy play (5.3.), focal points and fairness as potential alternative explanations of our findings (5.4.), and finally implications for future research (5.5).

5.1 Does prospect theory's value function generalize to games?

This main question of the study has to be answered separately for the case of predictions in pure strategies, i.e., for the interesting player combinations where at least one but not all players are losers, and for predictions in mixed strategies (in the remaining cases).

Starting with the latter, according to remarks 1 and 2 (see sections 3 and 4), mixed equilibrium play – either for individuals aggregating or segregating payoffs (i.e., taking into account or not taking into account prior experiences) – should differ for individuals applying prospect theory's value function and individuals not applying prospect theory's value function. For mixed strategy predictions, our results are not consistent with individuals applying prospect theory's value function. Potential reasons for a discrepancy between our theoretical predictions and the observed behavior will be discussed in the light of selected studies on mixed strategy play in section 5.3.

Our predictions in pure strategies, however, could be confirmed, most straightforward for male respondents. Indeed, males' behavior in the cases where at least one player (but not all players) made a loss experience is remarkably close to our predictions. Male players seem to aggregate prior outcomes with (potential) subsequent payoffs; their behavior is consistent with social projection, equilibrium selection, and with the convex-concave property of prospect theory's value function. Female respondents also seem to behave according to most premises of our theory, but females' behavior would imply that a reversed curvature of the value function has to be applied. Females' behavior with different prior outcomes was also less pronounced than the behavior of males. Alternative reasons for the differences between males' and females' behavior are therefore discussed in the following subsection.

Thus, prospect theory's value function partially generalizes to games.

5.2 Gender Effects

Female respondents played twice as many mixed strategies than males and often chose the pure strategy not predicted by our model. Females' behavior could differ from the behavior of males because risk preferences could differ. Heinemann, Nagel, and Ockenfels (2004) were able to verify an effect of risk propensity on behavior in coordination games and on outcomes. Also, various studies report on differences between females and males with respect to risk preferences (Byrnes et al. 1999; Gupta, Poulsen and Villeval 2005; Maccoby and Jacklin 1974; Magnan and Hinsz 2005). However, the results reported in these studies are somewhat heterogeneous. Moreover, risk propensity was measured in our experiments, and no difference between male and female respondents could be observed.[13] Consequently, an explanation for behavioral differences between males and females in our experiments might not be provided based on risk preferences.

The frequent use of mixed strategies by female respondents could indicate some uncertainty about what type of behavior to expect from the counterparts. This could be consistent with a violation of our social projection hypothesis – in the sense that by applying social projection, there is no uncertainty about the others' behavior – as well as with a conflict on part of the females as to what behavioral 'model' to apply in our coordination games. Indeed, several studies show that social projection is far less important for women than men (e.g. Karniol, Gabay, Ochion and Harari 1998; Knudson-Martin 1994).[14] But what type of behavioral 'model' might be conflicting with the TAP approach on part of the female respondents, and does this model also explain the fact that many females exhibit a behavioral pattern opposite to what we expected based on the TAP approach?

Females' oftentimes reversed reaction to prior gains and losses might imply that prior gains and losses are *interpreted* in a way different from what has been assumed by prospect theory and within our TAP approach. Specifically, even though allocated based on a visual random device, females might have *associated* losing or winning with some sort of signal indicating a respondent's relative 'ability' to compete. To illustrate, when playing against two winners in ME and being in a loss situation themselves, male respondents predominantly choose market entry, consistent with the TAP prediction (see Tab. 8). On the contrary, females predominantly opted to stay out in this situation (Tab. 9). Many female respondents might have argued with themselves in the following way: "I have been assigned the position of a 'loser', and the other two have been assigned the position of 'winners'. So they are 'better' players. This indicates that in this situation, they are designated to compete whereas I am designated not to compete." If this reasoning were socially projected, those female respondents might have derived a subjective equilibrium different from our TAP prediction and played accordingly.

[13] The analyses are available from the first author upon request.

[14] There is also evidence that reaction patterns of females toward others generally differ significantly from those of males (Day and Livingstone 2003; Hutson-Comeaux and Kelly 2002; Kimble and Hirt 2005; McCray, King and Bailly 2005; Rotundo 2004).

Why could females' perception of our experimental situation differ so much from the perception by the males? Although not directly related, recent findings from experimental economics demonstrate that men and women have different preferences for competition in general and specifically for competition against men and women.[15] An important result from the experimental research on competition is that women tend to shy away from it, especially with males whereas males do not shy away from competition and do not react differently to male and female opponents (Niederle and Vesterlund 2007; Gneezy, Niederle, and Rustichini 2003).

Since our experiments where carried out in mixed groups of males and females with the gender of the counterpart(s) in the games unrevealed to the players, players were faced with an uncertain situation: It was unclear in a specific experimental round, whether they were playing against males or females. Whereas the gender of the counterpart(s) is rather unimportant to males and competition nothing exceptional, the 'rivalry' aspect of experiments implementing real monetary incentives could have been a salient aspect for females. This might have led to the unexpected interpretation of the prior random outcomes by females and, since in conflict with the interpretation suggested by the TAP approach perhaps even on a individual level, to a pronounced uncertainty as to what type of situation they are in, what type of behavior to be expected from the counterpart(s) and hence, what responses to choose.

The latter interpretation is especially suggestive when looking at females' behavior in the asymmetric situations of the market entry game but also holds for the other scenarios to some extent. Here, a market entry probability of 50% appeared to be an extremely frequent response across all situations, and pure strategy play was somewhat balanced between 0% and 100% in many situations (see Tab. 9).

