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Abstract

It is documented that fetal exposure to sexual hormones has long lasting effects on human behavior. The second-to-fourth digit ratio (DR) is a putative marker for prenatal exposure to testosterone (compared to estrogens) while in uterus, with higher relative exposure to testosterone resulting in a lower DR. Although the existing literature documents the correlation of DR with various decisions, and testosterone has been related to competitive behaviors, little research has studied the effect of DR on competition in conflict situations *where skills do not matter*. We investigate this question in the laboratory. Based on a previously obtained large sample of student subjects, we *selectively* invite subjects to the laboratory if their right-hand DR is in the top (High type) or bottom (Low type) tercile for their gender. Unbeknownst to the subjects, we perform a controlled match of High and Low types as opponents in a 2-person Tullock contest. We find that Low type (higher exposure to testosterone) males expend significantly higher conflict effort than High type males, that is, they are more aggressive, which reduces their opponents' earnings. Among females, however, everyone is more aggressive against the High type (who respond less aggressively). These results can partially be explained through high joy of winning and/or spitefulness for Low type males, and high spitefulness for Low type females. This investigation sheds light on the importance of biological aspects in the ex-ante determinants of conflict, and on contest design.

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1. Introduction

Competition and conflict are closely related aspects of human life. Many competitive scenarios offer opportunities to "one-up" or deliberately harm a rival – often leading to the expenditure of resources with substantial opportunity cost, as well as escalation through retribution. Vendettas, riots, religious or ethnic tensions, as well as bidding wars and protracted legal battles are all examples of such situations. To better understand how excessive expenditure of resources can arise in these contexts, and how such conflict dynamically affects people's behavior in competition, it is important to understand what leads some people to behave more aggressively than others. Heterogeneity of conflictive behavior has various causes, including those commonly classed as nurture (e.g., upbringing, social norms, and stereotypes) or situational factors (e.g., socio-economic conditions, mental and physiological state). However, some part of it may also be determined by nature: some people are born more conflictive than others. In this study, we focus on this ex-ante biological aspect.

More specifically, we focus on how preferences for competition and conflict may develop in utero. Biological and psychological studies have shown that differences in fetal exposure to sex hormones (testosterone and estrogens) explain behavior in later life (Hines, 2006; Herbert, 2015). Our proxy for fetal hormone exposure is the length of the index finger divided by the length of the ring finger: known as the second-to-fourth digit ratio (DR), with a higher relative fetal exposure to testosterone (FT) resulting in a lower DR (Goy and McEwen, 1980; Manning and Taylor, 2001). To investigate DR as an explanatory variable of conflictive behavior, we conduct a controlled laboratory experiment with a multi-period 2-player lottery contest (Tullock, 1980). Crucially, we investigate how repeated interaction of different FT types affects dyadic competition outcomes.

Based on a previously obtained large sample of DR measures, we selectively invited only High (H) and Low (L) DR type subjects to our experiment. Unbeknownst to the subjects, we thus performed a controlled match of types as opponents in the contest - as either H-H, L-L, or H-L. We define a subject's type as H (L) if they are in the top (bottom) tercile of the DR distribution within their gender. Because DR is sexually dimorphic, its relationship to behavior is more meaningful for interactions with a member of the same gender. Moreover, conducting single-gender experimental sessions has the benefit of controlling for subjects' expectations of opponents' gender, to avoid subjects purposely moderating their competitive behavior – e.g., males being less competitive in the presence of female subjects (Van Den Bergh and Dewitte, 2006) or more likely to compete with other males (Gupta et al., 2011). For these reasons, we design our experiment as an intra-gender competition for monetary resources.

We find that L DR-type males expend significantly higher conflict effort than their H type counterparts. That is, they are more aggressive. However, they do not necessarily earn more than the H type; whereas anybody matched with a L type earns significantly less compared to when matched with a H type. When two L type males are matched, we observe the highest individual conflict effort and the highest aggregate conflict levels.

The results are different for the females: overall everyone is more aggressive against H types, who appear to respond less aggressively, and L types earn more than H types. While the highest conflict effort for females is exerted by L types when matched with H types, matching two L types results in the lowest aggregate conflict levels – exactly the opposite as for men. These findings can be partially explained through differences in underlying preferences, such as "joy of winning" utility and social preferences.

This paper contributes to the existing literature in several ways. First, this is the very first study that uses individual information on prenatal exposure to testosterone to match subjects in the laboratory, which means our H and L types are defined ex-ante *by design*. Second, previous studies reported a relationship between L DR and success in competitive scenarios (e.g., in financial trading, Coates et al., 2009, and sports, Manning and Taylor, 2001). However, these studies cannot assess whether L DR individuals prevail due to superior competitive preferences or superior skills. Our study uses a contest game where there are no differences in skills. Hence, our setup lets us isolate the effects of FT on conflict behavior regardless of the differences in personal abilities. Third, we contribute to the contest theory literature incorporating biological factors for the first time. Finally, we contribute to the literature on gender differences in competition by reporting the surprising finding that males act primarily in accordance with their own biological type whereas females react to their rival's type.

Viewing competition outcomes as a function of biological types can provide novel explanations for patterns observed in markets and society. When certain types are more likely to select into certain professions, such as financial trading (Sapienza et al., 2009) or entrepreneurship

(Nicolaou et al., 2017), this will affect the nature of the competition. The nature of the competition, in turn, may also attract or favor the survival of certain types. Having a type suited to a particular competitive environment may be so important as to be part of human adaptive machinery: Cecchi and Duchoslav (2018) show that the exposure of pregnant women to violent conflict in Uganda has resulted in children born with lower DRs, who cooperate less in a public good game. These findings hint at a biological feedback mechanism that may contribute to vicious circles in conflict-prone societies. If we are to break such vicious circles, understanding the feedback mechanisms that propagate overly competitive or conflictive behavior is of key importance.

Our findings have another practical implication for policymakers and contest designers. Asymmetric behavior in conflict or competition results in asymmetric outcomes in terms of the likelihood of winning and ex-post payoffs. Our results show that effort provision in such competition partly depends on the way people are born. Hence, a designer with objectives such as maximizing total effort (e.g., sports), minimizing total effort (elections) or maximizing maximum effort (R&D races) may want to consider such biological factor along with any socio-economic factors while designing a contest. An important tool for a social welfare maximizing designer is affirmative action where the designer tries to level the playing field by using mechanisms such as head-starts, handicaps, quotas or effort caps (Chowdhury et al., 2019). To implement such affirmative action tools effectively, one may want to take biological factors (such as the DR) into consideration.

The rest of the paper is organized as follows. In Section 2 we review the relevant literature. We provide a baseline theoretical benchmark for the experiment in Section 3. Section 4 elaborates the experimental design and outlines the main hypotheses. The experimental results are reported under Section 5. Section 6 introduces behavioral models to further explain the results based on preference parameters, and Section 7 concludes.

2. Literature Review

2.1. Testosterone and DR

Our main interest is the effect of prenatal exposure of the fetus to testosterone. Besides its primary function in the development of male reproductive organs, prenatal testosterone plays a key role in the 'masculinization' of the fetal brain (Arnold and Breedlove, 1985; Bao and Swaab, 2011; Goy and Ewen, 1980; Herbert, 2015), with male fetuses producing, and therefore being exposed to, much higher levels of testosterone than female fetuses (Rodeck et al., 1985; Finegan et al., 1989). Patients with androgen-related syndromes provide quasi-experimental evidence: males with Androgen Insensitivity Syndrome (unresponsive androgen receptors) have not only the outward appearance but also psychological traits characteristic of females; while females with Congenital Adrenal Hyperplasia (increased androgen production) display childhood play behaviors that are more typical of males (see Hines, 2006; Herbert, 2015). Despite these patients receiving postnatal treatments that address hormonal imbalances, the effect on sex-differentiated behaviors persists. Moreover, even naturally occurring levels of testosterone are correlated with sex-differentiated infant behaviors (Hines et al., 2002; Udry et al., 1995). A key implication of this evidence is that prenatal testosterone exposure predicts post-natal behavior in both males and females.[1]

Our marker of prenatal hormone exposure is the digit ratio (DR). The DR, also known as the second-to-fourth DR or 2D:4D, is the ratio of the length of the index finger to the length of the ring finger. There is an abundance of evidence on the negative correlation between the DR and exposure to prenatal testosterone in humans[2]: e.g., testosterone levels in amniotic fluid (Lutchmaya et al., 2004; Ventura et al., 2013), androgen spillovers in dizygotic twins (Van Anders et al., 2006), and individuals with androgen-related syndromes (Brown et al., 2002; Berenbaum et al, 2009; Manning et al., 2013).[3] The DR is a stable proxy - it can be measured reliably after 3 months of fetal gestation (Galis et al., 2010; Malas et al., 2006) and is consistent throughout childhood and adulthood (Garn et al., 1975; Manning et al., 1998; McIntyre et al., 2005; Trivers et al., 2006). The DR is sexually dimorphic, i.e., males have lower average DR than females (although distributions largely overlap). Due to its stability and relative ease of measurement, the DR has become a popular proxy for researchers investigating the effects of pre-natal physiology on adult behavior.

[1] Although the evidence is strongly suggestive of testosterone-driven masculinization in utero, it is still unclear whether fetal testosterone levels are also related to other factors that affect the child's upbringing. Note, for example, evidence that fetal and maternal testosterone levels are positively correlated (Gitau et al., 2005; but see also Rodeck et al., 1985) and a negative correlation between a mother's DR and the likelihood of having a son (Kim et al., 2015).
[2] See Brañas-Garza et al. (2018b) for an extensive discussion.
[3] There is also a growing literature of experimental evidence from non-human mammals (Auger et al, 2013; Talarovicova et al., 2009; Zheng and Cohn, 2011).

2.2. DR and competitive behavior

The DR has been shown to correlate with various aspects of competitive behavior outside the laboratory. Studies show relationships with psychological measures such as a desire for dominance (Neave et al., 2003; Manning and Fink, 2008), aggression (Bailey and Hurd, 2005; Benderlioglu and Nelson, 2004; Turanovic et al., 2017), and self-reported competitiveness (Bönte et al., 2017). The literature also documents relationships with professional outcomes such as performance in athletes (Bennet et al., 2010; Honekopp and Schuster, 2010; Tester and Campbell, 2007) and trading styles and profits in financial professionals (Coates and Herbert, 2008; Coates et al., 2009; Cronqvist et al., 2016). Furthermore, some professions appear to attract certain DR types. For example, Sapienza et al. (2009) find that L DR individuals are more likely to self-select into financial services jobs and Nicolaou et al. (2017) find the same relationship for entrepreneurship. These suggest that interactions in certain markets and professions may be more "testosterone-driven", due to specific DR types both selecting into these interactions and prevailing in the long run (Bönte et al., 2016; Dabbs and Dabbs, 2000; Coates et al., 2010).

There is also a substantial literature on correlations of the DR with behavior in economic games in the laboratory. Here we will restrict ourselves to the evidence on types of behavior relevant to competitive situations. First, we note that the relationship between testosterone exposure and social preferences appears complex. Whereas Buser (2012) and Cecchi and Duchoslav (2018) report that public good game contributions are lower for L DR types (in line with the hypothesis that high-testosterone types are less cooperative), Brañas-Garza et al. (2013) and Galizzi and Nieboer (2015) find that dictator game giving is significantly lower for those with H and L DR, compared to those with average DR. Brañas-Garza et al. (2019) find no direct correlation between DR and dictator game giving, fairness or trust. In contrast, studies on risk taking present a more harmonious set of findings. Several studies have documented a negative relationship between DR and risk taking with financial incentives (Dreber and Hoffman, 2007; Garbarino et al., 2011; Ronay and von Hippel, 2010; Brañas-Garza and Rustichini, 2011; Strenstrom et al., 2011; Brañas-Garza et al., 2018). Taking risks is a feature of many competitive situations, and gender differences have been observed for both preferences over risk (Charness and Gneezy, 2012; Croson and Gneezy, 2009; Eckel and Grossman, 2008) and preferences for competitive situations (Niederle and Vesterlund, 2007). With respect to other factors that may influence competition behavior, we also note that L DR individuals, contrary to expectations, appear to be less likely to exhibit overconfidence, at least in tasks where overconfidence is maladaptive (Dalton and Ghosal, 2018; Neyse et al., 2016).

