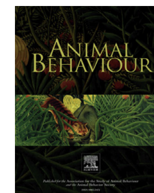
Animal Behaviour 207 (2024) 101–107

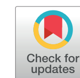
Contents lists available at ScienceDirect

Animal Behaviour

journal homepage: www.elsevier.com/locate/anbehav



Winner and loser effects in humans: evidence from randomized trials



Noah M. T. Smith, Reuven Dukas*

Department of Psychology, Neuroscience, and Behaviour, McMaster University, Hamilton, ON, Canada

ARTICLE INFO

Article history:
Received 2 June 2023
Initial acceptance 24 July 2023
Final acceptance 19 September 2023

MS. number: A23-00273R

Keywords:
competition
contest
sports
video game
winner and loser effect

In many animals, contest winners are more likely to win subsequent matches while contest losers tend to lose their later fights. Such winner and loser effects can have long-lasting impacts on individual behaviour and fitness. Recent observations suggest that winner and loser effects may occur in humans, and we thus critically tested this proposition in two experiments involving video games and reading comprehension. We randomly assigned human participants to either win or lose in phase 1 by manipulating their task difficulty. Then we tested their performance in phase 2, which was moderately difficult for all participants. In both experiments, randomly assigned phase 1 winners performed significantly better in phase 2 than did randomly assigned phase 1 losers. The effect size was higher in the video game experiment than in the reading comprehension test, perhaps because the former involved an overt contest with one winner and one loser. Finally, men and women exhibited similar magnitudes of winner and loser effects. Our experimental approach as well as further critical experiments with humans can help us better understand winner and loser effects in general as well as their possible important influence on human performance.

© 2023 The Association for the Study of Animal Behaviour. Published by Elsevier Ltd. All rights reserved.

Long ago, students of animal behaviour noted that individuals with winning experience are more likely to win a fight against a new opponent, while individuals with losing experience are more likely to lose again (Ginsburg & Allee, 1942; Seward, 1946). Numerous follow-up experiments in a wide variety of species have established winner and loser effects as empirical rules of animal contest (Hsu et al., 2006; Rutte et al., 2006). For example, Bakker and Sevenster (1983) arbitrarily assigned focal male sticklebacks (*Gasterosteus aculeatus*) to either win or lose a fight by either introducing males into the focal males' territories or placing the focal males into other males' territories, respectively. Afterwards, the focal males were matched with inexperienced opponents in a new water tank. While the previous winners won all fights, the previous losers lost all but one fight.

The literature on winner and loser effects has focused on physical aggression in nonhuman species. Physical aggression, however, plays a lesser role in humans than in nonhuman species (Barkow, 1989; Chen Zeng et al., 2022; Hawley, 1999). Nevertheless, recent observational studies have attempted to assess winner and loser effects in humans competing in sports like tennis, judo and football (Cohen-Zada et al., 2017; Gauriot & Page, 2018, 2019; Page & Coates, 2017). For example, among similarly ranked professional male tennis players, winners of closely fought tie-breaks were more likely to win a subsequent set than losers (Page & Coates, 2017).

The studies suggesting winner and loser effects in humans are intriguing. If winner and loser effects play a significant role in human cognition and behaviour, then they might help explain a wide range of phenomena including performance in academic pursuits, sports and business (Amabile & Kramer, 2011; Gauriot & Page, 2019; Helsen et al., 2005; Musch & Grondin, 2001; Niederle & Vesterlund, 2011; Weick, 1984), abuse of power by political and other leaders (Klaas, 2021), stereotype threat (Spencer et al., 2016), problem gambling (Cummins et al., 2009) and investment decisions (Coates, 2013; Shiller, 2015).

Given the broad relevance of possible winner and loser effects in humans, we require critical tests of this phenomenon. Ideally, such tests should consist of experiments that include random assignment of subjects to winner and loser treatments. Random assignment eliminates selection bias, whereby the winners (or losers) of a first encounter possess intrinsic properties that increase (or decrease) their likelihood of winning (or losing) in the first as well as subsequent encounters (Bégin et al., 1996; Chase et al., 1994). For example, the simplest explanation for the observations that winners in one stage are more likely to win the next stage, even when controlling for ranking, is that they perform slightly better than their opponents owing to temporal variation caused by a variety of factors including their recent

* Corresponding author.
E-mail address: dukas@mcmaster.ca (R. Dukas).

https://doi.org/10.1016/j.anbehav.2023.10.017
0003-3472/© 2023 The Association for the Study of Animal Behaviour. Published by Elsevier Ltd. All rights reserved.

training regime, exhaustion, diet, hydration level, sleep quality and mood.

