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Original Article

Winner and loser effects in human competitions. Evidence from equally matched tennis players

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ABSTRACT

Animals winning an agonistic encounter are more likely to win their next encounter while losers are less likely, even when controlling for motivation and physical size. Do these winner and loser effects exist in human competitions? Drawing on a large database of professional tennis matches, we were able to control for players' ability and thereby test for winner and loser effects. We narrowed the database to matches between players who on average did not differ significantly in rank, and further to matches in which the first set was fought to a long tie-break. These closely fought matches present a natural experiment because players are assigned to treatment conditions – winning or losing a set – despite similar ability and performance. We found that among men, the winner of a closely fought tie-break had an approximate 60% chance of winning the second set, the loser a 40% chance. These effects did not exist among women, a finding consistent with the hypothesis that androgens mediate winner and loser effects. Our results may help in the design of competitions in sport as well as in work environments, where it may prove useful to either encourage winner effects or to attenuate their occasional adverse consequences.

1. Introduction

A phenomenon known as the 'winner effect' has been documented in a large number of animal species, from insects (Whitehouse, 1997; Kasumovic, Elias, Sivalinghem, Mason, & Andrade, 2010), fish (Hsu & Wolf, 2001, Oliveira, Silva and Canario, 2009a, b, Dijkstra, Schaafsma, Hofmann, & Groothuis, 2012), reptiles (Garcia, Murphree, Wilson, & Earley, 2014) to mammals (Oyegbile & Marler, 2005; Jennings, Carlin, & Gammell, 2009) and non-human primates (Bernstein, Gordon, & Rose, 1989; Franz, McLean, Tung, Altmann, & Alberts, 2015). In behaviour displaying the winner effect, an animal that has won a fight or a competition for territory is more likely to win its next agonistic encounter (Rutte, Taborsky, & Brinkhof, 2006; Dugatkin, 2013).

Animal behaviour studies documenting the winner effect have controlled for a number of factors that could help an animal sustain a winning streak, such as its resource holding potential, in other words, the resources, like size and metabolic reserves, it can draw on in an all-out fight; its motivation, because a hungry animal will fight harder over a carcass than a sated one; and its aggression, a more aggressive animal being able to fight off a larger but less aggressive one (Smith, 1982; Neat, Huntingford, & Beveridge, 1998; Hurd, 2006; Fawcett & Johnstone, 2010). Even when controlling for these physiological advantages, pure winner and loser effects emerge, suggesting that winning and losing in themselves contribute to future performance (Rutte et al., 2006; Lehner, Rutte, & Taborsky, 2011). It is thought that these effects help establish a social hierarchy in round-robin animal competitions. Importantly, though, with winner and loser effects, this hierarchy cannot be predicted from the pre-existing physiological advantages of the animals - it emerges from the competition itself. In other words, the result of the competition is path-dependent (Dugatkin & Druen, 2004; Hock & Huber, 2009).

How does a prior victory help an animal win again? Answers to this question have been proposed by animal behaviourists on both theoretical and empirical grounds. Game theoretic models have suggested several mechanisms (Mesterton-Gibbons, Dai, & Goubault, 2016). First, the outcome of a fight can provide information to both winners and losers about their relative chances of winning future fights or about their resource holding potential (Mesterton-Gibbons, 1999; Fawcett & Johnstone, 2010; Dugatkin & Reeve, 2014). Winners revise upwards their beliefs about their strength and become more likely to engage in fights and win them. Second, it has been suggested that a winning experience can increase the animal's resource holding potential (Hsu, Earley, & Wolf, 2006; Kura, Broom, & Kandler, 2016). Third, when a series of fights decides the overall winner, the winner of a first fight has a greater incentive than the loser to invest resources in later fights simply because the former is now closer to an overall victory; while the loser can suffer a "discouragement effect" (Konrad, 2009; Konrad & Kovenock, 2009).