The study closest to ours is the first-price sealed-bid auction experiment by Pearson and Schipper (2012), who investigate the *correlation* between DR and bidding behavior in pairs of subjects (stranger matching) in which the gender of the counterpart was unknown (experimental sessions contained both males and females). Based on prior research on the relationship of DR with risk taking and aggression, they hypothesize that L DR individuals will bid higher amounts. But they find no evidence of such a relationship. The authors speculate that such effects may either be non-existent or too small, as well as reflecting that "*the 'aggression' motive may not be present in the auction because subjects may view it more like an individual decision task*" (p. 526, quotation marks in original). Our experimental set-up is arguably more conducive to conflictive behavior, by deliberately matching extreme DR types for multiple periods in a partner design, conducting single-gender sessions and using a Tullock all-pay contest instead of a winner-pay auction.

Since circulating levels of hormones may correlate to behavior in competition, one remaining question of interest is whether there is a relationship between DR and the circulating level of testosterone. Although some recent findings (Crewther et al., 2015) suggest a negative relationship, pointing at circulating testosterone as a mechanism by which FT indirectly affects behavior, there is currently not enough evidence. Part of the issue is the apparent complex role of circulating testosterone in competitive settings. Circulating testosterone rises in anticipation of competition (Mazur and Lamb, 1980; Suay et al., 1999; Schultheiss and Rohde, 2002) and higher circulating testosterone levels are associated with more aggressive behavior (Berman et al., 1993; Carre et al., 2008; Kivlighan et al., 2005; Salvador et al., 1999). But the latter findings cannot exclude confounding factors and, while several laboratory studies offer some support for a causal relationship,[4] field studies on testosterone (self-)administration yield mixed evidence (Anderson et al., 1992; O'Connor et al., 2002, 2004; Tricker et al., 1996).

[4] Males after testosterone administration are more likely to respond aggressively to points deducted by a competitor in an incentivized real-effort task (Pope et al., 2000); females after administration respond less fearfully and less empathetically to angry faces (Van Honk et al., 2012; 2004; Hermans et al., 2006) and take more risk on the Iowa gambling task (Van Honk et al., 2004). Studies on the ultimatum game, a paradigm with elements of dyadic

2.3. Contest literature

A unique feature of many situations in competition and conflict is that the agents involved expend costly resources such as physical effort, time, or money to win a prize; and irrespective of the outcome they lose the resources spent, i.e., the costs are irreversible. The area of game theory that investigates specifically this type of games is called Contest Theory. The application of this area of research includes, among others, conflict, rent-seeking, innovation races, legal battles, and sports. The theoretical basis of contests can be found in books such as Konrad (2009) or Vojnovic (2015). An important feature of any contest is the rule that determines how the probability of winning depends on the resources (we call it 'efforts' in the continuation) spent. A function that maps the vector of efforts into probabilities of winning is called a Contest Success Function or CSF (Skaperdas, 1996). A CSF, coined by Tullock (1980), considers the probability proportionate to the effort spent for each player – similar to a lottery. Due to its theoretical tractability as well as applicability in various contest situations, it is one of the most popular CSFs.

Since it is easily implementable in the laboratory and easy for the subjects to understand, the Tullock (1980) contest is also the most popular contest used in experimental contest literature (Ducheneaux et al., 2015). Researchers have employed this contest to investigate rent-seeking (Potters et al., 1989), gender differences (Price and Sheremeta, 2015), group conflicts (Abbink et al., 2010), and identity related conflict (Chowdhury et al. 2016) to name a few.

Two robust phenomena in experimental Tullock contests are 'overbidding' and 'overspreading'. Overbidding shows subjects spending more effort (or bidding more) than the level predicted by Nash equilibrium (Ducheneaux et al., 2015), whereas overspreading shows subjects bidding with higher variation than predicted by the Nash equilibrium (Chowdhury et al., 2014). Several behavioral factors, such as joy of winning, errors, social preference and experimental design are argued to be responsible for these phenomena (Sheremeta, 2013; Chowdhury et al., 2018).

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bargaining (e.g., Espín et al., 2015) have yielded conflicting results (Cueva et al., 2017; Eisenegger et al., 2010; Zak et al., 2009).

3. Theoretical benchmark

As mentioned above, to replicate conflict behavior in the lab, we introduce a Tullock contest (Tullock, 1980). There are two identical players. Player i (with $i = 1, 2$) chooses his effort $e_i \in [0, B]$ from budget B to win a prize of common value $V > 0$. There is no prize for the loser and, irrespective of the outcome of the contest, players forgo their efforts. The probability that player i wins, $p_i(e_1, e_2)$, is represented by a lottery Contest Success Function:

$$p_i(e_1, e_2) = \begin{cases} e_i/(e_1 + e_2) & \text{if } e_1 + e_2 \neq 0 \\ 1/2 & \text{otherwise} \end{cases} \tag{1}$$

That is, the probability of winning depends on player i's own effort relative to the sum of both players' efforts. Given (1), the expected payoff for player i, $E(\pi_i)$, can be written as:

$$E(\pi_i) = p_i V + (B - e_i). \tag{2}$$

It can be shown directly from Szidarovszky and Okuguchi (1997) and Chowdhury and Sheremeta (2011) that a Nash Equilibrium in pure strategies exists, and it is unique. Following standard procedure, the unique Nash equilibrium effort for risk-neutral players is:

$$e^* = \begin{cases} V/4 & if\ B > V/4 \\ B & otherwise \end{cases}. \tag{3}$$

In our experiment we set $B = V > V/4$ to ensure the interior solution and the equilibrium payoff is $\pi^* = B + V/4$. The equilibrium effort remains the same for finite repetition of this game. We also set the prize value at 180 tokens, and hence the equilibrium effort is 45 tokens.

Naturally, this theoretical prediction does not consider any effect of the contestants' DR. Given the literature outlined above, we have framed our experiment neutrally, in terms of 'bidding for a prize' – where the bids are equivalent to the effort in a conflict. Hence, our experimental procedure may elicit effects of DR on bidding behavior and in the next section we provide with our behavioral hypotheses. Those hypotheses, however, do not consider through which mechanism such outcome may arise. It may be possible that if prenatal exposure to sex hormones correlates with key behavioral features, variations in effort provision arises through such features. Two of such prominent features uncovered in the literature (e.g., Sheremeta, 2013) are the 'joy of winning', a psychological value of win over and above the pecuniary value; and social preference – especially 'spite', the desire to earn more than the other party's payoff. We discuss these features as well as their corresponding theoretical predictions in Section 6.

4. Hypotheses and experimental procedure

4.1. Hypotheses

Given the literature on the effects of FT on competition-related behaviors we can coin the following hypotheses:

1. A higher FT exposure, reflected by a lower DR should result in more aggressive behavior in conflict irrespective of the rival, in the form of higher bids in the experiment – both (i) in overall bidding over all periods (ii) as well as bidding in the very first period.
2. Someone matched with a L-DR opponent should face higher bid and (i) react by bidding more irrespective of their own type across all periods, i.e., L DR should face higher bid levels; (ii) this should not be the case in the first period bid (as the bid of the other player is not observed), i.e., L and H DR should face the same bid level in the first period.

Whereas Hypothesis 1 comes directly from the DR literature, Hypothesis 2 comes from the contest literature where a lagged bid of the opponent often has a positive effect on own bid (see, e.g., Chowdhury et al., 2018). These hypotheses are expected to hold especially among males, given the literature on (prenatal) testosterone and male-male competition. Previous studies suggest that the results may differ by gender (Herbert, 2018).

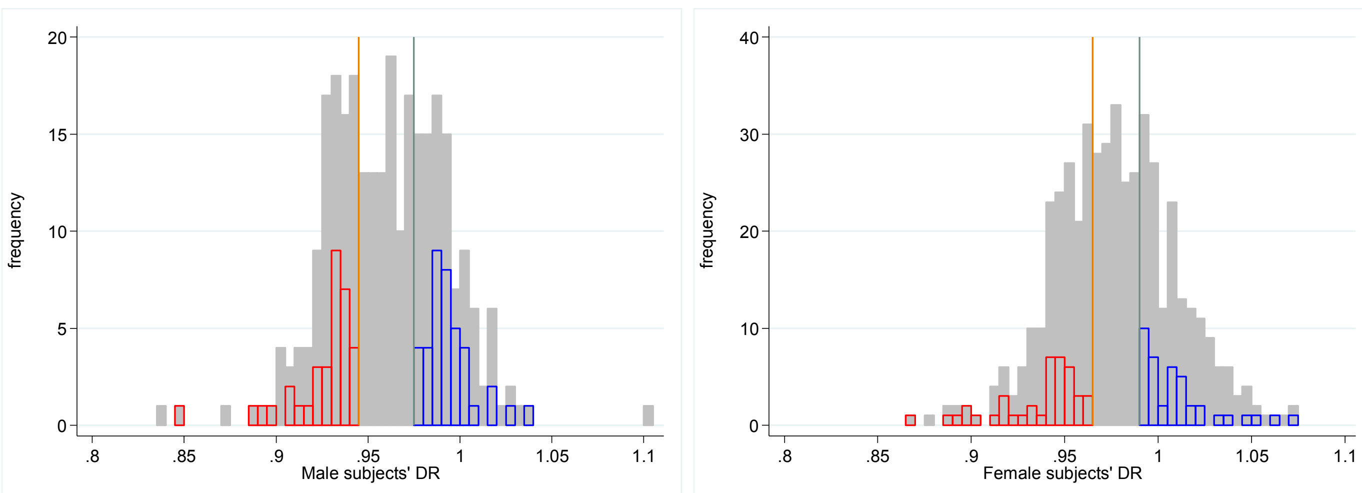
4.2. Procedures

The current study has two distinct innovative aspects: the investigation of conflict behavior and its relation to the DR, and the matching mechanism of subjects in the experiment to investigate the question. The latter feature is embedded in our experimental procedure. We run six treatments in which subjects play exactly the same contest game. The variation, however, comes from how the subjects are matched in different treatments. We match a particular DR type (H or L) of subject to another without the knowledge of the subjects, and separately for each gender. Since we manipulate matching between DR types, ours is not a purely correlational study, in contrast to the standards in the DR-behavior literature. Below we explain the matching mechanism in detail.

Based on a previously obtained large sample of volunteer student subjects ($n = 920$), after a semester we selectively invited subjects to the experimental laboratory if their right-hand DR is in the top (H type) or bottom (L type) tercile for their gender. Unbeknownst to the subjects, we performed a controlled matching of H and L types as opponents in a 2-player rent-seeking contest. Hence we implemented a 3x2 factorial design {L vs. L, L vs. H, H vs. H} x {Male, Female}.[5]

Figure 1 displays the distribution of right-hand DRs (left panel for males, right panel for females) for all subjects in the initial sample (in grey) and for those finally participating (L-DR in red, H-DR in blue). Cut points defining the DR terciles are depicted by vertical lines.

Figure 1. Distribution of DR in the initial and final samples: males and females



Notes: Distribution of right-hand DRs (left panel for males, right panel for females) for all subjects in the initial sample (in grey) and for those finally participating (L-DR in red, H-DR in blue). Cut points defining the DR terciles are depicted by vertical lines.