The vast majority of nonhuman animal studies of winner and loser effects focus on males (Hsu et al., 2006), because it is most often the males who fight within either the direct or indirect context of access to females. Humans share similar sex differences in physical aggression (Archer, 2019; Campbell, 2013; Geary, 2021; Stockley & Campbell, 2013; Wilson & Daly, 1985). Furthermore, on average, women are less eager to compete than men (Campbell, 2013; Niederle & Vesterlund, 2011). Finally, two of the observational human studies cited above reported winner and loser effects in men but not in women (Cohen-Zada et al., 2017; Page & Coates, 2017). Hence, although the data are limited, they suggest higher prospects for finding winner and loser effects in men than in women.

To critically test for winner and loser effects in humans, we conducted two experiments. The first experiment involved a scenario simulating aggression as it typically occurs in widely popular video games. In the second experiment, we wished to test whether winner and loser effects are relevant for activities other than simulated aggression. Such nonaggressive activities dominate human behaviour and often involve either explicit success and failure, or a ranking component. Examples include performance in academic pursuits, business, employment, investment and politics. We thus administered a reading comprehension test similar to ones used in entrance exams to competitive professional programmes such as medical schools. In both experiments, we predicted that randomly assigned phase 1 winners would perform better in phase 2 than randomly assigned phase 1 losers. While we predicted winner and loser effects in both experiments, we expected smaller effects in the reading comprehension experiment because it did not include explicit binary winner and loser outcomes. We also predicted weaker winner and loser effects in women than in men.

METHODS

Ethical Note

Both our experiments received ethics approval from McMaster University Research Ethics Board (application number 5792). We recruited subjects through McMaster's undergraduate recruitment system. All participants signed an informed consent form and obtained credit for an introductory psychology course. Participants also competed for monetary incentives of $50 (CAD) for the two best performers and $25 (CAD) for the two runners-up in each experiment. Monetary incentives are standard in human studies.

Experiment 1: Video Game

Once registered, participants received a self-report survey, on which they stated their gender and the average amount of weekly time they had played first-person shooter video games using a mouse and keyboard over the past 6 months. This experience factor had three levels: less than 1 h per week, between 1 and 10 h per week and more than 10 h per week.

Upon registration, we randomly assigned and counterbalanced participants to one of two treatments: phase 1 winner or phase 1 loser. All participants faced pre-programmed computer opponents that varied in difficulty based on each participant's treatment and experience. We used the workshop feature in the video game Overwatch to code these opponents (see Appendix). Participants randomly assigned to a phase 1 win faced an easy phase 1 opponent, whereas participants randomly assigned to a phase 1 loss faced a difficult phase 1 opponent. Then all participants faced a phase 2 opponent of moderate difficulty. Within each level of difficulty, we coded three sublevels corresponding to participants' self-reported video game experience. For example, the easy opponent was easiest for inexperienced players, moderately easy for players with moderate experience and least easy for experienced players (Appendix, Fig. A1).

We ran Overwatch at 60 frames/s using two graphically capable laptops, 60 Hz monitors, standard computer keyboards, optical mice and on-ear headphones. To record each participant's gameplay and scores, we used Open Broadcaster Software (OBS Studio, https://obsproject.com/). Participants began by playing through a brief tutorial, which taught the basics of Overwatch including aiming, walking around and shooting. We then told participants that they would play two successive Overwatch rounds of one-versus-one against two different participants located in a different room in the building and gave them further game instructions (see Appendix).