5.3 Prior Evidence on Mixed Strategy Play and Mental Accounting

Bloomfield (1994), Ochs (1995), and Shachat (2002) allowed the participants to explicitly mix and the game-theoretic prediction also was the play of the SMNE. Most of the respondents in these studies did not show the predicted behavior; instead they played pure strategies or selected mixtures inconsistent with the SMNE (see also Camerer 2003, p. 142). A striking similarity between our findings and those of Bloomfield (1994), Ochs (1995), and Shachat (2002) can be observed when investigating our symmetric situations (e.g., (G,G,G) in Table 11). Here, hardly any of the male respondents plays the SMNE, but the average strategy is the SMNE. Note that our symmetric situations closely resemble the game situations investigated by these authors. Hence, a potential reason for discrepancies between our mixed strategy predictions and the observed behavior might be the fact that people are unwilling or unable to explicitly mix, instead of a rejection of basic premises of our theory.

According to early mental accounting experiments on non-strategic and non-risky situations, multiple gains will be segregated (Thaler 1985). This proposition can be tested in the relevant

[15] We are grateful to Sabrina Boewe who suggested this line of reasoning to us.

mixed equilibrium prediction scenarios in BOS, i.e., for (N,N), *G vs. N*, and *N vs. G* situations (Tables 5 and 6). We observe pronounced differences between (N,N), *G vs. N*, and *N vs. G* situations so that a consistent behavior was not observed. This seems to contradict the general proposition based on Thaler's early approach. However, our overall behavioral tendencies after gain experiences are consistent with other empirical studies on risky situations where prior outcomes are always aggregated with subsequent outcomes (e.g. Weber and Camerer 1998).

5.4 Focal points and fairness as alternative explanations?

An alternative explanation for the behavior observed in our experiments is *fairness* (e.g., Bolton and Ockenfels 2000) or *inequity aversion* (e.g., Fehr and Schmidt 1999). However, fairness may be a less plausible behavior to be observed in a competitive setup such as the ME game. Since behavioral patterns are strikingly similar between BOS and ME, this may be seen as first evidence against a fairness reinterpretation of our findings. Furthermore, we are not aware of any application of existing fairness models to the case of potential losses and/or prior gain and loss experiences. We nevertheless applied the Fehr and Schmidt (1999) model of inequity aversion to our games (when prior and subsequent outcomes are fully aggregated). However, the model fails to predict the behavior in the ME game. In fact, the equilibrium forecasts coincide with the normative game theoretic prediction.[16]

Another alternative explanation that should be considered with respect to equilibrium selection in coordination games is provided by *focal points* (Schelling 1960; for a formal representation of a focal point theory see Casajus 2001). According to Schelling, certain equilibria may be salient because the labels of the corresponding strategies are interpreted by large parts of the population as "suggesting themselves," e.g., meeting in New York City implies meeting at 12 noon at the information desk of Grand Central (see also Mehta, Starmer, and Sugden 1994). However, a simple form of this theory does not help in our setup. A central prediction of our approach supported by experimental data is the dependence of strategy choices on the *combination* of gain and loss experiences of the players. If certain strategies' labels would suggest these strategies as "natural," the salient equilibria would be the same independent of any differences in the combination of prior experiences of the players. For example, a player in BOS should select the same strategy (and perceive the same equilibrium as salient) irrespective of whether she is playing against a loss or a gain player. We expected and observed just the opposite.

A more complex alternative explanation in terms of focal points would be an application of fairness considerations to combinations of different gain and loss experiences of players. E.g., a 'fairness norm' could imply that losers are to be supported by granting them access to their preferred equilibrium. However, norms such as fairness are „local" concepts (Biccieri 1999). They do not generalize between games. Blanco, Engelmann and Hormann (2007) have demonstrated that individuals' other-regarding preferences differ between situations. Hence,

[16] The calculations are available from the first author upon request.

fairness as a basis of possible focal points in a coordination game may not be a general concept. Or in other words, what may be a focal point in game A may not be a focal point in game B. The consistency of behavior across games having such a different appeal to fairness norms like a two-person BOS and a three person ME would be quite surprising. Furthermore, fairness norm considerations are in sharp contrast to the behavior of females in our experiment who do not grant the loser access to her preferred equilibrium but rather behave in the opposite way. Why should only males obey to a certain social norm and make it a focal point?

5.5 Implications and Future Research

Our experimental findings offer an exciting avenue for a large number of future studies on females' behavior in our type of coordination games. The next step to be taken would be carrying out experiments where experimental sessions are either run with only females or only males. We would expect that the behavior of male respondents would not change substantially but that the behavior of females would. In fact, we would expect females to be more in tune with our theoretical predictions when the possibility of 'competing' against male respondents is precluded by the mere fact that only female respondents can be observed in the laboratory. When males are absent, the competitive 'flavor' of the experiments might become less salient to the females. Consequently, wining or losing in the initial lottery might not be (re-)interpreted in terms of abilities to compete. Thus we would expect them to be more in tune with the TAP approach. Another avenue to be taken is running the experiments in mixed groups but communicating the gender of the counterpart(s). The disadvantage of such a design might be demand effects to this type of information, however, the advantage would be to also understand behavior in mixed groups of counterparts – when playing against a male and a female, e.g., in a market entry game.