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These game theoretic models predict a winner effect between contests taking place across dyads. But several also predict a winner effect within a dyad. This is the case with the family of models unpacking a contest as a series of smaller fights (Konrad, 2009). This is also the case with models where a first win increases the animal's resource holding potential (Kura et al., 2016) or increases merely its perception of this potential (Dugatkin & Reeve, 2014). Whenever the animal's resource potential or its self-perception increases after an early victory within a dyad, a winner effect can be expected. This effect of winning can therefore be one of the mechanisms creating an asymmetry between otherwise equally matched contestants (Van Doorn, Hengeveld, & Weissing, 2003; Hsu et al., 2006; Dugatkin & Reeve, 2014).

Empirical research has led to the suggestion that winning leaves physical traces, such as odour, which broadcast an animal's recent victory and these can deter a new opponent from escalating an encounter (Rutte et al., 2006). Still other research, investigating the physiological mechanisms of winner effects (Chase, Bartolomeo, & Dugatkin, 1994; Chang, Li, Earley, & Hsu, 2012; Earley, Lu, Lee, Wong, & Hsu, 2013), have focused on the role of androgens in mediating the winner effect. Several research groups have found that competition raises testosterone levels (Wingfield, Hegner, Dufty, & Ball, 1990) and that victory raises them still further (Hsu & Wolf, 2001, Trainor, Bird, & Marler, 2004, Oyegbile & Marler, 2005, Oliveira, Silva and Canario, 2009a, b, Fuxjager, Oyegbile, & Marler, 2011). Victory may also up-regulate the androgen receptor, leaving an animal more sensitive to a given level of circulating testosterone (Fuxjager et al., 2010). Rising levels of testosterone can increase, with varying time lags, the animal's lean muscle mass, its haemoglobin and hence its blood's capacity to carry oxygen, as well as its confidence (Boissy & Bouissou, 1994) and persistence (Andrew & Rogers, 1972; Archer, 1977). The winner effect may thus be mediated by a physiological feedback loop in which winning leads to higher levels of, or increased sensitivity to, testosterone, which in turn raises the likelihood of further victories.

There have been relatively few studies of the winner effect in human competitions. Some studies have used avatars in video games to rig a winning situation and observe its real effects afterwards on the players (Yee, Bailenson, & Ducheneaut, 2009). Other studies have tested for the existence of a related phenomenon known as the ‘hot hand’. Athletes are said to have a hot hand when they or their supporters believe that a streak of scoring increases the likelihood of further scoring. Early studies dismissed this phenomenon as an illusion stemming from a bias in subjective judgements regarding random sequences (Gilovich, Vallone, & Tversky, 1985): people tend to believe that random sequences of independent events should display only short strings of repetition, so when presented with longer strings, even in a purely random game, people tend to reject the hypothesis of independence. After >20 years of research into the hot hand, the evidence is mixed, with some studies finding a hot hand (Malueg & Yates, 2010), others not (Bar-Eli, Avugos, & Raab, 2006).

A notable feature of the hot hand debate, however, is that it has not been linked to the biological research conducted by animal behaviourists on the winner effect, surveyed above. Nor has it been linked to research in physiology showing that testosterone levels in athletes are elevated after a win (Gladue, Boechler, & McCaul, 1989; Zilioli & Watson, 2014), a phenomenon observed in for, example, tennis (Booth, Shelley, Mazur, Tharp, & Kittok, 1989) and ice hockey (Carre & Putnam, 2010), as well as non-sporting competitions such as chess (Mazur, Booth, & Jr, 1992) and even trading in the financial markets (Coates & Herbert, 2008; Coates & Page, 2009). The hormonal mechanism that is thought to drive the winner effect in animals has thus been identified in humans. If the mechanism exists, does the winner effect itself? This paper proposes an answer to that question by attempting to bridge the research on animal winner effects with the research on athletes' hot hand.

Testing for a winner effect in humans, however, faces a difficulty: How can we know that a winning streak is not due to a player's greater ability? If an athlete's ability and fitness were constant over time, it could be controlled for by using fixed effects/within subject regression estimation (Jones, 2007). However, the ability and fitness of an athlete can vary, even during a single match, due to factors such as fatigue, injury, confidence, and learning. If ability varies across time with positive autocorrelation then standard fixed effect/within subject regression will produce a spurious winner effect: a win will be followed by further wins (Bar-Eli et al., 2006). As individual ability is not fully observable, and can vary over time, it is difficult to solve this problem with standard regression techniques.