In phase 1, participants had a maximum of 15 min to eliminate their opponent as many times as they could while minimizing being eliminated by their opponent. The score limit was 40 eliminations, meaning that the first player (participant or opponent) to reach 40 eliminations would win. Participants could see their own and their opponents' current scores throughout the game. The difficulty level of each participant's opponent was easy for assigned winners and difficult for assigned losers, with further adjustments for participants' experience, as described above and in the Appendix (Fig. A1). After 15 min or 40 eliminations, whichever came first, we ended phase 1 and participants saw their own and their opponent's final score, meaning that they knew the magnitude of their win or loss. We then told participants that they could begin phase 2, which we said was against a different participant than the one they had played against in phase 1. In reality, phase 2 was similar to phase 1, except for the computer opponent, which was at an identical, moderate difficulty for both assigned winners and losers in phase 1, with the only adjustment being for participant experience (Appendix, Fig. A1). Participants then played phase 2 for either 15 min or up to 40 eliminations.

We recruited 233 participants but had to exclude five participants owing to computer errors (either game crashes or lost internet connection). Based on a priori criteria and prior to recording phase 2 results, we also excluded six participants due to incongruence between phase 1 assignment and phase 1 outcome (1 assigned winner who lost and 5 assigned losers who won). Lastly, we had to exclude three participants due to obvious disengagement with the task. This left us with 219 participants (134 men, 85 women).

We calculated participants' scores in each of the two phases by subtracting the number of times they were eliminated from the number of eliminations they acquired in phase 2. For example, a participant who eliminated her opponent 36 times and was eliminated 20 times had a score of 16. Hence the possible scores for each phase ranged from +40 to −40. In phase 1, participants assigned to the winner treatment had a much higher score than those assigned to the loser treatment (mean ± 1 SE: +20.8 ± 0.5 versus −19.9 ± 0.8; $F_{1,215} = 2121$, $P < 0.001$).

Experiment 2: Reading Comprehension

This experiment was a remote, online study. We randomly assigned and counterbalanced participants to one of two treatments:

phase 1 high score or phase 1 low score. We then emailed participants a link and an access token to the online experiment, which was conducted via LimeSurvey. All participants first filled out a brief self-report section, which recorded gender and experience in reading long-form print media such as books, news articles and scientific papers. The experience factor had three levels: less than 1 h per week, between 1 and 10 h per week and more than 10 h per week. Here, however, we could not titrate task difficulty based on participants' declared experience (Appendix, Fig. A2). After the self-report portion, participants advanced to phase 1. Phase 1 comprised two parts, each involving reading a passage containing about 600 words and answering five multiple choice questions, each with four possible answers. The two passages and the questions varied in difficulty, with assigned high scorers having a relatively easy task and assigned low scorers experiencing a difficult task.

After phase 1, all participants received fictional feedback about their decile performance on the questions. Phase 1 high scorers received feedback saying they were in the top decile of test takers, while phase 1 low scorers received feedback saying they were in the bottom decile of test takers. The actual phase 1 scores of participants were consistent with our feedback: those randomly assigned to the high-scorer treatment had a much higher score than those randomly assigned to the low-scorer treatment (mean ± 1 SE proportion correct: 0.80 ± 0.02 versus 0.39 ± 0.26; $F_{1,154} = 61.9$, $P < 0.001$). We included feedback about participants' relative performance in order to simulate social competition. Furthermore, providing fictional feedback facilitated our goal that all phase 1 high scorers would feel relatively highly successful, i.e. winners, while all phase 1 low scorers would feel relatively unsuccessful, i.e. losers.

After receiving feedback, participants began phase 2. In phase 2, all participants read the same two moderately difficult passages of approximately 600 words and answered five questions about each passage (Appendix, Fig. A2). All passages and questions came from a practice resource for medical school admission tests.

We recruited 186 participants fluent in English. As in the video game experiment, we had a priori decided to exclude participants who clearly did not engage in the reading comprehension tasks. Such disengagement is heightened in online studies (Ward & Meade, 2023). Each of the four reading passages had about 600 words followed by five questions. The range of reading speed for nonfiction is 175–300 words/min (Brysbaert, 2019). We thus excluded the 19 participants (9 assigned winners and 10 assigned losers) that spent less than 2 min on reading and answering the questions on any one of the four passages. We also excluded the only participant who got zero scores in both phases. This left us with 166 participants (77 men, 89 women). Our response variable was participants' number of correct answers to the 10 questions in each phase.