Another way to directly test (a) the social projection hypothesis and (b) the behavioral 'model' that different respondents might have would be the explicit elicitation of beliefs about the opponents' behavior after different prior experiences in each round of the game. We did not ask for such beliefs because we were afraid that this might affect the respondents' behavior too much. Or in other words, our 'no feedback' plus 'no beliefs' setup sacrificed the possibility of testing the validity of our social projection premise and different behavioral models for the sake of having a 'clean' representation of individuals' behavior after gains and losses. A study concentrating on that hypothesis might want to choose the opposite approach. We would expect that the higher uncertainty of females with respect to the behavior expected from the counterparts would show up in such a study. Another step would involve a combination of the above experiments on different gender compositions and on communicating gender of the counterpart(s) with the approach of eliciting beliefs. This could answer the question whether females expect different behaviors from males than females.

The mathematical representation of individuals' strategic behavior in BOS and ME games via an implementation of prospect theory's value function is a first step, only, toward a 'prospect game theory'. From the perspective of a further development of such an approach in the field of mathematical psychology, the most important next step is to generalize our approach to different classes of games.

Another important step would be implementing the entire prospect theory by also integrating probability weighting. Mathematically, this is a non-trivial endeavor. The major difficulty here is the existence of equilibria when the probability weighting functions of all players enter the calculation. Also, are probabilities that implicitly arise within a strategic game (endogenous risk) weighted in the same way as probabilities that individuals are confronted with in a situation with exogenous risks (games against 'nature' with given probabilities)?

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Appendix A: Fundamentals

The mathematical basis for the respective derivations is the following

LEMMA 1: *Let* $I \subseteq \mathbb{R}^n$. *For each function* $\phi : I \to \mathbb{R}$ *the following conditions i) – v) are equivalent:*

i) *The function* ϕ *is strictly concave (strictly convex).*

ii) *For all* $a, b, t \in I$ *where* $a < t < b$ *the following holds:*

$$\phi(t) > (<) \phi(a) + \frac{\phi(b) - \phi(a)}{b - a}(t - a).$$

iii) *For all* $a, b, t \in I$ *where* $a < t < b$ *the following holds:*

$$\frac{\phi(t) - \phi(a)}{t - a} > (<) \frac{\phi(b) - \phi(a)}{b - a}.$$

iv) *For all* $a, b, t \in I$ *where* $a < t < b$ *the following holds:*

$$\frac{\phi(b) - \phi(a)}{b - a} > (<) \frac{\phi(b) - \phi(t)}{b - t}.$$

v) *For all* $a, b, t \in I$ *where* $a < t < b$ *the following holds:*

$$\frac{\phi(t) - \phi(a)}{t - a} > (<) \frac{\phi(b) - \phi(t)}{b - t}.$$

vi) *For all* $a, b \in I$ *and all* $\alpha \in (0,1)$

$$\phi(\alpha \cdot a + (1 - \alpha) \cdot b) > (<) \alpha \cdot \phi(a) + (1 - \alpha) \cdot \phi(b).$$

Appendix B: Equilibrium Selection in the Bos Game

PROOF OF PROPOSITION 2. Let π_i^k be the transformed payoff of player i and π_j^k the payoff of player j in the pure strategy equilibrium $\tilde{s}^k$, $k \in \{i, j\}$. Then with respect to risk-dominance we have to first show (see Harsanyi and Selten 1988, pp. 86-88) that for (L,G) and (L,N) it must be true that:

(B1) $\pi_L^i \cdot \pi_G^i > \pi_L^j \cdot \pi_G^j$,

(B2) $\pi_L^i \cdot \pi_N^i > \pi_L^j \cdot \pi_N^j$.

According to the TAP approach (B1) is equivalent to

$$\left[v^{convex}(0) - v^{convex}(-y)\right]\left[v^{concave}(x+y) - v^{concave}(y)\right]$$
$$> \left[v^{convex}(-y+x) - v^{convex}(-y)\right]\left[v^{concave}(2y) - v^{concave}(y)\right],$$

which can according to (2) be rewritten as

$$\frac{v^{concave}(y) - v^{concave}(0)}{v^{concave}(y) - v^{concave}(y-x)} > \frac{v^{concave}(2y) - v^{concave}(y)}{v^{concave}(x+y) - v^{concave}(y)}.$$

Now we choose in iv) of Lemma 1 especially $a = 0 < t = y - x < b = y$ and in iii) of Lemma 1 especially $a = y < t = x + y < b = 2y$ then we obtain

$$\frac{v^{concave}(y) - v^{concave}(0)}{v^{concave}(y) - v^{concave}(y-x)} > \frac{b-a}{b-t} = \frac{y}{x} \text{ and } \frac{y}{x} = \frac{b-a}{t-a} > \frac{v^{concave}(2y) - v^{concave}(y)}{v^{concave}(x+y) - v^{concave}(y)}.$$

Relation (B2) is equivalent to

$$\left[v^{convex}(0) - v^{convex}(-y)\right]v^{concave}(x) > \left[v^{convex}(-y+x) - v^{convex}(-y)\right]v^{concave}(y)$$

$$\underset{\text{(2) in the main text}}{\Leftrightarrow}$$

$$\frac{v^{concave}(y) - v^{concave}(0)}{v^{concave}(y) - v^{concave}(y-x)} > \frac{v^{concave}(y)}{v^{concave}(x)}.$$

$$\frac{v^{concave}(y) - v^{concave}(0)}{v^{concave}(y) - v^{concave}(y-x)} \underset{\substack{\text{(iv) of Lemma 1} \\ \text{with} \\ a=0<t=y-x<b=y}}{>} \frac{y}{x} \underset{\substack{\text{(ii) of Lemma 1} \\ \text{with} \\ a=0<t=x<b=y}}{>} \frac{v^{concave}(y)}{v^{concave}(x)}.$$

Q.E.D.