Here, we propose a protocol that we argue can control for ability. Drawing on a large database of professional tennis matches, we construct a quasi-experimental situation in which to test for within-match momentum. Tennis provides a unique competition in which to do so, for in it we can control for long term ability by focusing on matches fought between players who on average do not differ significantly in rank, and for playing form on the day of competition by focusing on matches which are fought to long tie-breaks in the first set. Here players differ on average only in their assignment to treatment condition – i.e., winning or losing the first set – but not in ability. We can then look at the causal effects of a first set win on the probability of winning the second set. Situations such as these are termed ‘natural’ or ‘quasi-experimental’ because the experimenters do not control the assignment of players to treatment and control groups; this randomization is found ready-made in the study population (Shadish, Cook, & Campbell, 2002).

A quasi-experimental protocol looks at treatment and control groups closely clustered either side of a threshold or discontinuity, where the local differences are small; the protocol then involves testing for substantial effects caused by assignment to these groups (Thistlethwaite & Campbell, 1960). For example, the awarding to students of a letter of merit creates a discontinuity: a student either receives it or not. To assess the effects of this letter on future academic performance we cannot compare average grades of everyone who did receive the letter with those who did not. These averages will include at one end students who failed and at the other end students of the highest distinction. Looking at these averages will merely show that past academic achievement predicts future. To isolate the effect of the letter itself, we should look rather at students just above the merit cut-off line, say an average grade of 75.5%, and those just below, say 74.5%. Here differences in students' ability are trivial, yet if we find that after receipt of the letter the winners perform substantially better then we can conclude that the letter contributed to that performance. In our study, long tie-breaks between equally ranked tennis players create a similar discontinuity – the winning of the first set.

Our study design focuses only on a winner effect within a given dyad of opponents, and not between dyads. While most of the literature on the winner effect is on the effect of winning on future encounters against new opponents here we look at the effect of winning in the early stage of a contest on the chances of a later match victory. As discussed above, many game theoretic models predict a winner effect in a series of fights within a dyad (Van Doorn et al., 2003; Konrad, 2009; Dugatkin & Reeve, 2014; Kura et al., 2016).

Our study does not permit us to test for the physiological substrate of winner and loser effects, but the database is deep enough to allow us to run separate analyses for men and women. A smaller winner effect in women would lend support to the hypothesis that the winner effect is mediated by androgens, because women have lower levels of circulating testosterone than men (Davis & Marler, 2003; Huhman et al., 2003; Oliveira, Gouveia and Oliveira, 2009; Jiménez, Manuel, & Alvero-Cruz, 2012).

2. Data and method

In tennis a set is won if a player wins 6 games provided they have won a minimum of 2 games more than their opponent. If a set reaches

6 games apiece, it is then decided by a final game tie-break: players alternately serve until one wins a minimum of 7 points with at least 2 points more than the opponent. In many close fought sets, the end result of the entire set can come down to winning a mere 2 points more in the tie-break. In a 7-6 set, with an average of 6 points played per game (a conservative estimate), players enter the tie-break having played around 78 points. If they play a long tie-break ending in a score such as 10-8, the results of the set will therefore depend on a difference of only 2 points out of a total of around 96 played. While the difference in performance in the first set is thus very small, a large discontinuity is created because the score in sets becomes 1-0, half the number of sets required to win a typical best-of-3 set match.

Our dataset contains an almost exhaustive list of all the matches played by male tennis players at the international professional level between 1990 and 2012, and by professional female tennis players over the period 1998–2012. Most of the matches from male players are from Grand Slam and ATP tournament or lower level ITF (International Tennis Federation) tournaments known as Challengers, Futures and Satellite. All the matches from the female players come from WTA (Women Tennis Association) tournaments, the highest level tournaments in women's tennis. Players' rankings were provided by the Association of Tennis Players (ATP) for men and Women's Tennis Association (WTA) for women.