Statistics

We analysed the data in SPSS version 29 (IBM, 2022). In both experiments, we used a general linear model and verified model fit by visually inspecting plots of model residuals. In the video game model, we included phase 2 score as the dependent factor and treatment, sex and their interactions as independent factors. In the reading model, the dependent factor was phase 2 reading score, which we squared to handle a negative skew. Treatment, sex, experience and all interactions were the independent factors. We included experience in the reading model, but not in the video game model, because we could readily adjust task difficulty for participant experience in the video game experiment but could not do so in the reading experiment.

RESULTS

In the video game experiment, participants randomly assigned to win in phase 1 had significantly higher scores in phase 2 than those randomly assigned to lose in phase 1 ($F_{1,215} = 13.3$, $P < 0.001$, effect size: $d = 0.25$; Fig. 1, Appendix, Table A1). Men performed better than women ($F_{1,215} = 45.1$, $P < 0.001$), and the treatment∗sex interaction was not significant ($F_{1,215} = 1.7$, $P = 0.19$).

In the reading experiment, participants randomly assigned to receive high scores in phase 1 had significantly higher scores in phase 2 than those randomly assigned to receive low scores in phase 1 ($F_{1,154} = 4.2$, $P = 0.04$, effect size: $d = 0.16$; Fig. 2, Appendix, Table A2). There was neither a sex difference ($F_{1,154} = 0.05$, $P = 0.8$), nor a treatment∗sex interaction ($F_{1,154} = 0.01$, $P = 0.9$).

DISCUSSION

In both the video game and reading comprehension experiments, participants randomly assigned to receive a high score in phase 1 performed better in phase 2 than did participants randomly assigned to receive a low score in phase 1 (Figs 1 and

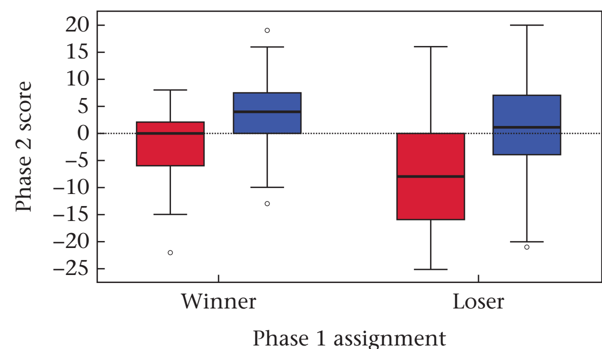


Figure 1. Scores in phase 2 of the video game experiment of female (red) and male (blue) participants ($N = 219$) randomly assigned to either win or lose in phase 1. The horizontal lines in the box plots show the medians, the boxes contain the middle 50% of data (interquartile range, IQR), the whiskers above and below each box represent values within ±1.5 of the IQR, and points depict outliers.

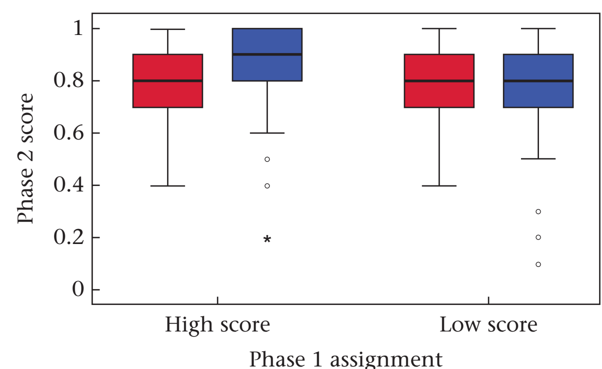


Figure 2. The proportion of correct answers in phase 2 of the reading experiment of female (red) and male (blue) participants ($N = 166$) randomly assigned to either receive a high or low score in phase 1.

2). Both women and men exhibited these winner and loser effects. Hence our results substantiate the observational studies suggesting winner and loser effects mentioned in the Introduction (Cohen-Zada et al., 2017; Gauriot & Page, 2018, 2019; Page & Coates, 2017). Some nonhuman animal studies noted that loser effects often are larger than winner effects (Hsu et al., 2006). While we did not design our protocols to quantify such possible differences, future studies may address both the magnitude and temporal effects of winner and loser aspects in humans.