Appendix C: Equilibrium Point Selection in the Me Game

PROOF OF PROPOSITION 3. Expression in (18) is the unique solution of the system:

$$\frac{\partial u_i(\tilde{p})}{\partial \tilde{p}_i} = \tilde{p}_j \cdot \tilde{p}_k \cdot u_i(-z) + (1-\tilde{p}_j)\cdot(1-\tilde{p}_k)\cdot u_i(z) = 0,$$
$$\frac{\partial u_j(\tilde{p})}{\partial \tilde{p}_j} = \tilde{p}_i \cdot \tilde{p}_k \cdot u_j(-z) + (1-\tilde{p}_i)\cdot(1-\tilde{p}_k)\cdot u_j(z) = 0,$$
$$\frac{\partial u_k(\tilde{p})}{\partial \tilde{p}_k} = \tilde{p}_i \cdot \tilde{p}_j \cdot u_k(-z) + (1-\tilde{p}_i)\cdot(1-\tilde{p}_j)\cdot u_k(z) = 0.$$

Q.E.D.

For the following Proofs, first we state some useful estimations:

Choose in vi) in Lemma 1 (Appendix A), specifically $a = 0$, $b = 2z$, and $\alpha = \frac{1}{2}$, then:

(C1) $v^{concave}(2z) < 2v^{concave}(z)$.

Choose in vi) in Lemma 1 (Appendix A), specifically $a = -2z$, $b = 0$, and $\alpha = \frac{1}{2}$, then:

(C2) $2v^{convex}(-z) < v^{convex}(-2z)$,

From (C1) follows for a winner (G) and his payoff, defined in (20), section 4.1.:

(C3) $u_G(-z) + u_G(z) = v^{concave}(0) - v^{concave}(z) + v^{concave}(2z) - v^{concave}(z) < 0$.

From (C2) follows for a loser (L) and his payoff, defined in (20), section 4.1.:

(C4) $u_L(-z) + u_L(z) = \lambda\left[v^{convex}(-2z) - 2v^{convex}(-z)\right] > 0$.

PROOF OF PROPOSITION 4. Consider for the game ME^{ε}_{TAP} the set of strategy combinations

(C5) $S_1 = \{(1-\varepsilon,\varepsilon,\varepsilon),(\varepsilon,1-\varepsilon,\varepsilon),(\varepsilon,\varepsilon,1-\varepsilon)\}$,

and

(C6) $S_2 = \{(1-\varepsilon,1-\varepsilon,\varepsilon),(1-\varepsilon,\varepsilon,1-\varepsilon),(\varepsilon,1-\varepsilon,1-\varepsilon)\}$.

Here, "ε" and "$1-\varepsilon$" identifies the probability for market entry. Now it is easy to show that for (L,L,L) the set S_2 and for (G,G,G) and (N,N,N) the set S_1 defines equilibria in the game ME^{ε}_{TAP}: For instance, for (L,L,L) and the strategy vector $(1-\varepsilon,1-\varepsilon,\varepsilon)$ forms an equilibrium, because for the expected payoff for the "$1-\varepsilon$"-playing player follows for small $\varepsilon>0$:

(C7) $$\tilde{u}_L(1-\varepsilon,1-\varepsilon,\varepsilon)=\varepsilon(1-\varepsilon)^2\left[u_L(-z)+u_L(z)\right]>0$$

For a "ε"-playing player from (C4) it follows from $u_L(z)>0$, $u_L(-z)<0$ and the fact that $\varepsilon>0$ is arbitrarily small:

(C8) $$\tilde{u}_L(1-\varepsilon,1-\varepsilon,\varepsilon)=\varepsilon\left[(1-\varepsilon)^2u_L(-z)+\varepsilon^2u_L(z)\right]<0.$$

Thus, no player has an incentive to deviate. The strategy vector $(\varepsilon,1-\varepsilon,\varepsilon)$ cannot form an equilibrium, because the "ε"-playing player has according to (C4) an incentive to deviate:

(C9) $$\tilde{u}_L(\varepsilon,1-\varepsilon,\varepsilon)=\varepsilon^2(1-\varepsilon)\left[u_L(-z)+u_L(z)\right]>0.$$

The analyses for (G,G,G) can be done accordingly, based on (C3). The analyses for (N,N,N) is based on the assumption of loss aversion. For an "ε"-playing player in $(\varepsilon,1-\varepsilon,\varepsilon)$ we have:

(C10) $$\tilde{u}_N(\varepsilon,1-\varepsilon,\varepsilon)=\varepsilon^2(1-\varepsilon)\left[\lambda u_N(-z)+u_N(z)\right]<0.$$

For an "$1-\varepsilon$"-playing player in $(\varepsilon,1-\varepsilon,\varepsilon)$ we have for small $\varepsilon>0$:

(C11) $$\tilde{u}_N(\varepsilon,1-\varepsilon,\varepsilon)=(1-\varepsilon)\left[\varepsilon^2\lambda u_N(-z)+(1-\varepsilon)^2u_N(z)\right]>0.$$

But for an "ε"-playing player in $(1-\varepsilon,1-\varepsilon,\varepsilon)$ we have:

(C12) $$\tilde{u}_N(1-\varepsilon,1-\varepsilon,\varepsilon)=(1-\varepsilon)^2\varepsilon\left[\lambda u_N(-z)+u_N(z)\right]<0.$$

If there is more than one equilibrium in ME^{ε}_{TAP}, according to the General Equilibrium Point Selection Theory of Harsanyi and Selten (1988), one has to apply the logarithmic tracing procedure. Since, according to Theorem 4.13.1 (Harsanyi and Selten 1988, p. 173), this procedure is always feasible, well defined, and its outcome is always unique, the only unique solution with respect to the player indices and the equilibrium structure, is the TMNE.