We focused on singles matches that were decided by the best of 3 sets. The dataset contains 363,423 matches for men and 25,089 matches for women. We then narrowed the dataset to those matches in which the first set ended in a tie-break. To eliminate the possible confound of an ability to win tie-breaks, only matches where the second set did not end in a tie-break are kept. Our final dataset is composed of N = 37,541 matches for men and N = 12,603 matches for women (Fig. 1).

We randomly designated one player as the reference player and looked at whether he/she won the first set; and then at their chances of winning the next set, and therefore the match. We measured the score for tie-breaks by the percentage of points won by the designated player. The closer this percentage is to 50%, the closer the tie-break. For instance, a player winning a tie-break 7-3 wins 70% of the points; a player winning 11-9 wins 55% of the points, and so on. As the score of the tie-break increases, the percentage of points won by the winner approaches 50%.

3. Results

We began by controlling for the rank of players. Not all matches in our database included rankings, but for the subset of matches with rankings, we found that players who won tie-breaks were on average ranked higher than their opponents. The difference in rank was significant for men (Diff = 33.02, *t*-test, $p < 0.0001$, N = 13,416) and women (Diff = 22.01, *t*-test, $p < 0.0001$, N = 10,780). In order to control for this difference in rank we assumed it would decrease as the tie-breaks became longer. And we did indeed find this: Once we reach tie-breaks lasting >20 points (i.e., scores higher than 11-9) we find no significant difference in average ranking for winners and losers, neither for men (Diff = 1.73, *t*-test, p = 0.9435, N = 235) nor for women (Diff = −22.35, *t*-test, p = 0.5807, N = 140). We took this score as a cut-off point beyond which winners and losers of the first set are on average equally matched in ability; and we used this as our cut-off point even when analysing the larger dataset which includes matches for which we do not have rankings.

Focusing thus on first sets decided by a lengthy tie-break, we then looked at the effects of winning these sets on a player's probability of winning the second set. We performed our analysis separately for men and women. For men, we found that, even when rank was controlled for, the act of winning or losing the first set tie-break created a large discontinuity in the probability of winning the second set. For first set tie-breaks lasting >20 points, where the percentage of points won by the winner was 54.5% or less, the winner had a 60% chance of winning the second set versus 39% for the loser (between-group proportion test, $p < 0.0001$, N = 617, Fig. 2).

We also employed a logit regression of the binary variable "winning in the second set" on a binary variable "winning in the first set", controlling for the percentage of points won in the tie break and the difference in rank between players. This analysis confirms that winning the first set tie break has a positive effect on the chance of winning the second set ($p < 0.001$), even after controlling for the percentage of points won