Research not explicitly addressing winner and loser effects is consistent with our experimental results. Welling et al. (2013) randomly assigned male participants to either win or lose in a video game. Afterwards, winners showed a stronger preference than did losers for feminine female faces. This suggested that the winners felt more dominant and hence more attractive to women. Many observational studies as well as experiments that randomly assigned participants to either win or lose tested whether winning and losing was associated with changes in testosterone concentrations. While these studies did not test for the effect of winning and losing on subsequent contest outcome, and results have been highly variable, a meta-analysis indicated a higher relative increase in testosterone after winning than after losing in both men and women (Geniole et al., 2017). The mechanistic links between winning and losing and testosterone, however, are unclear. A few recent studies in nonhuman species have documented neurobiological changes associated with winning and losing (Li et al., 2022; Padilla-Coreano et al., 2022; Uy et al., 2021; Zhou et al., 2017). Hence future studies should employ a broader perspective that encompasses all the potential mechanisms that underlie winner and loser effects.

Contrary to our prediction, women and men showed a similar magnitude of winner and loser effects. Future experiments, however, should further assess possible sex differences in humans' winner and loser effects. Such possible differences may vary as a function of the social environment and task context. In agreement with our expectation, we found a smaller effect size in the reading comprehension experiment than in the video game experiment ($d = 0.16$ versus 0.25, respectively). Our rationale for this expectation was that the reading comprehension experiment did not have either simulated aggression or overt winners and losers in phase 1. We would, however, need further experiments in order to quantify the magnitudes of winner and loser effects as a function of several relevant factors including the social settings, the set-up of contests, their relative importance and alternatives available to losers (Leimar & Bshary, 2022). For example, it is possible that the magnitude of winner and loser effects vary depending on social context, being highest in face-to-face contests between two people, intermediate in less direct, online one-on-one interactions and lowest in less direct, group tournaments.

Our experimental quantification of winner and loser effects in humans opens up exciting avenues for further research. By using human subjects, video games and other competitive scenarios, we could further our understanding of contests in general (Kasumovic et al., 2017) and the adaptive functions of winner and loser effects, in particular. As noted in the Introduction, winner and loser effects have been established as empirical rules of animal conflict (Hsu et al., 2006; Rutte et al., 2006). Hypotheses about the adaptive functions of winner and loser effects, however, have been limited and rarely translated into critical experimental tests. The simplest adaptive hypothesis for winner and loser effects in nonhuman species is that fighting has multiple costs, including time, injury and risk of death. Hence winners of a fight should display their apparent formidability to deter would-be challengers and quickly attack determined contenders, while losers should acknowledge their probable weakness and avoid further fights (Fawcett & Johnstone, 2010; Rutte et al., 2006; Whitehouse, 1997). In both nonhumans and humans, winners displaying their physical dominance may gain critical resources, social influence and mates. The fitness benefits of loser effects, however, are less clear.

The two most likely nonmutually exclusive benefits of loser effects are waiting and use of alternative strategies. First, loser effects can serve as a relatively safe waiting strategy until the dominant individual weakens or dies. This is similar to the developmental arrest of subadult males in the presence of dominant males in many primates (Maggioncalda et al., 2002; Virgin & Sapolsky, 1997). Second, loser effects may be associated with the losers adopting alternative strategies, which partially disengage them from the dominance hierarchy. For example, male fruit flies (*Drosophila melanogaster*) that had lost contests subsequently achieved lower precopulatory success but higher postcopulatory success than did the winners. This could be a result of the losers investing more than the winners in each mating given their expected lower number of copulations (Filice & Dukas, 2019). Both adaptive explanations for loser effects can be critically tested in future experiments using human subjects.

One could argue that winner and loser effects are not relevant for humans because, compared to many animals, they rarely engage in physical fighting. While our experiments were motivated by observations and anecdotes, it is possible to place humans' winner and loser effects within a functional framework. As a highly social species, humans are acutely aware of their rank along multiple dimensions including athletic performance, level of expertise on various skills and social competence (Cheng et al., 2014; Guinote & Vescio, 2010). Winner and loser effects are most likely among the mechanisms that guide people's rank assessment, which they can then use for determining their rank-dependent optimal behaviour. For example, an individual of low rank may elect to defer to an individual of high rank, or to abandon a certain endeavour in order to devote more time for more promising pursuits.