Q.E.D.

PROOF OF PROPOSITION 5. An equilibrium point in ME_{TAP} is only perfect, if it is a (strict) equlibrium in the game ME_{TAP}^{ε}. Therefore, we show that for the player combination (L,G,G) the game ME_{TAP}^{ε} consists exactly of the equilibrium $\tilde{s}^{L}$. We denote with $(1,0,0)$ the pure strategy equilibrium in the game ME_{TAP} concerning the player combination (L,G,G). In ME_{TAP}^{ε} the corresponding strategy vector is $(1-\varepsilon,\varepsilon,\varepsilon)$, respectively.

For the expected payoff of player L we conclude according to (C4):

(C13) $$\tilde{u}_L(1-\varepsilon,\varepsilon,\varepsilon)=(1-\varepsilon)\left[\varepsilon^2 u_L(-z)+(1-\varepsilon)^2 u_L(z)\right]>0.$$

For the expected payoff of a player G we conclude according to (C3):

(C14) $$\tilde{u}_G(1-\varepsilon,\varepsilon,\varepsilon)=\varepsilon^2(1-\varepsilon)\left[u_G(-z)+u_G(z)\right]<0.$$

Therefore $(1-\varepsilon,\varepsilon,\varepsilon)$ forms an equilibrium in ME_{TAP}^{ε}. We denote with $(0,1,0)$ the pure strategy equilibrium in the game ME_{TAP} concerning the player combination (L,G,G), again (this means, one of the winners enters the market, and the other players stay out). In ME_{TAP}^{ε} the corresponding strategy vector is $(\varepsilon,1-\varepsilon,\varepsilon)$, respectively. Now we show that $(\varepsilon,1-\varepsilon,\varepsilon)$ cannot be an equilibrium in ME_{TAP}^{ε}: Considering the expected payoff of the loser, then from (C4) follows:

(C15) $$\tilde{u}_L(\varepsilon,1-\varepsilon,\varepsilon)=\varepsilon^2(1-\varepsilon)\left[u_L(-z)+u_L(z)\right]>0,$$

this means, the loser has an incentive to choose "$1-\varepsilon$" instead of "ε".

The strategy combinations $(\varepsilon,1-\varepsilon,1-\varepsilon)$, $(1-\varepsilon,1-\varepsilon,\varepsilon)$ and $(1-\varepsilon,\varepsilon,1-\varepsilon)$ cannot form equilibria in ME_{TAP}^{ε}, because the "$1-\varepsilon$"-playing winners have an incentive for playing "ε":

(C16) $$\tilde{u}_G(1-\varepsilon,\varepsilon,1-\varepsilon)=\varepsilon^2(1-\varepsilon)\left[u_G(-z)+u_G(z)\right]<0.$$

The analyses for the remaining combinations can be completed accordingly, using (C3) and (C4). The main aspect for the analyses of player combinations including neutrals is based on loss aversion (see Proof of Proposition 4).

Q.E.D.

PROOF OF PROPOSITION 6. Similar to the approach in the Proof of Proposition 5 one can show that the set $S_1 = \{(1-\varepsilon,\varepsilon,\varepsilon),(\varepsilon,1-\varepsilon,\varepsilon),(\varepsilon,\varepsilon,1-\varepsilon)\}$ coincides with equilibria in ME^{ε}_{TAP}. Since the logarithmic tracing procedure cannot be applied because it requires the multinomial equations to be analytically solved (see 4.13.5-4.13.7 in Harsanyi and Selten 1988, pp. 167-168), which is impossible, the corresponding equilibria $(1,0,0)$, $(0,1,0)$, $(0,0,1)$ and the TMNE remain. From uniqueness of the logarithmic tracing procedure it follows that for (G,N,N) the pure strategy equilibrium $\tilde{s}^G$ and the TMNE, and for (G,G,N) the pure strategy equilibrium $\tilde{s}^N$ and the TMNE are solution candidates.

Q.E.D.

Appendix D: Solution Criteria, Measurement of Mixed Strategies

Perfectness

Consider the 2×2-game in figure 1, where player 1 has the strategy set $S_1 = \{s_1^1, s_1^2\}$ and player 2 has the strategy set $S_2 = \{s_2^1, s_2^2\}$, respectively.

Figure 1: Perfectness

		player 2	
		s_2^1	s_2^2
player 1	s_1^1	(1, 1)	(2,0)
	s_1^2	(0,2)	(2,2)

The game has two Nash-equilibria, namely $\tilde{s}^1 = (s_1^1, s_2^1)$ and $\tilde{s}^2 = (s_1^2, s_2^2)$. First, we consider $\tilde{s}^1$: We assume that player 2 speculates that player 1 knows that this strategy combination is an equilibrium point. However, player 2 has to expect, that player 1 deviates from her equilibrium strategy with a small probability $\varepsilon > 0$ (e.g. there is a small chance of error). This implies, that player 1 in fact plays the mixed strategy $(1-\varepsilon, \varepsilon)$ instead of the pure strategy s_1^1, where the first component identifies the probability for playing the first pure strategy and the second component identifies the probability for playing the second one, respectively. From the perspective of the second player, and in the case of playing s_2^1, she is faced with the expected payoff :

(D1) $u_2(1-\varepsilon, s_2^1) = (1-\varepsilon)\cdot 1 + \varepsilon \cdot 2 = 1 + \varepsilon$.