For three of the four subpopulations invited we find no significant difference between the DRs of those invited and of those who finally participated. The only significant difference arises for the L-DR females: those participating had lower DR than the invited subjects (mean DR: 0.934 vs. 0.945, *p=0.04*, two-tailed Mann-Whitney U test; all remaining comparisons yield *p>0.15*).

[5] The DR distribution is different for males and for females: the mean (SD) DR in our final sample is 1.010 (0.020) and 0.994 (0.013) for H type females and males, respectively, whereas it is 0.934 (0.024) and 0.925 (0.020) for L type females and males, respectively. Thus, we do not match subjects of different gender.

Each subject took part in only one session of a 15-period contest while fixed-matched with another subject. In each treatment each subject was given 180 tokens per period from which s/he could bid for a prize of 180 tokens. Players could enter bids up to one decimal place.

Table 1 summarizes the treatment details and number of observations. Note that "Eqbm bid" refers to equilibrium bid.

Table 1. Summary of Treatments

Treatment	Budget / period	Players / group	Prize value	Eqbm. bid	Total subjects
Male-L-L	180	2	180	45	16
Male-Mixed	180	2	180	45	34
Male-H-H	180	2	180	45	20
Female-L-L	180	2	180	45	22
Female-Mixed	180	2	180	45	24
Female-H-H	180	2	180	45	28

All experimental sessions were run at the Behavioural Research Lab at the London School of Economics and Political Science (LSE), following an experimental protocol approved by the LSE Research Ethics Committee. Subjects were students at the LSE.

We recruited the subjects in two stages. First, subjects were recruited from the Behavioural Research Lab's subject pool for an experiment without any eligibility criteria or exclusion restrictions. During this experiment, subjects performed a photo rating task, completed a questionnaire and took part in three incentivized preferences elicitation tasks: a time preferences task, a single-player dictator game (described in Galizzi and Nieboer, 2015) and a lottery choice task (Brañas-Garza et al., 2018). For this experiment, subjects were paid a participation fee plus the money they had earned in the preference elicitation tasks.

At the end of the experiment, we led subjects into a separate room where we had set up a computer with a high-resolution scanner (Canon LIDE 110). Subjects were asked to read an informed consent form, in which we explained the procedure of obtaining the DR by scanning both of their hands, and were explicitly informed this was voluntary and that they could ask as many questions as they wanted. If the subject agreed to provide a DR measure by signing the informed consent form, our research assistant scanned both hands to obtain the DR. The ID code assigned by the subject recruitment system (SONA) was used to identify scans, thus ensuring complete anonymity for the subjects. These experiments took place in February and March 2014, followed by an extra round of data collection in April 2015. In total, we obtained DR scans for 704 subjects (478 females).

Before the second stage, we computed the right-hand DR of each subject following the procedure of Neyse and Brañas-Garza (2014). We then grouped subjects by gender and ranked them according to their DR. Within each sample, we categorized subjects into 3 terciles according to their DR: H, Medium and L. Approximately a semester after collecting their DR, we invited only the subjects with H and L DR back to the laboratory for our rent-seeking contest experiment. The invitation for this experiment was sent through the LSE subject recruitment system and followed the standard invitation format. Specifically, the email did not mention (i) any detail of the experiment, (ii) that participation in the contest experiment was restricted to those with H and L DR and (iii) that only subjects who had participated in the earlier experiment were invited or (iv) that only same gender subjects were to be matched. Thus, there was no indication that any of our subjects suspected that the invitation was contingent on their earlier participation, or in any way related to the DR measure they had provided. Our final sample consists of 70 male and 74 female subjects (see Table 1 for details).

In what follows we will refer as L (H) to L (H) DR type subjects. For each session, which were always of same-gender, we recruited equal numbers of H and L types. Using the ID code assigned by the subject recruitment system, we could identify a subject's type upon arrival at the laboratory. After taking note of the numbers of H and L types present, we randomly allocated subjects to a computer cubicle in the laboratory. By asking subjects to provide their ID code in a computerized questionnaire at the start of the experimental session, we identified which computer cubicles had a H type and which cubicles had a L type. This information was crucial for the next step: matching L and H types in the 2-player contest according to our experimental design.

In our experimental design, subjects played fifteen periods of the same contest game with anonymous fixed (partners) matching. To ensure sufficient anonymity in the laboratory, sessions with lower sign-up rates of H and L types were supplemented with 'filler' subjects that did not attend the first stage sessions (and for which we do not have a DR measure).

Each subject participated in only one session and had not participated in a contest experiment before. Instructions were read aloud by an experimenter. Subjects were paid the combined earnings of five randomly chosen periods (with an exchange rate of 2 tokens for £0.01). All subjects in a session were paid for the same five periods. Before the payments were made, subject demographic information was collected through an anonymous survey. Each session took about 1 hour and average earnings per subject were £14.96. [6]

5. Results

To economize on notations, in the continuation the variables referring to the case of a H type playing against another H type are denoted as HH and those referring to of a L type against a L type are denoted as LL. Similarly, for mixed pairs the variables referring to a H type when playing against a L type are denoted as HL and those referring to a L type against a H type are denoted as LH.

Furthermore, we use Ø to refer to the aggregation of L and H types. Specifically, the case of L (H) type players when playing against either type (that is, independent of the opponent's type) is denoted by $LØ$ ($HØ$), whereas the aggregation of both types (that is, independent of the decision-maker's type) when playing against L (H) type players is denoted by $ØL$ (ØH).

5.1. Aggregate behavior

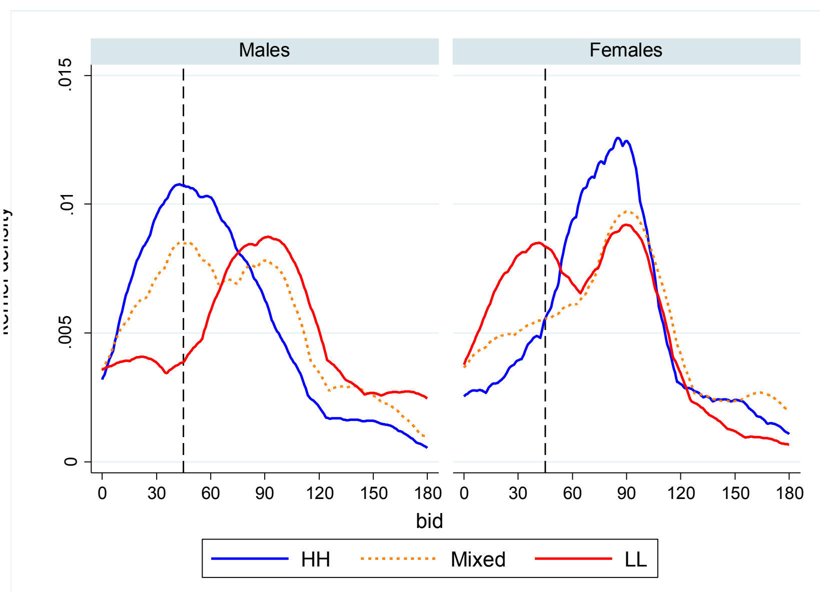
We start by reporting the aggregated bid expended by the subjects, separated by matching category (treatment) and by gender. The top panel of Figure 2 shows the Kernel density function for the aggregate data over the 15 periods: LL (in solid red), HH (in solid blue), Mixed (aggregating HL and LH: in dotted orange) for males and females separately. The lower panel shows the same for only the first period – in which there were no history or experience of interaction.

[6] We also ran an additional 15-period Tullock contest, for which we re-matched the subjects. The data from this additional contest is out of scope for the current study and, crucially, subjects did not know about the second contest until after the first contest had completed. Hence, for the purpose of this paper we will consider only the first part of the experiment (15 periods before the rematch) and no filler subjects.

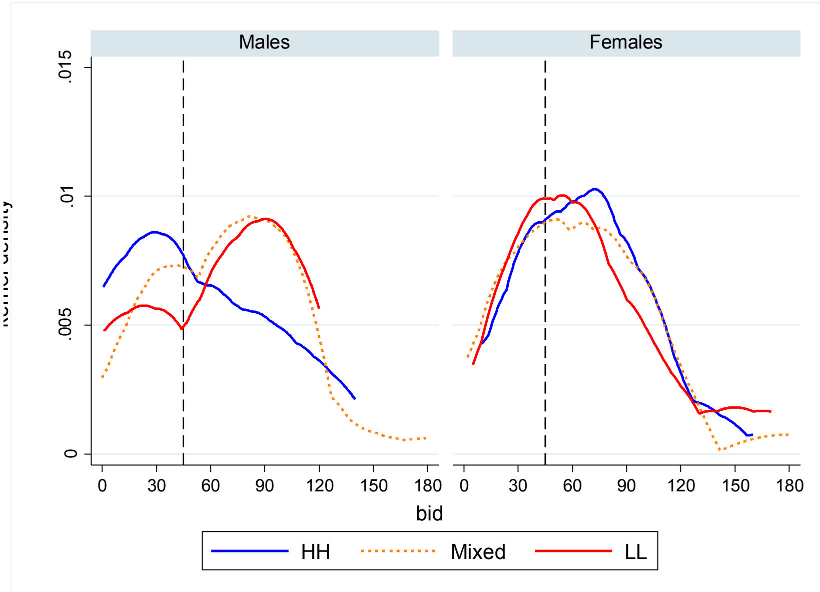
As can be seen in the top panel of the figure (all periods), among males there is a peak at around 45 for HH pairs, which coincides with the risk-neutral Nash equilibrium bid. The peak, however, is at around 90 for LL pairs. Thus, whereas HH pairs create relatively less overbidding (compared to the Nash prediction), LL pairs generate a larger amount of overbidding. Mixed pairs bids are somehow in the middle with dual mode near 45 and near 90. Among females, different patterns arise. HH shows notably high overbidding, similarly to Mixed pairs (both with peaks at around 90), while LL results in a bimodal distribution with peaks at around both 45 and 90. Average bids (Table 2) support all these observations.[7]

Note that an average high or low bid over the 15 periods may arise both due to one's own competitive disposition as well as a reaction to the opponent's bidding behavior. To tease out the response part, we also plot the bids distribution considering only the very first period in Figure 2 and provide with the same descriptive statistics in Table 2. The bottom panel of Figure 2, showing only the first period, replicates the result individually for males; i.e., LL pairs bid more than HH pairs. But the bid distribution is not much different for the different pair types among females.

Figure 2. Distribution of bids across conditions: Males and females



[7] Interestingly, the average bids of females are above those of males for HH and Mixed pairs but not for LL pairs. In the literature on contests, it is a common finding that females overbid more than males (Sheremeta, 2013). However, note that our design is not appropriate to analyze aggregate gender differences because one-third of the population (the central tercile of DR) is missing. However, our results indicate asymmetric gender effect of FT on bidding.



Note: The top plot refers to all 15 periods collapsed, whereas the bottom plot refers to only the first period. In both plots, the left panel displays the kernel density of bidding for males across the three treatments (HH, Mixed, LL), whereas the right panel displays the same for females. The dashed vertical line shows the Nash Equilibrium bid, 45.

The descriptive statistics in Table 2 are broadly in line with the observations from Figure 2. Furthermore, the table shows that L DR males bid more than H DR males (i.e, *LØ* vs. *HØ*) in the first period and overall. The difference between the mean bids of L and H DR males is in fact nearly identical when considering either the 15 periods or only the first one (i.e., about 13 tokens difference). That difference seems to be milder for females. As expected, for both males and females, there is no apparent difference in the first period bids when playing against the L and H DR individuals (i.e., *ØL* vs. *ØH*). But overall, L DR males seem to face larger bids than H DR males, whereas the result is the opposite, and the difference is stronger, for females.

The observations above indicate that even without interaction there seems to be an effect of FT on conflict behavior, in particular among males. For females, however, the effect of FT appears to be indirect and arising as the interaction develops: different DR types face different overall bids from their opponents. To understand this better, we further look at the dynamic behavior and conduct regression analyses to assess statistical significance.