While using human subjects can advance our general understanding of the evolutionary biology of winner and loser effects, their possible influence on human behaviour is as intriguing. A variety of popular accounts and observational studies suggest that winning and losing alter human decisions in a variety of contexts, including academic studies, sports, business, investment, gambling and politics (Amabile & Kramer, 2011; Buser & Yuan, 2019; Coates, 2013; Cummins et al., 2009; Klaas, 2021; Musch & Grondin, 2001; Robertson, 2013). Hence, follow-up experiments extending our approach can help us quantify the importance of winner and loser effects in humans.

Author Contributions

N.M.T.S. carried out the experiments. Both authors designed the experiments, contributed to the data analysis, writing and editing process of the manuscript.

Data Availability

Figshare Digital Repository: https://doi.org/10.6084/m9.figshare.22776197.

Declaration of Interest

We declare no conflict of interest.

Acknowledgments

We thank P. Barclay and B. Ruffle for helpful suggestions on our experiments and M. Daly, B. Ruffle, O. Leimar and an anonymous referee for thoughtful comments on the manuscript. R.D. was funded by a Discovery Grant from the Natural Sciences and Engineering Research Council of Canada (NSERC), Canada Foundation for Innovation and Ontario Ministry of Research and Innovation, and N.M.T.S. received a fellowship from NSERC.