In the case of playing s_2^2 the expected payoff is given by:

(D2) $u_2(1-\varepsilon, s_2^2) = (1-\varepsilon)\cdot 0 + \varepsilon \cdot 2 = 2\varepsilon.$

For small values of ε, player 2 maximizes her expected payoff by placing a minimal weight on s_2^2. By symmetry, player 1 should place a minimal weight on s_1^2 if player 2 is playing the mixed strategy $(1-\varepsilon, \varepsilon)$.

Therefore, the equilibrium $\tilde{s}^1$ satisfies the simple requirement of perfectness: It is robust with respect to small chances of error.

A similar argumentation fails to show that the equilibrium $\tilde{s}^2$ is perfect. Assuming player 1 plays the mixed strategy $(\varepsilon, 1-\varepsilon)$, then player 2's expected payoff by playing s_2^1 is

(D3) $$u_2(\varepsilon, s_2^1) = \varepsilon \cdot 1 + (1-\varepsilon) \cdot 2 = 2 - \varepsilon.$$

If player 2 plays s_2^2 she will receive

(D4) $$u_2(\varepsilon, s_2^2) = \varepsilon \cdot 0 + (1-\varepsilon) \cdot 2 = 2 - 2\varepsilon.$$

For all positive values of ε, player 2 maximizes her expected payoff by placing a minimal weight on s_2^2. Therefore $\tilde{s}^2$ is not perfect because player 2 (and, by symmetry, player 1) maximizes her expected payoff by deviating if there is a small chance of error.

In general, an equilibrium point $\tilde{s} \in S$ of a game G is called perfect, if for the so called ε-perturbed game G_ε (here, all pure strategies have to be played with a small minimum probability ε) a sequence $\tilde{s}_\varepsilon^k$ of equlibria exists, which converge for $k \to \infty$ to $\tilde{s}$.

Risk-Dominance

Consider the 2×2-game in figure 1, where $a_1 > b_1 > 0$ and $0 < a_2 < b_2$.

Figure 2: Risk-Dominance

		player 2	
		s_2^1	s_2^2
player 1	s_1^1	(a_1, a_2)	(0,0)
	s_1^2	(0,0)	(b_1, b_2)

(For $a_1 = b_2$ and $a_2 = b_1$ this is matrix presentation of the BOS game, studied in section 3.) Again, the strategy combinations $\tilde{s}^1 = (s_1^1, s_2^1)$ and $\tilde{s}^2 = (s_1^2, s_2^2)$ are (perfect) equilibrium points, but player 1 receives more in

$\tilde{s}^1$, and player 2 receives more in $\tilde{s}^2$. Assuming, both players know, that either $\tilde{s}^1$ or $\tilde{s}^2$ is the solution of the game, then the question arises which strategy they should play. If player 1 expects that player 2 will select s_2^1 with probability q (and s_2^2 with $1-q$, respectively), then from the expected payoff one can derive that she would play s_1^1 if $q > \frac{b_1}{a_1+b_1}$ and she would play s_1^2 if $q > \frac{a_1}{a_1+b_1}$. Similarly, if player 2 expects, that player 1 chooses s_1^1 with probability p (and s_1^2 with $1-p$, respectively), then she will select s_2^1 if $p > \frac{b_2}{a_2+b_2}$ and s_2^2 if $p > \frac{a_2}{a_2+b_2}$. Player 1's incentive to prefer s_1^1 over s_1^2 can be specified by the realation $\frac{a_1}{a_1+b_1} \cdot \frac{a_1+b_1}{b_1} = \frac{a_1}{b_1}$, and player 2's incentive to prefer s_2^2 over s_2^1 by the relation $\frac{b_2}{a_2+b_2} \cdot \frac{a_2+b_2}{a_2} = \frac{b_2}{a_2}$. If both players take this fact into account, they will be coordinated in $\tilde{s}^1$, if $\frac{a_1}{b_1} > \frac{b_2}{a_1}$, or $a_1 \cdot a_2 > b_1 \cdot b_2$ hold for the "Nash"-products.

In general, for the game in figure 2, one can specify, that the criterion of risk-dominance selects

(a) $\tilde{s}^1$, if $a_1 \cdot a_2 > b_1 \cdot b_2$,

(b) $\tilde{s}^2$, if $a_1 \cdot a_2 < b_1 \cdot b_2$,

(c) the complete mixed Nash-equilibrium $\tilde{p}$, if $a_1 \cdot a_2 = b_1 \cdot b_2$.

Mixed Strategies

Mixed strategies are defined as probability distributions about pure strategies. Since a mixed strategy equilibrium can be a solution of a (on risk-dominance based) selection concept, the question arises, how one can measure a mixed strategy.

Basically, in experimental studies one can distinguish between implicit and explicit randomization (see also Camerer, 2003). Implicit randomization means that subjects can only choose pure strategies and that the relative frequency will be interpreted as the mixture.

Explicit randomization identifies the situation in which people can state probability distributions directly. The advantage of this approach is that the experimentor has the possibility to measure a mixed strategy in a single round. Since, as found in the experimental studies of this work, the number of repetitions is small, the statement of a distribution by the subjects seems to be an appropriate approach to derive mixtures. We will realize this according to the procedure of Anderhub et al. 2002.

Appendix E: Instructions for the Battle of the Sexes (BOS) Game

Where necessary, explanations of experimental procedures are added in bold italics for better understandability. The actual instructions and information received by the participants is shown in boxes.