As discussed earlier, the aggregate behavior is a mix of (among others) the direct effect of FT on conflict behavior and an indirect effect coming through the reaction to the rival's behavior. We investigate this in three steps. First we analyze bidding behavior, then we look at the absolute outcomes of the contest, finally we investigate the relative outcomes for the mixed pairs.

Table 2. Average (standard error) of bids

	Males		Females	
Case	**All periods**	**First period**	**All periods**	**First period**
LL	83.63 (9.04)	62.94 (9.76)	66.26 (8.37)	67.27 (8.98)
HH	61.26 (7.86)	52.35 (9.38)	79.35 (6.67)	66.68 (6.62)
Mixed	71.10 (5.77)	68.53 (6.75)	79.02 (6.90)	64.30 (7.89)
LH	73.40 (6.31)	75.88 (7.85)	88.16 (7.56)	69.69 (7.22)
HL	68.80 (6.91)	61.18 (10.82)	69.88 (7.32)	58.92 (14.01)
LØ	78.51 (5.37)	69.61 (6.28)	77.21 (6.21)	68.13 (6.31)
HØ	65.03 (5.22)	56.41 (7.09)	74.62 (5.09)	64.35 (6.23)
ØL	76.21 (5.67)	62.03 (7.25)	68.07 (5.81)	64.32 (7.60)
ØH	67.33 (5.15)	63.16 (6.48)	83.76 (5.11)	67.58 (5.09)

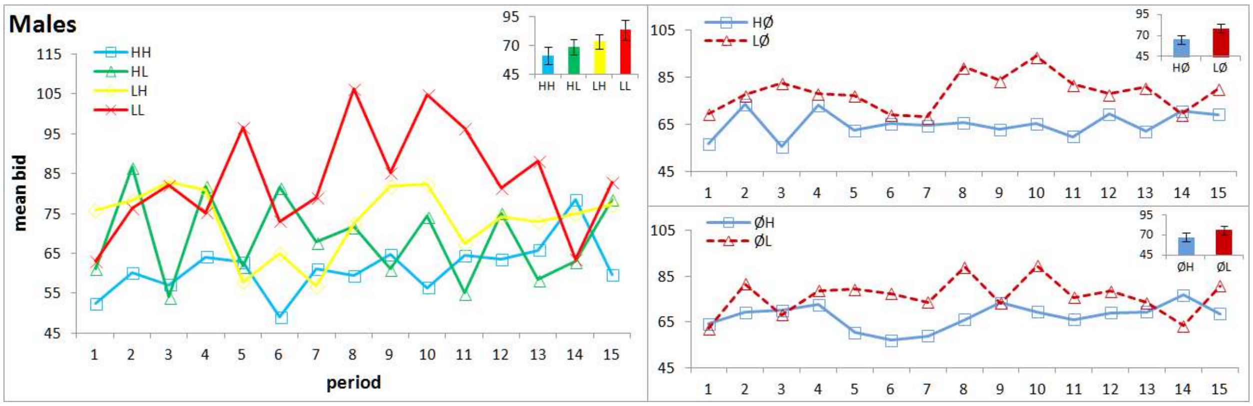
Notes: Robust SE clustered at the pair level are in parentheses.

5.2. Bidding behavior

Figures 3 and 4 show the dynamics of bidding behavior for males and females. First we discuss the behavior of different types (irrespective of the rival) and behavior against different types (irrespective of the decision maker's type), and then we move to the specific treatment pair-types.

The top right panel refers to the comparison between L and H decision makers ($LØ$ vs. $HØ$), regardless of the opponent's type. The bottom right panel refers to the comparison between L and H opponents ($ØL$ vs. $ØH$), regardless of the decision maker's type – i.e., how overall subjects behave against type L or type H, irrespective of their own type. The left panel displays the mean bids in each of the four possible conditions (HH, HL, LH, LL). The small-embedded figures display the corresponding mean bid collapsed across periods (analogous to Figure 2 and Table 2 above). In all cases, the horizontal axis cuts the vertical axis on the risk-neutral Nash equilibrium (i.e., bid=45).

Figure 3. Dynamics of mean bids (males)



Note: Top right panel compares bidding of L (LØ) vs. H (HØ) decision makers. Bottom right panel compares bidding when the decision maker's opponent is L (ØL) vs. H (ØH). Left panel displays bidding across the four conditions (HH, HL, LH, LL). Small-embedded figures show mean bids collapsed across periods (error bars display SEM clustered at the pair level).

On average, overbidding is observed for every treatment. However, this is a robust phenomenon in contest experiments (Ducheneaux et al., 2015; Sheremeta, 2013); and in the following we focus on the effects of DR type and treatment pair for each gender.

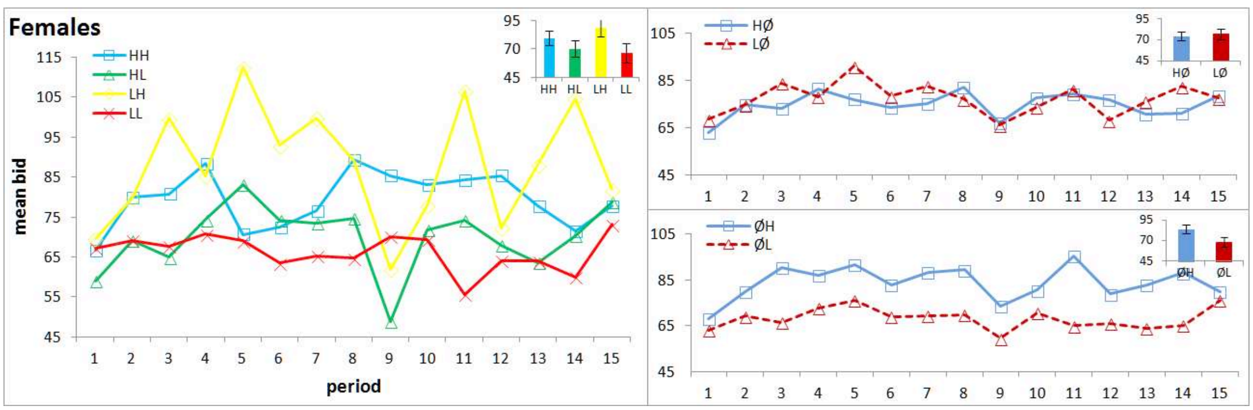
Focusing on the right panels of Figure 3, note (in line with earlier observation) that among males, L types bid more than the H types. This is true overall as well as for the very first period. This lends support for Hypothesis 1 that FT exposure makes males more aggressive in a conflict.[8] Note also that the bids against type L and H are similar to each other in the first period, although L rivals seem to trigger slightly higher bids than H rivals when considering all periods. Hence, combining we observe considerable support for Hypothesis 2 as well for males.

The left panel in Figure 3 provides with further intuitions. LL pairs bid more than their HH counterparts – both overall as well as in the very first period, supporting Hypothesis 1. But the consistent higher bids level for LL (compared to HH) also shows consistent responsive behavior against high or low bid levels. The bids of the mixed pairs are in between.

[8] We provide statistical tests with GLS regressions and a formal result below.

For females, the results are more complex. Observe in the right panels of Figure 4 that the bids by L types are not very different from those of H types – both in the first period as well as overall. However, bids against the H type are higher than bids against the L types overall, in clear contradiction with Hypothesis 2. Understandably, the bids against different types are not different in the first period since the opponent's behavior can only affect one's own behavior as the experiment develops. Furthermore, whereas L females show higher bids than H females in mixed pairs (i.e., LH vs. HL), the HH pairs bid more than the LL pairs – indicating strong responsive behaviors.

Figure 4. Dynamics of mean bids (females)



Notes: Top right panel compares bidding of L (LØ) vs. H (HØ) decision makers. Bottom right panel compares bidding when the decision maker's opponent is L (ØL) vs. H (ØH). Left panel displays bidding across the four conditions (HH, HL, LH, LL). Small-embedded figures show mean bids collapsed across periods (error bars display SEM clustered at the pair level).

Tables 3 and 4, respectively for males and females, investigate bidding behavior using a random-effects GLS regression with robust standard errors clustered on pairs. Results are consistent with figures above. Indeed, in the case of males, L types bid significantly more than H types ($M_{LØ}$=78.51, $M_{HØ}$=65.03, *p=0.04* in column 1, i.e., controlling only for time trend)[9]. Males also bid more when paired with a L compared to a H opponent, but not significantly so ($M_{ØL}$=76.21, $M_{ØH}$=67.33, *p=0.18*). Thus, we find considerable support for both Hypothesis 1 and 2 among males. For females, there is no significant difference in bidding between L and H decision makers ($F_{LØ}$=77.21, $F_{HØ}$=74.62, *p=0.62*) although, in line with Hypothesis 1, L types bid slightly

[9] This difference does not reach significance when considering only the first period although the coefficient is identical (coeff=13.4, *p=0.17*; OLS), probably due to a lack of statistical power.

more. Yet, females bid significantly less against L than against H opponents ($F_{ØL}$=68.07, $F_{ØH}$=83.76, $p<0.01$), in sharp contrast to Hypothesis 2.

Table 3. Individual bids as a function of DR types (males)

Dep var: *bid*$_t$	1	2	3	4	5	6
LØ (vs. HØ)	13.408**	12.137	7.116*	6.118	9.270**	4.007
	(6.464)	(9.805)	(3.791)	(4.909)	(4.171)	(4.794)
ØL (vs. ØH)	8.814	7.543	3.000	2.003	2.263	-3.170
	(6.497)	(10.192)	(3.742)	(5.087)	(4.447)	(5.373)
LØ x *ØL*		2.688		2.120		11.127
		(16.250)		(7.755)		(8.191)
bid$_{t-1}$			0.392***	0.392***	0.364***	0.359***
			(0.055)	(0.055)	(0.061)	(0.060)
partner bid$_{t-1}$			0.186***	0.186***	0.163***	0.161***
			(0.035)	(0.035)	(0.040)	(0.043)
win prize$_{t-1}$			-6.205**	-6.193**	-7.831***	-7.852***
			(2.502)	(2.506)	(2.884)	(2.874)
age					-0.212	-0.137
					(0.511)	(0.500)
intuitive					9.491**	8.718**
					(4.762)	(4.384)
risky					-1.784	-3.061
					(3.947)	(4.099)
BMI					-0.518	-0.689
					(0.514)	(0.486)
period	0.326	0.326	-0.064	-0.063	-0.121	-0.119
	(0.443)	(0.443)	(0.288)	(0.288)	(0.332)	(0.334)
Constant	58.069***	58.653***	29.594***	30.073***	48.039**	54.100***
	(6.800)	(8.012)	(5.102)	(5.846)	(19.006)	(17.794)
chi^2	5.411	5.501	159.677***	216.927***	247.894***	258.038***
N	1050	1050	980	980	812	812

Notes: Random-effects GLS estimates: *LØ* = 1 if the decision maker is L, = 0 if H, regardless of the opponent's DR type; *ØL* = 1 if he is playing against a L, = 0 if H, regardless of his own DR type; *intuitive* = 1 if above median # of intuitive responses in the CRT; *risky* = 1 if above median in preferences for risk; *BMI* = body mass index. Robust standard errors clustered on pairs are presented in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

The interaction between the decision maker's type and the opponent's type (*LØ x ØL*) is insignificant for both males ($p=0.87$, column 2) and females ($p=0.47$). This means that, for either sex, the effect of the decision maker's type on bids is similar when playing against L and H opponents, whereas the effect of the opponent's type is similar among L and H decision makers.