References

Amabile, T., & Kramer, S. (2011). *The progress principle: Using small wins to ignite joy, engagement, and creativity at work*. Harvard Business Review Press.
Archer, J. (2019). The reality and evolutionary significance of human psychological sex differences. *Biological Reviews, 94*, 1381–1415.
Bakker, T. C., & Sevenster, P. (1983). Determinants of dominance in male sticklebacks (*Gasterosteus aculeatus* L.). *Behaviour, 86*, 55–71.
Barkow, J. H. (1989). *Darwin, sex, and status: Biological approaches to mind and culture*. University of Toronto Press.
Bégin, J., Beaugrand, J. P., & Zayan, R. (1996). Selecting dominants and subordinates at conflict outcome can confound the effects of prior dominance or subordination experience. *Behavioural Processes, 36*, 219–226.
Brysbaert, M. (2019). How many words do we read per minute? A review and meta-analysis of reading rate. *Journal of Memory and Language, 109*, Article 104047.
Buser, T., & Yuan, H. (2019). Do women give up competing more easily? Evidence from the lab and the Dutch math olympiad. *American Economic Journal: Applied Economics, 11*, 225–252.
Campbell, A. (2013). *A mind of her own: The evolutionary psychology of women* (2nd ed.). Oxford University Press.
Chase, I. D., Bartolomeo, C., & Dugatkin, L. A. (1994). Aggressive interactions and inter-contest interval: How long do winners keep winning? *Animal Behaviour, 48*, 393–400.
Chen Zeng, T., Cheng, J. T., & Henrich, J. (2022). Dominance in humans. *Philosophical Transactions of the Royal Society B: Biological Sciences, 377*. Article 20200451.
Cheng, J. T., Tracy, J. L., & Anderson, C. (2014). *The psychology of social status*. Springer.
Coates, J. (2013). *The hour between dog and wolf: How risk taking transforms us, body and mind*. Penguin.
Cohen-Zada, D., Krumer, A., & Shtudiner, Z. (2017). Psychological momentum and gender. *Journal of Economic Behavior & Organization, 135*, 66–81.
Cummins, L. F., Nadorff, M. R., & Kelly, A. E. (2009). Winning and positive affect can lead to reckless gambling. *Psychology of Addictive Behaviors, 23*, 287–294.
Fawcett, T. W., & Johnstone, R. A. (2010). Learning your own strength: Winner and loser effects should change with age and experience. *Proceedings of the Royal Society B: Biological Sciences, 277*, 1427–1434.
Filice, D. C. S., & Dukas, R. (2019). Winners have higher pre-copulatory mating success but losers have better post-copulatory outcomes. *Proceedings of the Royal Society B: Biological Sciences, 286*, Article 20182838.
Gauriot, R., & Page, L. (2018). Psychological momentum in contests: The case of scoring before half-time in football. *Journal of Economic Behavior & Organization, 149*, 137–168.
Gauriot, R., & Page, L. (2019). Does success breed success? A quasi-experiment on strategic momentum in dynamic contests. *Economic Journal, 129*, 3107–3136.
Geary, D. C. (2021). *Male, female: The evolution of human sex differences* (3rd ed.). American Psychological Association.
Geniole, S. N., Bird, B. M., Ruddick, E. L., & Carré, J. M. (2017). Effects of competition outcome on testosterone concentrations in humans: An updated meta-analysis. *Hormones and Behavior, 92*, 37–50.
Ginsburg, B., & Allee, W. C. (1942). Some effects of conditioning on social dominance and subordination in inbred strains of mice. *Physiological Zoology, 15*, 485–506.
Guinote, A., & Vescio, T. K. (2010). *The social psychology of power*. Guilford.
Hawley, P. H. (1999). The ontogenesis of social dominance: A strategy-based evolutionary perspective. *Developmental Review, 19*, 97–132.
Helsen, W. F., van Winckel, J., & Williams, A. M. (2005). The relative age effect in youth soccer across Europe. *Journal of Sports Sciences, 23*, 629–636.
Hsu, Y., Earley, R. L., & Wolf, L. L. (2006). Modulation of aggressive behaviour by fighting experience: Mechanisms and contest outcomes. *Biological Reviews, 81*, 33–74.
IBM. (2022). *IBM SPSS statistics for Windows*. IBM Corporation Version 29. .
Kasumovic, M. M., Blake, K., & Denson, T. F. (2017). Using knowledge from human research to improve understanding of contest theory and contest dynamics. *Proceedings of the Royal Society B: Biological Sciences, 284*, Article 20172182.
Klaas, B. (2021). *Corruptible: Who gets power and how it changes us*. Scribner.
Leimar, O., & Bshary, R. (2022). Reproductive skew, fighting costs and winner–loser effects in social dominance evolution. *Journal of Animal Ecology, 91*, 1036–1046.
Li, S. W., Zeliger, O., Strahs, L., Báez-Mendoza, R., Johnson, L. M., McDonald Wojciechowski, A., & Williams, Z. M. (2022). Frontal neurons driving competitive behaviour and ecology of social groups. *Nature, 603*, 661–666.
Maggioncalda, A. N., Czekala, N. M., & Sapolsky, R. M. (2002). Male orangutan subadulthood: A new twist on the relationship between chronic stress and developmental arrest. *American Journal of Physical Anthropology, 118*, 25–32.
Musch, J., & Grondin, S. (2001). Unequal competition as an impediment to personal development: A review of the relative age effect in sport. *Developmental Review, 21*, 147–167.
Niederle, M., & Vesterlund, L. (2011). Gender and competition. *Annual Review of Economics, 3*, 601–630.
Padilla-Coreano, N., Batra, K., Patarino, M., Chen, Z., Rock, R. R., Zhang, R., Hausmann, S. B., Weddington, J. C., Patel, R., Zhang, Y. E., Fang, H.-S., Mishra, S., LeDuke, D. O., Revanna, J., Li, H., Borio, M., Pamintuan, R., Bal, A., Keyes, L. R., … Tye, K. M. (2022). Cortical ensembles orchestrate social competition through hypothalamic outputs. *Nature, 603*, 667–671.
Page, L., & Coates, J. (2017). Winner and loser effects in human competitions. Evidence from equally matched tennis players. *Evolution and Human Behavior, 38*, 530–535.
Robertson, I. (2013). *The winner effect: The science of success and how to use it*. Bloomsbury.
Rutte, C., Taborsky, M., & Brinkhof, M. W. G. (2006). What sets the odds of winning and losing? *Trends in Ecology & Evolution, 21*, 16–21.
Seward, J. P. (1946). Aggressive behavior in the rat. IV. Submission as determined by conditioning, extinction, and disuse. *Journal of Comparative Psychology, 39*, 51–76.
Shiller, R. J. (2015). *Irrational exuberance*. Princeton University Press.
Spencer, S. J., Logel, C., & Davies, P. G. (2016). Stereotype threat. *Annual Review of Psychology, 67*, 415–437.
Stockley, P., & Campbell, A. (2013). Female competition and aggression: interdisciplinary perspectives. *Philosophical Transactions of the Royal Society B: Biological Sciences, 368*, Article 20130073.
Uy, F. M. K., Jernigan, C. M., Zaba, N. C., Mehrotra, E., Miller, S. E., & Sheehan, M. J. (2021). Dynamic neurogenomic responses to social interactions and dominance outcomes in female paper wasps. *PLoS Genetics, 17*, Article e1009474.
Virgin, C. E., & Sapolsky, R. M. (1997). Styles of male social behavior and their endocrine correlates among low-ranking baboons. *American Journal of Primatology, 42*, 25–39.
Ward, M. K., & Meade, A. W. (2023). Dealing with careless responding in survey data: Prevention, identification, and recommended best practices. *Annual Review of Psychology, 74*, 577–596.
Weick, K. E. (1984). Small wins: Redefining the scale of social problems. *American Psychologist, 39*, 40–49.
Welling, L. L., Persola, L., Wheatley, J. R., Cárdenas, R. A., & Puts, D. A. (2013). Competition and men's face preferences. *Personality and Individual Differences, 54*, 414–419.
Whitehouse, M. E. A. (1997). Experience influences male–male contests in the spider *Argyrodes antipodiana* (Theridiidae: Araneae). *Animal Behaviour, 53*, 913–923.
Wilson, M., & Daly, M. (1985). Competitiveness, risk taking, and violence: The young male syndrome. *Ethology and Sociobiology, 6*, 59–73.
Zhou, T., Zhu, H., Fan, Z., Wang, F., Chen, Y., Liang, H., Yang, Z., Zhang, L., Lin, L., Zhan, Y., Wang, Z., & Hu, H. (2017). History of winning remodels thalamo–PFC circuit to reinforce social dominance. *Science, 357*, 162–168.