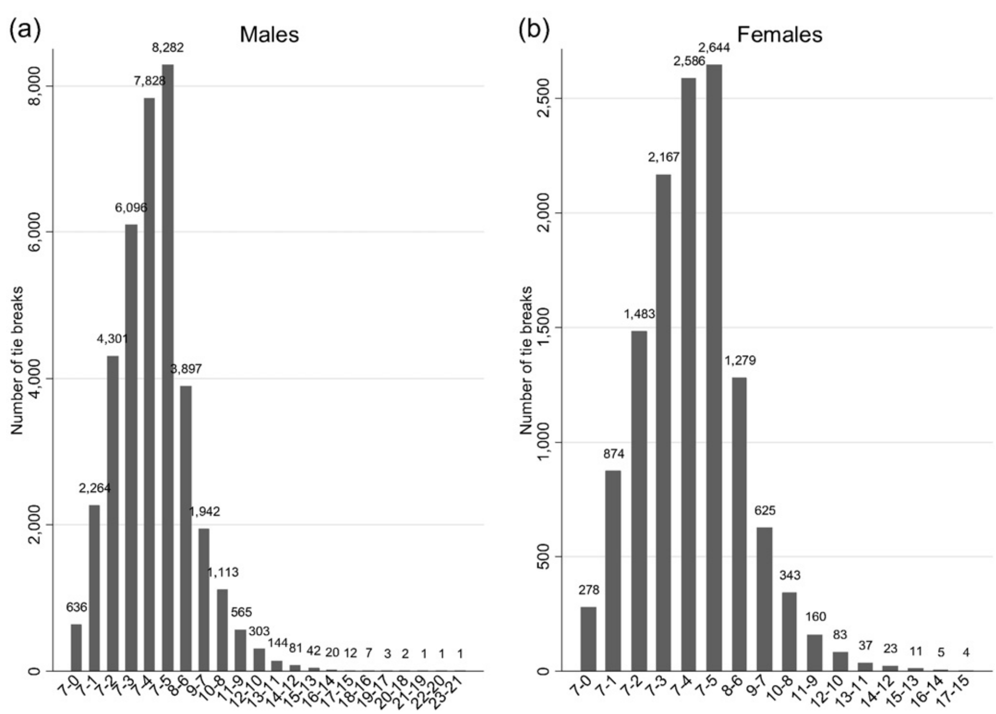

Fig. 1. Breakdown of tie-break scores for (a) male and (b) female players.

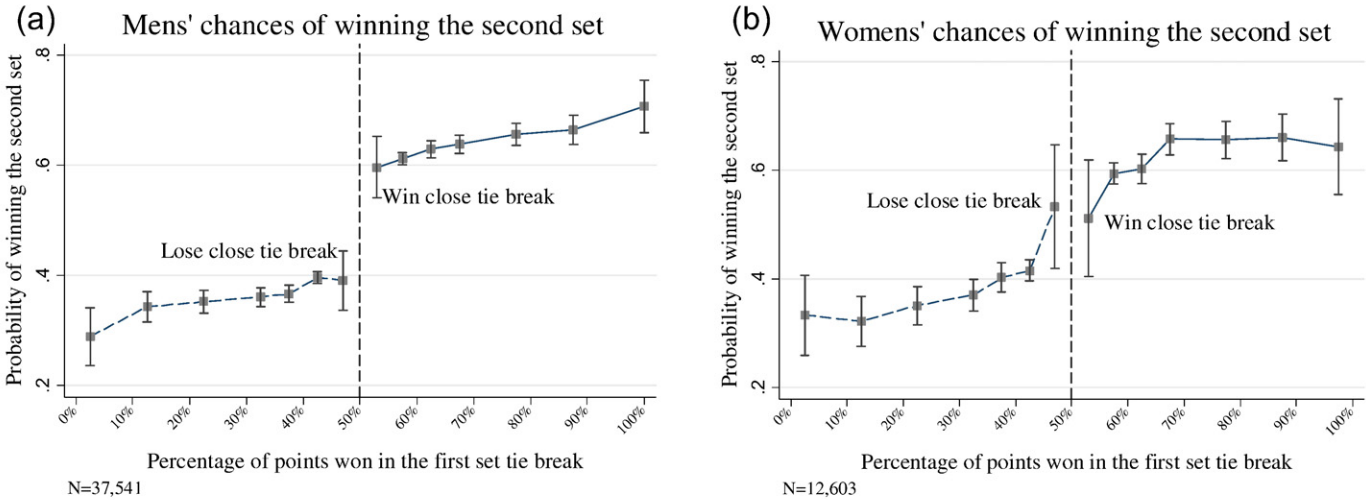

Fig. 2. Effect of winning the first set tie-break on the probability of winning the second set for (a) men and (b) women. The horizontal axis plots the percentage of points won in the tie-break; the closer this percentage is to 50%, the closer the result of the tie-break. The dots represent the average number of points won in bins of 2.5 percentage points. The break in the plot line for men illustrates the jump in the probability of winning the second set consequent upon winning the two points needed to win the tie-break. The gap provides a measure of the winner effect.

in the tie-break ($p < 0.001$) and the difference in rank between players ($p < 0.001$). The estimated second set winning probabilities for hypothetically identical players (equal ranks and same number of points won in the tie-break) are 42.4% for the loser and 57.3% for the winner.