In our next model specification, we control for the bids of both players in the previous period and for whether the decision maker won the prize in the previous period (the first period is not considered; see columns 3 and 4 of Tables 3 and 4), as is standard in the literature on repeated contest games (Ducheneaux et al., 2015). The results for males are not qualitatively affected (the p-value of the effect of the decision maker's type increases slightly, from *p=0.04* to *p=0.06*). However, among females, the effect of the decision maker's type, which was non-significant in the first specification, now becomes significant: when we control for the previous period behaviors and outcome, L females bid more than H females (*p=0.06*, column 3, Table 3), indicating different responses to identical situations. The remaining results regarding main or interaction effects are not affected by the inclusion of these controls.

In the last specification (columns 5 and 6), we also control for the decision maker's age, intuitive (vs. reflective) cognitive style (Bosch-Domènech et al., 2014; Sheremeta, 2016), risk preferences (Brañas-Garza et al., 2018; Chowdhury et al., 2014) and body mass index (Fink et al. 2003). The results remain nearly identical to those obtained from columns 3 and 4 (among males, the p-value of the decision maker's DR type falls again below 5%; *p=0.03*), although we lose a non-negligible number of observations due to missing values, especially among males (12 males and 1 female are excluded from the analyses).[10]

In sum, for both sexes, L-type subjects appear to bid more aggressively than H-type subjects as predicted by Hypothesis 1, but the effect is not significant across all model specifications for females. In addition, females bid significantly less when paired with a L than when paired with a H, in sharp contrast to Hypothesis 2, while the opposite is observed for males, in line with Hypothesis 2, although not significantly so.

These results explain why, as shown in the left panel of Figures 3 and 4, the highest (lowest) bid levels are observed in conditions LL and LH (HH and HL) among males while, among females, highest (lowest) bid levels are observed in conditions LH and HH (LL and HL).

[10] Note that, for males, running regression 1 with the sample of regression 5 (people without missing values in controls) yields coeff=14.901, *p=0.04* for *LØ* (vs. *HØ*) and coeff=7.436, *p=0.30* for *ØL* (vs. *ØH*), whereas regression 3 using the sample of regression 5 yields coeff=7.780, *p=0.09* for *LØ* (vs. *HØ*) and coeff= 2.592, *p=0.56* for *ØL* (vs. *ØH*). For females, regression 1 using the sample of regression 5 yields coeff= 3.955, *p=0.47* for *LØ* (vs. *HØ*) and coeff= -16.646, *p<0.01* for *ØL* (vs. *ØH*), whereas regression 3 using the sample of regression 5 yields coeff= 5.982, *p=0.03* for *LØ* (vs. *HØ*) and coeff= -11.044, *p<0.01* for *ØL* (vs. *ØH*). Thus, the different samples result in similar estimates.

Table 4. Individual bids as a function of DR types (females)

	1	2	3	4	5	6
Dep var: *bid*$_t$						
LØ (vs. HØ)	2.840	8.816	5.410*	8.098*	5.862*	7.729*
	(5.644)	(9.825)	(2.846)	(4.482)	(2.993)	(4.521)
ØL (vs. ØH)	-15.440***	-9.464	-10.428***	-7.740*	-11.104***	-9.352*
	(5.632)	(9.653)	(2.914)	(4.323)	(3.094)	(4.785)
LØ X ØL		-12.441		-5.642		-3.652
		(17.257)		(7.252)		(7.584)
bid$_{t-1}$			0.417***	0.415***	0.414***	0.413***
			(0.052)	(0.053)	(0.053)	(0.053)
partner bid$_{t-1}$			0.228***	0.226***	0.222***	0.220***
			(0.044)	(0.044)	(0.045)	(0.044)
win prize$_{t-1}$			-3.975*	-3.982*	-4.432**	-4.415**
			(2.084)	(2.081)	(2.139)	(2.133)
age					-0.117	-0.046
					(0.391)	(0.416)
intuitive					3.705	3.603
					(3.271)	(3.283)
risky					-1.849	-2.279
					(4.035)	(4.152)
BMI					-0.493	-0.477
					(0.494)	(0.498)
period	0.063	0.063	-0.240	-0.240	-0.244	-0.244
	(0.376)	(0.376)	(0.161)	(0.161)	(0.166)	(0.166)
Constant	80.639***	78.846***	33.839***	33.300***	46.748***	44.543***
	(5.732)	(6.238)	(6.802)	(6.746)	(14.423)	(14.872)
chi^2	18.530***	18.732***	129.072***	131.164***	162.238***	171.664***
N	1110	1110	1036	1036	1022	1022

Notes: Random-effects GLS estimates. See notes on Table 3 for a description of the variables used. Robust standard errors clustered on pairs are presented in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Thus, overbidding is most commonly displayed by L in both sexes, but in different conditions: whereas for males maximal overbidding occurs in the condition in which two L compete (M_{LL}=83.63), for females it occurs when a L competes against a H (F_{LH}=88.16).Indeed, among males, the only significant difference between conditions is observed between LL and HH (M_{LL}=83.63, M_{HH}=61.26, $p=0.05$, all remaining comparisons yield p>0.17; Wald tests on the interaction coefficients in column 2, Table 3; similar results are obtained from columns 4 and 6). In the case of females, bids are higher in condition LH compared to LL (F_{LH}=88.16, F_{LL}=66.26, *p=0.045*; Wald test on the interaction coefficients in column 2, Table 4) and HL (F_{HL}=69.88, *p<0.01*); all remaining comparisons yield p>0.20.

When the bids and outcomes from the previous period are accounted for, the results again change slightly among females (we report p-values obtained from column 4; those from column 6 are very similar). Whereas LH is still associated with higher bids than LL and HL (both *p<0.01*), now LH also shows higher bids than HH (F_{HH}=79.35) and the latter higher bids than HL, although in both cases the comparison is only marginally significant (both *p=0.07*; the remaining comparisons yield *p>0.21*).

Thus, regarding bidding behavior, we have shown that,

For males: LL > HH and LØ > HØ. Hence L-types are more aggressive *irrespectively of the composition* of the pair (regarding FT).

For females: LH > HL, LH > LL (and weakly LØ > HØ). Hence L-types behave more aggressively in front of H-types (mixed pairs) but not when they are matched together. Besides ØH > ØL, which means that any bidder (L or H) behave less aggressively in front of L-types.

As a main result we conclude,

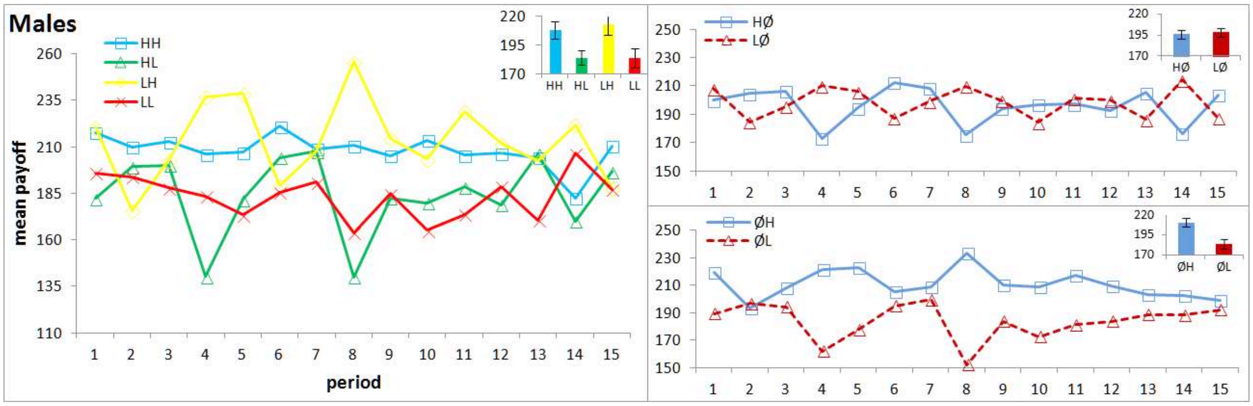
Result 1 (bidding): Males act primarily according to their own type (L is more aggressive than H) and respond weakly to their opponent type while, in sharp contrast, females (re)act according their opponent type (H face more aggressive behavior than L) and weakly according to their own type.

5.3. Payoff outcomes

In this subsection we investigate how these differences in bidding behavior translate into outcomes. This is important because whereas the audience may be more interested in the effort provision in a competition, a designer might also take into account the payoff outcomes. Figures 5 and 6 show the dynamics of the decision makers' (realized) payoffs, respectively for males and females, using the same format of Figures 3 and 4.

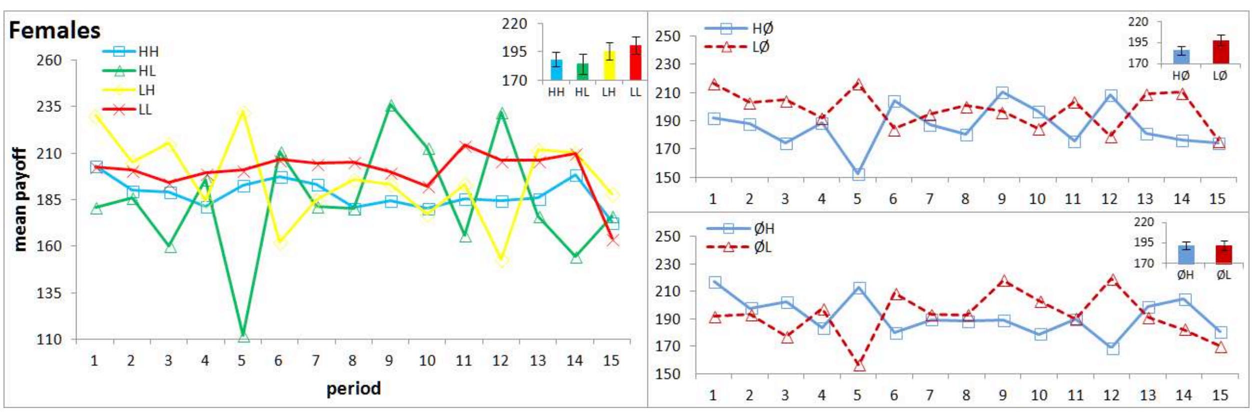
Contrary to the bidding results in the previous subsection, the opponent's type is the main driver of males' earnings (bottom right panel), whereas the decision maker's type is the main driver of females' earnings (top right panel). The regressions presented in column 1 of Tables 5 and 6 indeed corroborate these observations (i.e., only controlling for period; note that controlling for the decision maker's characteristics beyond type makes no sense here given that payoffs depend on both players' behavior).

Figure 5. Dynamics of mean payoffs (males)



Note: Top right panel compares payoffs of L (LØ) vs. H (HØ) decision makers. Bottom right panel compares payoffs when the decision maker's opponent is L (ØL) vs. H (ØH). Left panel displays payoffs across the four conditions (HH, HL, LH, LL). Small embedded figures show mean payoffs collapsed across periods (error bars display SEM clustered at the pair level).

Figure 6. Dynamics of mean payoffs (females)



Notes: Top right panel compares payoffs of L (LØ) vs. H (HØ) decision makers. Bottom right panel compares payoffs when the decision maker's opponent is L (ØL) vs. H (ØH). Left panel displays payoffs across the four conditions (HH, HL, LH, LL). Small embedded figures show mean payoffs collapsed across periods (error bars display SEM clustered at the pair level).

The payoffs of L and H males do not differ ($M_{LØ}$=198.73, $M_{HØ}$=197.00, $p=0.76$) but males earn significantly less when matched with L compared to H opponents ($M_{ØL}$=183.65, $M_{ØH}$=210.46, $p<0.01$). L females, on the other hand, earn (marginally) significantly more than H females ($F_{LØ}$=198.83, $F_{HØ}$=186.89, $p=0.09$) but the opponent's type does not affect females' payoffs ($F_{ØL}$=194.70, $F_{ØH}$=190.41, $p=0.98$).

Moreover, the interaction between the decision maker's type and the opponent's type (LØ x ØL) is non-significant for both males (*p=0.73*, column 2) and females (*p=0.60*). This means that, for either sex, the effect of the decision maker's type on earnings is similar when playing against L and H opponents, whereas the effect of the opponent's type is similar for L and H decision makers.