After being seated at their places, and before beginning with the computer-based part of the experiment, the participants were paid a participation fee of € 11.00 and told to pocket it.

They were then informed of the following:

We will now conduct a lottery with the following features:

There are 12 balls with numbers from 1 to 12 in a bingo cage. They will be drawn without replacement, i.e. once drawn, a ball will not be placed back into the cage.
A draw of a ball with the numbers 1-4 will result in a gain of € 9.00 for you.
A draw of a ball with the numbers 5-8 results in no payment (€ 0.00).
A draw of a ball with the numbers 9-12 will result in a loss of € 9.00.

The draws will take place in private at each participant's seat and will only be seen by that participant.

The individual bingo ball lotteries were then conducted and the respondents informed about their (gain, loss, or neutral) outcome.

The following information was then provided:

In the experiment you will play games with changing counterparts. In addition to the rules of the game, the only information all of you will have is the outcome of the lottery we just conducted. In other words, you will always be informed about the outcome of your respective counterpart, as he or she will be about your outcome.

The participants began playing the computer-based game. All of them were presented with the following screens in the order given here (Screen type A through G).

Screen type A:

<u>Welcome to our experiment on decision making!</u>

Your decisions in this experiment will depend on your skill and luck, and will result in real payments of different amounts. We will need some information about you, to identify and pay you at the end of the experiment.

Please copy your participant number as shown on the screen to your form and then completely fill out the form.

You have participant number: 1

All information will be kept strictly confidential.

Screen type B:

<u>Information</u>

Conditions of Payment:

This experiment will take place over several rounds. While the results of each round will not be displayed, a summary of the whole experiment's results will be provided at the end of the experiment. Out of all rounds, one will randomly be selected by the computer. Your game result in this randomly chosen round will then be added to your result in the lottery conducted at the beginning of the experiment. At the end of the experiment, the experiment's supervisor will settle your account by paying out or collecting the payments from you.

Have fun participating in the game!!

The values in parantheses varied depending on the participant's own result and the result of their opponent in the bingo cage lottery.

Screen Type C:

<u>Information</u>

Reminder: In the lottery conducted at the beginning of the experiment you {suffered a loss of € 9.00 / achieved a neutral result of € 0.00 / gained a profit of € 9.00}, which (in addition to any potential gains or losses made during the experiment) will be settled at the end of the experiment.

Thus your current account balance is {€ -9.00/€ 0.00/€ 9.00}.

Screen type D:

Rules of the Game

You are playing with an opponent randomly selected by the computer. Both of you have the choice between the two alternative strategies, A and B, with the following payoffs:

You play strategy A,

… and your opponent chooses strategy A, then you gain € 3.00 and your opponent gains € 9.00.
… and your opponent chooses strategy B, then both of you receive a payment of € 0.00.

You play strategy B,

… and your opponent chooses strategy B, then you gain € 9.00 and your opponent gains € 3.00.
… and your opponent chooses strategy A, then both of you receive a payment of € 0.00.

Game

Information: In the lottery at the beginning of the experiment your opponent {suffered a loss of € 9.00 / achieved a neutral result of € 0.00 / gained a profit of € 9.00}.

Your decision will be made with the help of a virtual raffle drum whose contents will be determined by you. You can fill it with a total of 100 tickets (A and B tickets). If an A ticket is drawn, strategy A will be chosen for you by the computer. If a B ticket is drawn, strategy B will be chosen. Please now specify the contents of the drum by stating the number of A and B tickets to be included:

Please indicate the number of A tickets to be placed in the drum: _______

Please indicate the number of B tickets to be placed in the drum: _______

Subsequently, multiple rounds with changing opponents were played according to screen type D. To ensure that the participants noticed that conditions changed from round to round, screen type E was presented prior to type D before to each round (except the first).

Screen type E:

Information

Attention: In this round, the conditions of the game have changed. Please pay close attention to the information concerning the outcomes.

Several psychometric scales and questions followed the actual experiment and preceded the payout rounds; results are not reported in this paper.

Based on the results from the round randomly chosen by the computer and the bingo cage lottery conducted at the very beginning of the experimental sessions, screen type F was used to calculate final payments.

Screen type F:

Game Summary

The following table provides a summary of all rounds played: your respective chosen number of A and B tickets, the resulting strategies (A or B), and your results. You can identify your opponent's number and result for every round.

Round	Number of A tickets	Number of B tickets	Drawn ticket 1=A,2=B	Your Result	Your Opponent (number)	Opponent's Result
{1…12}	{0…100}	{0…100}	{1/2}	{0.00/3.00/9.00}	{1…12}	{0.00/3.00/9.00}

Screen type G:

Final Result

To calculate your payout, round {1…12} was randomly selected of all rounds by the computer.

In the selected round {1…12} you {achieved a neutral result of € 0.00 / gained a profit of € 3.00 / gained a profit of € 9.00}.

In the lottery at the beginning of the experiment you {suffered a loss of € 9.00 / achieved a neutral result of € 0.00 / gained a profit of € 9.00}.

Added to the result of {€ 0.00/€ 3.00/€ 9.00} in round {1…12} your total payout is € {-9.00/-6.00/0.00/3.00/9.00/12.00/18.00}.

An amount of € {-9.00/-6.00/0.00/3.00/9.00/12.00/18.00} will be settled with you.

This is the end of the experiment. Thank you very much for participation. Please quietly stay seated and wait until the supervisor has balanced accounts with you.

Appendix F: Game Instructions for the Market Entry (ME) Game:

Where necessary, explanations of experimental procedures are added in bold italics for better understandability. The actual instructions and information received by the participants is shown in boxes.