For women, however, there was no significant discontinuity in the probability of winning the second set. Women winning first tie-breaks lasting >20 points had a 51% chance of winning the second set, losers 53% (between group proportion test, $p = 0.7871$, $N = 159$, Fig. 2).

We ran one further analysis to test our assumption that long tie-breaks present a quasi-experimental situation where players are equally matched in ability. To do so, we carried out a so-called "placebo test". A placebo test assesses the validity of an experimental protocol to measure a treatment effect by seeing if it predicts effects where they should not exist.

If players winning a close tie-break possess greater ability, then second sets should predict first sets just as much as first ones predict second (Jones, 2007). We therefore ran a placebo regression looking at the potential "effect" of the second set result, when it ends up in a close tie-break, on the results of the first set (Fig. 3).

For players winning second set tie-breaks lasting >20 points, there was no significant difference in the probability of their winning the first set, neither for men (Diff $= -0.03$, between group proportion test, $p = 0.4303$, $N = 514$) nor for women (Diff $= 0.132$, between group proportion test, $p = 0.123$, $N = 116$). The absence of an *ex-ante* difference in performance between winners and losers of close tie-breaks in the second set supports our identification assumption that winners and losers of close tie-breaks can be considered to have on average similar ability. Close tie-breaks thus offer a quasi-experimental setting in which to estimate the causal effect of winning on later performance.

4. Discussion

In this study we attempted to bring insights from animal studies of the winner effect into the study of human competitions, something that has so far been largely absent from studies of, for example, the hot hand in sports. We also proposed a protocol that we believe enables us to control for two people's ability when testing for a winner effect. Employing a quasi-experimental approach involving a discontinuity design we examined closely fought first sets in tennis matches between players who do not on average differ significantly in rank. When one player wins the extra two points needed to win the first set tie-break,

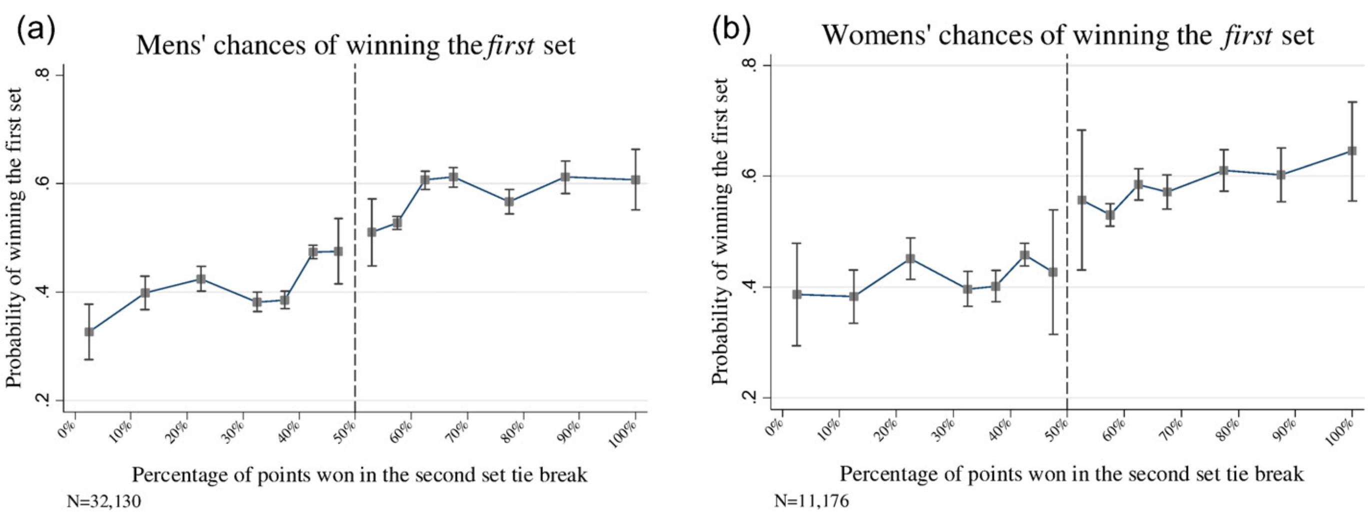

Fig. 3. Placebo regression of the effect of winning the second set tie-break on the first set result for (a) men and (b) women. The second set tie-break is used to "predict" the first set result. No jump is observed around the 50% line.