In sum the results show how DR relate differently to payoffs across genders, *males earn less against L opponents compared to against H opponents, whereas L females earn more than H females*.

Table 5. Realized outcomes as a function of DR types (males)

	1	2	3	4
Dep var:	$payoff_t$	$payoff_t$	$win\ prize_t$	$relative\ payoff_t$
LØ (vs. HØ)	2.411	5.051	0.188***	58.576***
	(7.772)	(11.737)	(0.073)	(21.017)
ØL (vs. ØH)	-26.876***	-24.237**		
	(7.630)	(9.870)		
LØ X ØL		-5.582		
		(16.158)		
period	-0.363	-0.363	-0.001	0.000
	(0.436)	(0.436)	(0.001)	(0.000)
Constant	212.254***	211.041***	0.409***	-29.288***
	(6.786)	(8.003)	(0.038)	(10.508)
chi^2	16.111***	16.082***	13.762***	10.675***
N	1050	1050	510	510

Notes: Random-effects GLS estimates. Dependent variables are displayed on top of the columns. In columns 3 and 4, the sample is reduced to conditions HL and LH; thus *LØ* here refers to the comparison LH vs. HL. Robust standard errors clustered on pairs are presented in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

As can be seen from the left panel of Figures 5 and 6, the above effects result in males' payoffs being highest (lowest) in conditions LH and HH (LL and HL) while females' highest (lowest) payoffs are observed in conditions LL and LH (HL and HH). Thus, among males, the highly competitive environment of condition LL is associated with the lowest absolute payoffs (M_{LL}=183.37), very similar to that obtained by H-types when paired with L-types (M_{HL}=183.90, *p=0.96*; Wald test on the interaction coefficients in column 2 of Table 5). In order to get high payoffs, both L and H males must be paired with H-types (M_{LH}=213.19, M_{HH}=208.14, which do not differ, *p=0.67*, and both yield higher earnings than in LL and HL, all *p<0.04*). On the other hand, given that there is no escalation of conflict between L females in condition LL, the payoffs in this condition are the highest (F_{LL}=200.47) and similar to those obtained by L females when paired with H-types (F_{LH}=195.84). H females get low payoffs, irrespective of whether they are paired with L-types (F_{HL}=184.12) or H-types (F_{HH}=188.08). However, none of the pairwise comparisons between conditions reach significance for females (all $p>0.16$; Wald tests on the interaction coefficients in column 2 of Table 6).

Table 6. Realized outcomes as a function of DR types (females)

	1	2	3	4
Dep var:	$payoff_t$	$payoff_t$	$win\ prize_t$	$relative\ payoff_t$
LØ (vs. HØ)	11.884*	7.755	0.167***	23.439
	(7.023)	(9.876)	(0.056)	(21.279)
ØL (vs. ØH)	0.165	-3.964		
	(7.099)	(11.187)		
LØ X ØL		8.597		
		(16.473)		
period	-0.593	-0.593	-0.002	-0.000
	(0.410)	(0.411)	(0.001)	(0.000)
Constant	191.583***	192.822***	0.424***	-11.719
	(5.400)	(5.953)	(0.027)	(10.639)
chi^2	4.107	4.180	9.177**	2.098
N	1110	1110	360	360

Notes: Random-effects GLS estimates. Dependent variables are displayed on top of the columns. In columns 3 and 4, the sample is reduced to conditions HL and LH; thus *LØ* here refers to the comparison LH vs. HL. Robust standard errors clustered on pairs are presented in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Thus, regarding payoffs, we have shown,

For males: HH > HL, HH > LL, LH > HL, LH > LL and ØH > ØL. Earnings are lower when subjects are matched with L-Types.

For females: LØ > HØ. L-types earn more money.

As a main result we conclude,

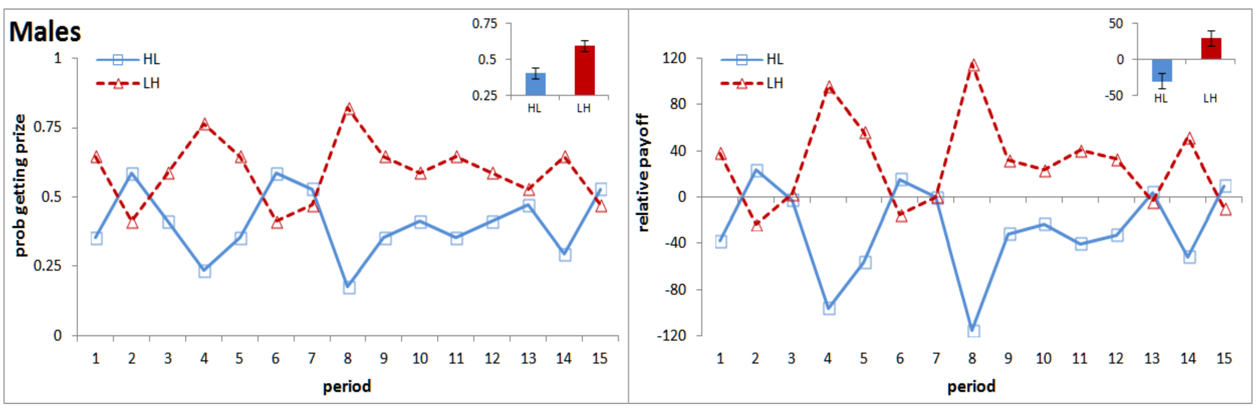
Result 2 (payoffs): L-type males make the contest more aggressive and consequently they do not earn high payoffs. Furthermore, they also make their counterparts to earn less. L-type females bid marginally more as well as earn marginally more than their H-type counterparts but cause no impact on opponents' earnings.

5.4. Mixed pairs: Winning versus earning

Competition seems to be a fundamental force for L-type males, especially when paired with another L-type. However, L-type females display high competitiveness mostly against H opponents (who do not respond very competitively). Since L and H-types are matched together in mixed pairs (HL and LH), it is interesting to analyze these conditions in greater detail. Specifically, we aim to investigate whether L-types (while matched with H-types) are more likely to win the prize and earn more than the rival; arguably, two main drivers of competition behavior (Sheremeta, 2013). Figures 7 and 8 display the dynamics of these two variables for H-types and L-types while matched with each other, for males and females, respectively.

The left panels of Figure 7 and 8 refer to the realized (ex-post) probability of getting the prize; which, combined with the previously analyzed bid levels, determines the subjects' (realized) relative payoffs, depicted in the right panels. These diagrams show that overall both the ex-post probability of winning and the relative payoff is higher for the L-type than the H-type (for both male and female) when they are matched to each other.

Figure 7. Relative comparisons: Winning and payoffs differences. HL/LH (males)

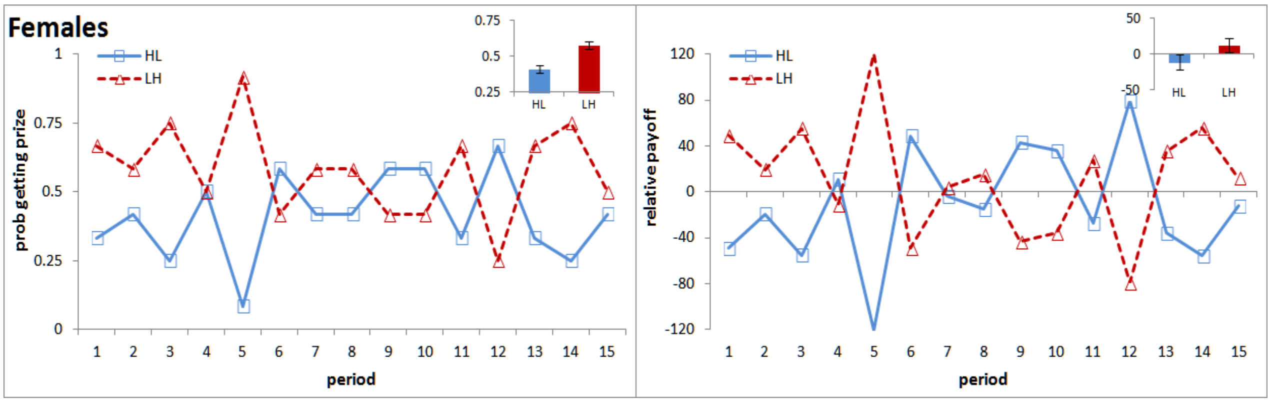


Notes: Left panel refers to the decision maker's (realized) probability of getting the prize. Right panel refers to the decision maker's relative payoff. Small-embedded figures show means collapsed across periods (error bars display SEM clustered at the pair level).

The regression analyses are shown in columns 3 and 4 of Tables 5 and 6 for males and females, respectively. For both sexes, L-types are more likely to get the prize than H-types (nearly 60% and 40% on average, respectively, $p<0.01$ for both males and females; column 3 in Tables 5 and 6). Also, L males earn relatively more than their H counterparts, in particular, they obtain about

29 tokens more ($p<0.01$, column 4). The effect is also positive for L females (12 tokens) but not significant ($p=0.27$).

Figure 8. Relative comparisons: Winning and payoffs differences. HL/LH (females)



Notes: Left panel refers to the decision maker's (realized) probability of getting the prize. Right panel refers to the decision maker's relative payoff. Small-embedded figures show means collapsed across periods (error bars display SEM clustered at the pair level).

The following result summarize this section:

Result 3 (mixed pairs): L-type males win more often and earn more than their H counterparts. L-type females win more often but not necessarily earn more.

6. DR and preference mechanisms

From the above results, it is still not clear through which mechanism the observed behavioral differences turn out. In the experimental contest literature several behavioral and preference-related aspects are indicated to be responsible for players' high bids. It is possible that the effect of FT exposure works through such channels. Sheremeta (2013) mentions several such mechanisms including the joy of winning, social preference, error, risk preference etc. It is unlikely that the difference in bidding by DR is due to error in our experiment. Also, we control for risk preferences. So, two main aspects through which DR may affect bidding are the joy of winning and social preference, which are closely related to the likelihood of getting the prize and to the relative payoffs analyzed, respectively. In this section we investigate both.

6.1. Joy of winning

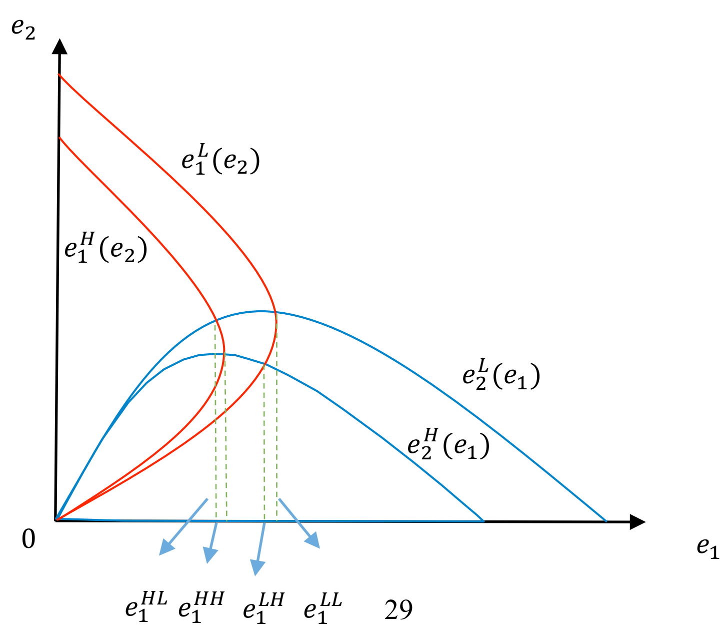
It is noted in the literature that non-monetary value of win may explain overbidding in contest experiments (Sheremeta, 2010). It might be that L DR players value the win more than their H

DR counterparts and this leads them to exert higher conflict effort. In such a case let us denote the psychological prize value for a L DR player as V_L and that for a H DR player as V_H with $V_L > V_H$. Also, denote the effort by a L DR against a L DR as e_{LL}, effort by a L DR against a H DR as e_{LH}, effort by a H DR against a H DR as e_{HH}, and effort by a H DR against a L DR as e_{HL}. It can then be shown easily, following standard procedures, that the Nash equilibrium efforts are $e_{LH} = \frac{V_L^2 V_H}{(V_L+V_H)^2}$ and $e_{HL} = \frac{V_H^2 V_L}{(V_L+V_H)^2}$. Furthermore, $e_{LL} = \frac{V_L}{4}$ and $e_{HH} = \frac{V_H}{4}$. Hence, given $V_L > V_H$ we get: $e_{LL} > e_{LH} > e_{HH} > e_{HL}$.