After being seated at their places, and before beginning with the computer-based part of the experiment, the participants were paid a participation fee of € 14.00 and told to pocket it.

They were then informed of the following:

We will now conduct a lottery with the following features:

There are 12 balls with numbers from 1 to 12 in a bingo cage. They will be drawn without replacement, i.e. once drawn, a ball will not be placed back into the cage.
A draw of a ball with the numbers 1-4 will result in a gain of € 6.00 for you.
A draw of a ball with the numbers 5-8 results in no payment (€ 0.00).
A draw of a ball with the numbers 9-12 will result in a loss of € 6.00.

The draws will take place in private at each participant's seat and will only be seen by that participant.

The individual bingo ball lotteries were then conducted and the respondents informed about their (gain, loss, or neutral) outcome.

The following information was then provided:

In the experiment you will play games with changing counterparts. In addition to the rules of the game, the only information all of you will have is the outcome of the lottery we just conducted. In other words, you will always be informed about the outcome of your respective counterpart, as he or she will be about your outcome.

The participants began playing the computer-based game. All of them were presented with the following screens in the order given here (Screen type A through G).

Screen type A:

Welcome to our experiment on decision making!

Please pay attention to the following:

- Your decisions in this experiment will depend on your skill and luck, and will result in real payments of different amounts.
- This experiment will take place over several rounds.
- While the results of each round will not be displayed, a summary of the whole experiment's results will be provided at the end of the experiment.
- Out of all rounds, one will randomly be selected by the computer. Your game result in this randomly chosen round will then be added to your result of the lottery conducted at the beginning of the experiment.
- At the end of the experiment, the experiment's supervisor will settle your account by paying out or collecting the payments from you.
- You will find a red button at the bottom of each screen. When you understood and completed all tasks on that screen, press it to continue.
- All information is anonymous and will be kept confidential.

Have fun participating in the game!!

Screen type B:

You will now play a three person game over several rounds.

Your opponent will change from round to round as previously and randomly determined by the computer.

The values in parantheses varied depending on the participant's own result and the result of their opponents in the bingo cage lottery.

Screen type C:

Reminder

In the lottery conducted at the beginning of the experiment you {suffered a loss of € 6.00 / achieved a neutral result of € 0.00 / gained a profit of € 6.00}, which (in addition to any potential gains or losses made during the experiment) will be settled at the end of the experiment.

Thus your current account balance is {€ -6.00/€ 0.00/€ 6.00}.

Screen type D:

Your Game Situation:

You and your two opponents have the choice of entering a market with limited demand.

If all three of you decide to enter the market, everyone will suffer a loss of € 6.00.

If two of you decide to enter the market, the two entering players as well as the not entering player will receive € 0.00.

If only one of you decides to enter the market, he receives € 6.00 and the other two players who did not enter receive € 0.00.

If none of you decide to enter the market, all three players receive € 0.00.

In the lottery at the beginning of the experiment, your two opponents in this round had the following results:

One opponent {suffered a loss of € 6.00 / achieved a neutral result of € 0.00 / gained a profit of € 6.00 }.

Your other opponent { suffered a loss of € 6.00 / achieved a neutral result of € 0.00 / gained a profit of € 6.00}.

Your decision:

Your decision will be made with the help of a virtual raffle drum whose contents will be determined by you. You can fill it with a total of 100 tickets (E_{ntry} and N_oE_{ntry} tickets). If an E_{ntry} ticket is drawn, you will enter the market. If a $N_o E_{ntry}$ ticket is drawn, you will not enter the market. Please now specify the contents of the drum by stating the number of E_{ntry} and N_oE_{ntry} tickets to be included:

Please indicate the number of E_{ntry} tickets to be placed in the drum: _______

Please indicate the number of $N_o E_{ntry}$ tickets to be placed in the drum: _______

Subsequently, multiple rounds with changing opponents were played according to screen type D. To ensure that the participants noticed that conditions changed from round to round, screen type E was presented prior to type D before each round (except the first).

Screen type E:

Information

Attention: In this round, the conditions of the game have changed. Please pay close attention to the information concerning the outcomes.

Several psychometric scales and questions followed the actual experiment and preceded the payout rounds; results are not reported in this paper.

Based on the results from the round randomly chosen by the computer and the bingo cage lottery conducted at the very beginning of the experimental sessions, screen type F was used to calculate final payments.

Screen type F:

Game Summary

The following table provides a summary of all played rounds with your chosen number of E_{ntry} and N_oE_{ntry} tickets, the resulting strategies (E_{ntry} and N_oE_{ntry} tickets), and your results of each round. Moreover, you can identify your opponents' strategies for every round.

Round	Number of E Tickets	Number of NE Tickets	Drawn Ticket	Choice of 1st Opponent	Choice of 2nd Opponent	Your Result
{1…29}	{0…100}	{0…100}	{NE/E}	{NE/E}	{NE/E}	{-6.00/0.00/6.00}

Screen type G:

Final Result

To calculate your payout, round {1…29} was randomly selected of all rounds by the computer.

Source	Amount [€]
Lottery at the beginning of the experiment	{-6.00/0.00/6.00}
Result of randomly chosen round {1…30}	{-6.00/0.00/6.00
Total:	{-12.00/-6.00/0.00/6.00/12.00}

An amount of € {-12.00/-6.00/0.00/6.00/12.00} will be settled with you.

This is the end of the experiment. Thank you very much for participation. Please quietly stay seated and wait until the supervisor has balanced accounts with you.

About the Authors

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