even though these two points represent a small percentage of total points played in the set, this player's chances of winning the second set jump to 60% while the losers' fall to 39% (Fig. 2a). This large discontinuity provides evidence that the act of winning and losing in themselves, independently of ability, increases the chances of further wins and losses. It also provides a measure of the magnitude of this winner effect.

While we found evidence that a winner effect exists in men we found no evidence for its existence in women (Fig. 2b). This finding lends support to the hypothesis that the winner effect is mediated by an androgenic feedback loop, in which victory raises testosterone levels which in turn raises the likelihood of a further victory (Elias, 1981; Booth et al., 1989; Gladue et al., 1989; Mazur et al., 1992; Coates & Herbert, 2008; Carre & Putnam, 2010). Women have circulating testosterone levels on average about 10% those of men, and this may account for a smaller winner effect (Davis & Marler, 2003; Huhman et al., 2003; Oliveira, Gouveia and Oliveira, 2009; Jiménez et al., 2012). We cannot, however, be certain of this interpretation, as we do not have the data needed to rule out other non-androgenic mechanisms mediating the winner effect.

Our finding of a winner effect in a human competition contrasts with the findings of many studies which find no hot hand in sports. Many of these studies focus on basketball and it may be suggested that the differences in our results come from the differences in the sports studied. In tennis, players achieve within-match benchmarks (winning a set) while in basketball a series of won points leads to no such intra-game discontinuity. Winner effects may thus depend on the existence of benchmark achievements.

The winner effect is a powerful mechanism. Animals have even been observed trying to control this effect. Dominant males sometimes break up fights between subordinates in order to deprive the stronger of these combatants (and potential rivals) of the benefits of winning (Dugatkin, 1998; Jennings et al., 2009). Winner effects have also been observed in the business world, in, for example, tournaments for promotion (Rosen, 1986; O'Flaherty & Siow, 1995; Dubey & Haimanko, 2003; Gershkov & Perry, 2009), patent races (Harris & Vickers, 1985; Harris & Vickers, 1987), and elsewhere, in political campaigns (Klumpp & Polborn, 2006). Animals, athletes, business executives, and politicians, without knowing the science, appear nonetheless to understand the importance of depriving a rival of momentum.

There are times when it may be advantageous for an organisation to foster a winning streak, and others to discourage it. Research into winner and loser effects could help in the optimal design of tournaments and competitions, and of incentive structures within the workplace. It could also help players and employees formulate strategies within these settings (Prendergast, 1999; Dugatkin & Reeve, 2014). Indeed, there is one environment where understanding the winner effect may prove to be of particular importance – the financial world (Coates, 2012). Something like the winner effect appears to exist among traders, in which an above-average profit raises testosterone levels which in turn increases risk appetite (Coates & Herbert, 2008; Coates & Page, 2009; Apicella, Dreber, & Mollerstrom, 2014). There is evidence as well that something like a loser effect exists, instilling risk aversion during periods of high volatility and market losses, such as a credit crisis (Kandasamy et al., 2014).

A winner effect among traders may account for the dangerous and frequent phenomenon where a star trader, increasing his trading size while on a winning streak, eventually suffers losses of such magnitude that they threaten the existence of his employing firm. In these situations the trader could benefit from something like a rain break, a mandatory vacation period, which could have the effect of arresting this winning-induced expansion of risk. Another way of dampening the winner effect in the financial community is to increase the number of women and older men managing money, for they have lower testosterone levels than young men (Coates, Gurnell, & Sarnyai, 2009; Fawcett & Johnstone, 2010) and thus may be less susceptible to the adverse consequences of the winner effect.

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