A graphical representation of this is given in Figure 9. The red lines are the best response of player 1 whereas the blue lines are the best response of player 2. The best responses inside correspond to the case when the player is H DR, and the ones outside correspond to the case when the player is L DR. The resulting rankings are obvious and are indeed similar to what we observe for males.

In our empirical strategy, we estimate "joy of winning" for the different types following the methodology of Herrmann and Orzen (2008). In contrast to Herrmann and Orzen (2008), our participants did not respond to specific bids of their opponents (strategy method), thus we base our estimates on the concept of myopic best response (Fallucchi et al. 2013, Lim et al. 2014). That is, we assume that individuals best respond to their opponent's bid in the previous period, which seems to be a reasonable assumption (Rockenbach and Waligora 2016).

Figure 9. Equilibria with joy of winning



In particular, to incorporate the idea that players enjoy winning the prize per se we assume that the value of the prize is perceived by the subjects to be different (i.e., higher) than its objective value of 180. The myopic best response function for any *partner* bid_{t-1} between 0 and 180 is given by

$$bid_t = \sqrt{P * partner\ bid_{t-1}} - partner\ bid_{t-1} \tag{4}$$

where P is the perceived value of the prize. We estimate the value of P using the following econometric model:

$$z_{i,t} = \theta_1 x_{i,t} + \varepsilon_i \tag{5}$$

where $z_{i,t} = \overline{bid_i} + partner\ bid_{i,t-1}$, $\theta_1 = \sqrt{P}$ and $x_{i,t} = \sqrt{partner\ bid_{i,t-1}}$.

Performing this estimation separately for both the L and H subsamples we obtain,

- for males: $\widehat{P_{LØ}} = 352.11$, $\widehat{P_{HØ}} = 295.29$
- for females: $\widehat{P_{LØ}} = 336.48$, $\widehat{P_{HØ}} = 337.40$

Comparing these values with the prize value, 180, we find that on average subjects notably overvalue the prize. Among males, L-types value the prize 95.6% more than its actual value, while H-types value it 64.05% more. Among women there is a huge overvaluation but virtually no differences between L-types (86.9%) and H-types (87.4%).[11] Although again the methodological differences do not allow us to directly compare these estimates to those of Herrmann and Orzen (2008), note that their estimations yield overvaluations of up to about 50%.

Result 4: L-type males have higher joy of winning than H-types. The joy of winning is not different for L-type and H-type females.

6.2. Social preferences

It is shown in the experimental contest literature that spitefulness carries a significant behavioral role in effort provision (Chowdhury et al., 2018). Hence, it may also be possible that the difference in conflict behavior for different DR emerges through heterogeneous social preferences – especially spite. To estimate such social preferences parameters from a generalized

[11] Note however that, as in Herrmann and Orzen (2008), this procedure does not allow us to test whether estimated differences are statistically significant because we cannot obtain dispersion measures of the values, but only central measures. The same applies to the social preference estimations in the next subsection.

version of Fehr-Schmidt (1999) as introduced below, we estimate the relevant parameters α and β.

$$U_i(e_i, e_j) = \pi_i - \alpha \max(\pi_j - \pi_i, 0) - \beta \max(\pi_i - \pi_j, 0) \quad (6)$$

Where U_i is the utility and π_i is the own payoff; whereas α reflects disadvantageous inequality aversion (envy) and β reflects advantageous inequality aversion (compassion). A high positive α combined with a high negative β indicates a high level of spite, that is, a high willingness to reduce others' payoffs (Herrmann and Orzen, 2008).

Here, theoretical predictions are not as straightforward as in the case of the joy of winning because there are two parameters to be considered and therefore many possible combinations can arise. However, let us offer equilibrium predictions for the extreme case in which L-DR individuals display maximal spite, i.e., $\alpha=\infty$ and $\beta=-\infty$, while H-DR individuals display no spite, i.e., $\alpha=0$ and $\beta=0$. In this case, L players only care about the relative payoffs, disregarding their own absolute payoff, whereas H players only care about their own absolute payoff. Following Mago et al. (2016), the symmetric Nash equilibrium for relative-payoff maximizing players, that is, for LL pairs in our experiment assuming the above, would be $e_{LL} = 90$ whereas, trivially, that for HH pairs would be $e_{HH} = 45$. In mixed pairs, equilibrium efforts should be in between these two values. Recall that peaks at bids of 90 and 45 tokens were recursively observed in overall bid distributions (top panel of Figure 2) and, in particular, these predictions seem to fit in nicely the case of males.

Following Herrman and Orzen (2008), we consider the following myopic best response function:

$$bid_t = \sqrt{\frac{1+\alpha-\beta}{1-\beta} P * partner\ bid_{t-1} - \frac{2(\alpha+\beta)}{1-\beta} partner\ bid_{t-1}^2} - partner\ bid_{t-1} \quad (7)$$

where the parameters α and β are estimated from the model: $z_{i,t} = \theta_1 x_{it} + \theta_2 x_{it}^2 + \varepsilon_i$, with $z_{i,t} = \left(\overline{bid_i} + partner\ bid_{i,t-1}\right)^2$, $\theta_1 = (1 + \alpha - \beta)P/(1 - \beta)$, $\theta_2 = -2(\alpha + \beta)/(1 - \beta)$ and $x_{it} = partner\ bid_{i,t-1}$.

Regarding envy, this estimation yields,

- for males: $\widehat{\alpha_{L\emptyset}} = 2.30$, $\widehat{\alpha_{H\emptyset}} = -0.13$

- for females: $\widehat{\alpha_{L\emptyset}}$ = 3.02, $\widehat{\alpha_{H\emptyset}}$ = 0.84

This shows that exposure to FT impacts on both males and females: L-type subjects are more envious than H-type subjects irrespective of the gender. Note that Herrmann and Orzen (2008) estimate envy values of up to 1.55 in their experiments.

We repeat the same estimation regarding compassion. This estimation yields,

- for males: $\widehat{\beta_{L\emptyset}}$ = -6.62, $\widehat{\beta_{H\emptyset}}$ = -1.91
- for females: $\widehat{\beta_{L\emptyset}}$ = -9.16, $\widehat{\beta_{H\emptyset}}$ = -4.24

Here we also observe a strong effect of FT. Both male and female L-types *enjoy* advantageous inequality (i.e., display stronger negative compassion) more than H-types, but females seem to be more spiteful than males (see also Espín et al. 2017). Note that Herrmann and Orzen (2008) estimate negative compassion values of up to -1.40 in their experiments. The strongly negative compassion of females may explain why they are more aggressive against less aggressive opponents (i.e., against H types).

There are several reasons why these results are important. First, these are new results in the literature. While joy of winning and spiteful preferences were documented earlier in the contest literature, gender differences in these behavioral mechanisms were not. Second, these results show that the exposure to FT may affect one's conflict behavior through his or her joy of winning or spitefulness. Finally, it shows that the gender difference in conflict behavior can be traced into gender differences in spitefulness.

7. Discussion

Our results contribute to the growing literature on the effect of biological factors on behavior in competitive settings. Specifically, we provide controlled evidence that dyadic competition yields very different outcomes depending on the FT 'types' of those interacting. One of the potential confounding factors that our study controls for is ability – ruling out the explanation that differences in behavior and outcomes are driven by differences in (unobservable) ability that correlate with FT exposure. We thus extend the literature on how FT relates to individuals' preferences for, and outcomes in, competitive settings such as sports, financial trading and entrepreneurship (Manning and Taylor, 2001; Bennett et al., 2010; Sapienza et al., 2009;

Nicolaou et al., 2017). Furthermore, our study is the first to perform a controlled match of different FT (DR) types.

We find that L (DR) type males expend higher effort, but do not earn more than H type males. Anybody matched with L type males earns less than when matched with H type males. In addition, all females exert more effort against H types, and consequently H type females earn less than L type females. To explain these results, we estimate two 'behavioral' models of preferences: one in which subjects can derive extra utility from winning ("joy of winning", Sheremeta, 2010) and a generalized version of Fehr-Schmidt social preferences. We find that our results can be partially explained by high joy of winning and high spitefulness (positive envy and negative compassion) for L type males, and high spitefulness for L type females.

Our main result thus shows that males act primarily according to their own type and react weakly to their opponent's type while, in sharp contrast, females (re)act primarily according their opponent's type. Although gender differences in attitudes toward competition have been documented before (e.g. Niederle and Vesterlund, 2007), our findings suggest that (i) biological factors matter for both genders and (ii) although the observed competitive behavior is to some sense intuitive (L type men being more aggressive; H type women encountering more aggression from others), men and women have a fundamentally different approach to dyadic competition.

Interestingly, our main result may be related to Croson and Gneezy's (2009) observation that females' behavior is more context dependent. It may be that the type of an opponent in competitive situations, as inferred from their actions, is treated the same as contextual factors. Our finding that females react according to their opponent's type, in turn, can explain some of the existing observations in the literature such that: females reacting more than males in identity related conflict (Chowdhury et al., 2016), or females exerting more effort against other females, but males not reacting to gender (Mago and Razzolini, 2018).

Our findings may help explain outcomes in certain professional settings, especially those dominated by a single gender and/or favored by certain biological types. Financial trading and professional sports, two male-dominated profession that disproportionately attract L DR types, would be predicted to feature aggressive competition for a win, for example. This prediction is in line with anecdotal evidence, as well as reports of cases where a "win at all costs" mentality has led some competitors to breaking rules. Because we also find that L type males compete more fiercely than (and out-earn) H type males in direct competition (i.e., in mixed pairs), this may explain why L type males are more likely to prevail in certain settings. Our results also matter from from a designer point of view. When a designer is interested in either competitive balance, or maximizing or minimizing total effort exerted in a contest, our findings suggest that biological factors such as FT and gender are important aspects to consider while matching contestants and setting the rules of the game.

One potential caveat we wish to point out is that it is currently unclear whether selection into different levels of FT is independent of other indirect influences on behavior. Is it, for example, possible that physiological characteristics of the mother affect both the effective level of testosterone exposure in utero and aspects of the child's upbringing? Whether this is merely a theoretical possibility or a factor of significance is important, as it affects the interpretation of the DR as a proxy for strictly biological factors.

The relationship between prenatal development, competition and conflict is a fruitful area for further research. Follow-up studies could look at wider consequences for society, for example by asking how FT affects group conflict and coalition formation. We have already noted the findings of Cecchi and Duchoslav (2018) on civil conflict in Uganda. More generally, it will be important to consider how biological factors affect behavior in common social settings, such as networks and organizations. For example, Kovarik et al. (2017) find that L (DR) type males are more likely to occupy central positions in social networks, which arguably puts them in a privileged position for information exchange and therefore access to resources. It will be important to understand if such benefits do indeed materialize, as well as the role that competition (e.g. leadership contests) and conflict (e.g. for resources or influence) fulfil in these contexts.

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Appendix: Experimental instructions

GENERAL INSTRUCTIONS

This is an experiment in the economics of decision making. This experiment consists of two unrelated parts. Instructions for the first part are given next and the instructions for the second part will be provided after the first part of the experiment is finished.

The instructions are simple. If you follow them closely and make appropriate decisions, you can earn an appreciable amount of money.

It is very important that you remain silent and do not look at other people's work. If you have any questions, or need assistance of any kind, please raise your hand and an experimenter will come to you. If you talk, laugh, exclaim out loud, etc., you will be asked to leave and you will not be paid. We expect and appreciate your cooperation.

Experimental Currency is used in the experiment and your decisions and earnings will be recorded in tokens. At the end of today's experiment, you will be paid in private and in cash. Tokens earned from both parts of the experiment will be converted to Pound Sterling at a rate of:

_2_ tokens = **_1_** Pence (£0.01).

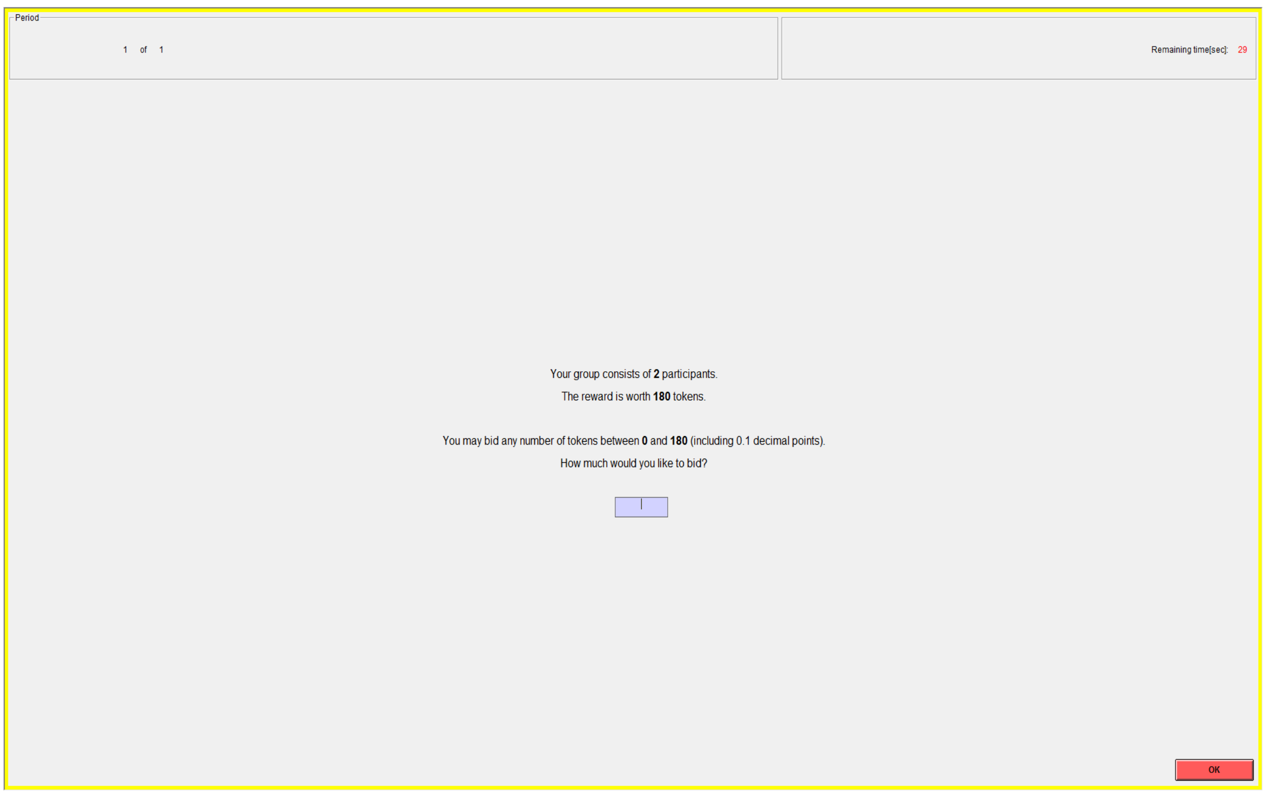
NB: Please do not write on these instruction sheets

INSTRUCTIONS – PART 1

YOUR DECISION

This part of the experiment consists of **15** decision-making periods. At the beginning, you will be randomly and anonymously placed into a group of **2 participants** – you and someone else in the room. The composition of your group will remain the same for all 15 periods. You will **not** know who the other group member is at any time.

Each period you will receive an initial endowment of **180** tokens. Each period, you may bid for a reward of **180 tokens**. You may bid any number between **0** and **180** (including 0.1 decimal points). An example of your decision screen is shown below.



YOUR EARNINGS

For each **bid** there is an associated **cost** equal to the bid itself. The cost of your bid is:

Cost of your bid = Your bid

The more you bid, the more likely you are to receive the reward. The more the other participant in your group bids, the less likely you are to receive the reward. Specifically, your chance of receiving the reward is given by your bid divided by the sum of the 2 bids in your group:

$$\text{Chance of receiving the reward} = \frac{\text{Your bid}}{\text{Sum of all 2 bids in your group}}$$

You can consider the amounts of the bids to be equivalent to numbers of lottery tickets. The computer will draw one ticket from those entered by you and the other participant, and assign the reward to one of the participants through a random draw. If you receive the reward, your earnings for the period are equal to your endowment of 180 tokens *plus* the reward of 180 tokens *minus* the cost of your bid. If you do not receive the reward, your earnings for the period are equal to your endowment of 180 tokens *minus* the cost of your bid. In other words, your earnings are:

If you receive the reward: Earnings = Endowment + Reward – Cost of your bid = 180 + 180 – your bid

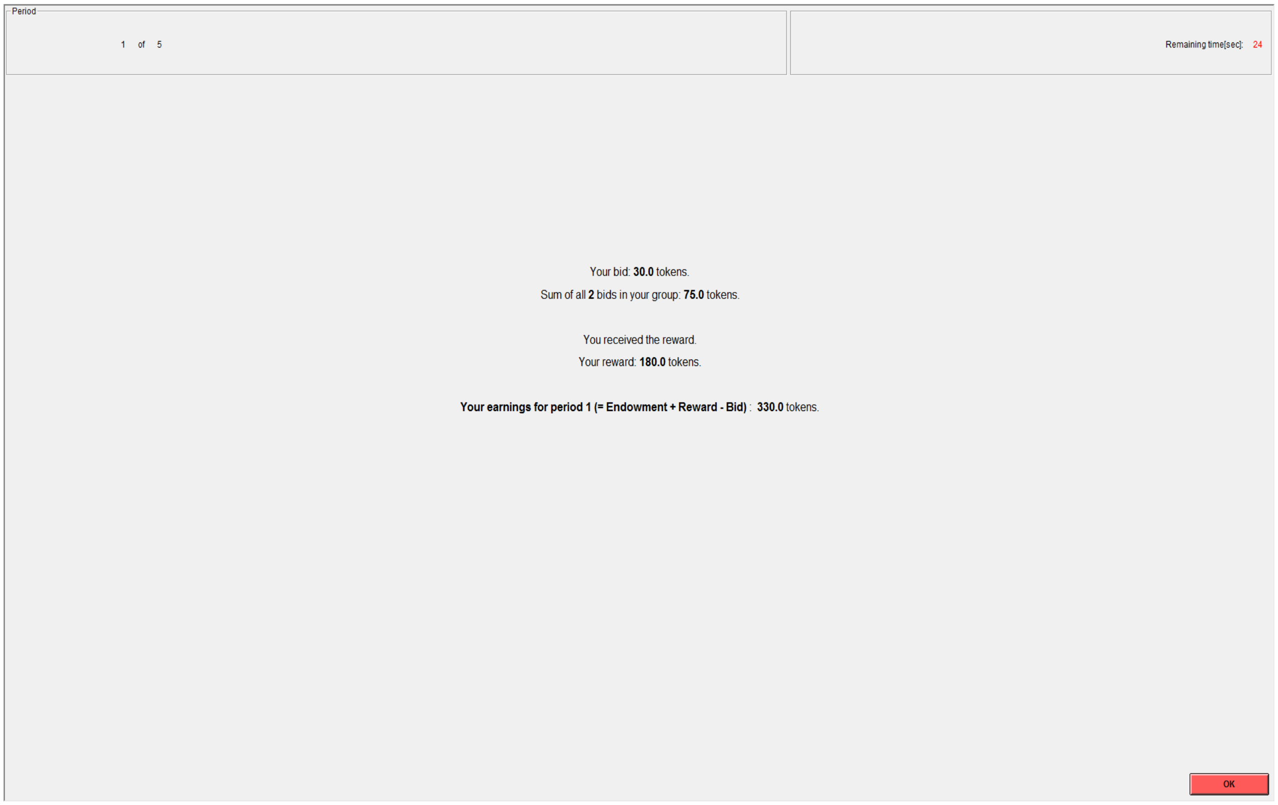
If you do not receive the reward: Earnings = Endowment - Cost of your bid = 180 – your bid

An Example (for illustrative purposes only)

Let's say participant 1 bids 30 tokens and participant 2 bids 45 tokens. Therefore, the computer assigns 30 lottery tickets to participant 1 and 45 lottery tickets to participant 2. Then the computer randomly draws **one lottery ticket out of 75** (30 + 45). As you can see, participant 2 has the **highest chance** of receiving the reward: **60% = 45/75** and participant 1 has **40% = 30/75** chance of receiving the reward.

Assume that the computer assigns the reward to participant 1, then the earnings of participant 1 for the period are 330 = 180 + 180 – 30, since the reward is 180 tokens and the cost of the bid is 30. Similarly, the earnings of participant 2 are 135 = 180 – 45.

At the end of each period, your bid, the sum of the 2 bids in your group, your reward, and your earnings for the period are reported on the outcome screen as shown below. Once the outcome screen is displayed you should record your results for the period on your **Personal Record Sheet** (provided separately) under the appropriate heading.



IMPORTANT NOTES

At the beginning of this part of the experiment you will be randomly grouped with another participant to form a 2-person group. You will not be told which of the participants in this room are assigned to which group.

At the end of the experiment the computer will randomly choose **5 of the 15** periods for actual payment for this part of experiment. You will be paid the earnings in these 5 periods. These earnings in tokens will be converted to cash at the exchange rate of _**2**_ tokens to _**1**_ Pence (£0.01) and will be paid at the end of the experiment.

Are there any questions?

QUIZ

NB: Please do not write on these sheets – try to answer the question for yourself, then check the answer on page 6.

1. Does group composition change across periods in this part of the experiment?

Ans. Yes No

2. What is the value of 1 token in Pence?

Ans. 1 Pence ½ Pence 9 Pence

Questions 3 to 6 apply to the following information.

In a given period, suppose the bids by participants in your group are as follows.

Bid of participant 1: 55 tokens

Bid of participant 2: 70 tokens

3. What is the chance that participant 1 will receive the reward?

Ans. _______ out of ________

4. What is the chance that participant 2 will receive the reward?

Ans. _______ out of ________

5. If you are Participant 1 and you **did not receive** the reward what are your earnings this period?

Ans. ___________ tokens

6. If you are Participant 2 and you **received** the reward what are your earnings this period?

Ans. ___________ tokens

EXPLANATIONS FOR QUIZ ANSWERS

1. Does group composition change across periods in this part of the experiment?

Ans. No

2. What is the value of 1 token in Pence?

Ans. ½ Pence

3. What is the chance that participant 1 will receive the reward?

Ans. 55 out of 125.

4. What is the chance that participant 2 will receive the reward?

Ans. 70 out of 125.

5. If you are Participant 1 and you **did not receive** the reward what are your earnings this period?

Ans. 125 tokens (= Endowment – bid = 180 – 55)

6. If you are Participant 2 and you **received** the reward what are your earnings this period?

Ans. 290 tokens (= Endowment + Reward – Bid = 180 + 180 – 70)