Appendix

Additional Methods for Experiment 1: Video Game

Participants registered for time slots through McMaster University's undergraduate recruitment software. One to two participants came to the experiment site (McMaster's University's Psychology Building) at a time. Once they arrived, participants signed two forms: an experimental letter of information and a COVID-19 letter of information. After participants read and signed their forms, we asked them to put their smartphones in their bags to avoid any distractions during the experiment. Then, we led them to their computers. Once seated at their computers,

we began a screen recording using Open Broadcaster Software (OBS). Participants then played through a brief tutorial, which taught the basics of Overwatch (aiming, walking around, shooting). After the tutorial ended, we told participants that they would be playing two rounds of one-versus-one against two different participants located in a different room in the building. In reality, participants played against the computer opponents they had been randomly assigned to when they registered and provided their first-person shooter video game (FPS) experience. To ensure that participants believed that they were playing against peers, we occasionally referred to their competitors by telling them things like, 'the other participants have arrived' or 'the participant you will be playing in the first round is waiting for you to join, so you can begin now'.

We then gave participants directions for how to play the game. Before the start of phase 1, we told participants that both players, themselves and their opponents, would use the same character (Soldier: 76). For the controls, participants could walk forwards (W), left (A), right (D) and backwards (S). They could also aim (by moving the mouse) and shoot (by clicking the left mouse button). We told participants that their goal was to aim at, shoot and eliminate their opponent. Participants could score eliminations by aiming their crosshair at the opponent and shooting (holding the left mouse button). However, the opponent could also shoot back at the participant simultaneously, so participants had to focus on being accurate and hitting their opponent. After hitting the opponent several times, the participant would eliminate the opponent, scoring the participant an elimination. After being eliminated, the computer opponent would disappear from the arena for 10 s, after which it would respawn with full health and begin shooting at the participant (at which point the participant would begin to shoot back). If the computer eliminated the participant (after a series of hits), participants had to wait 10 s to respawn. After respawning, participants had full health. Participants had a maximum of 15 min to eliminate the computerized opponent as many times as they could. The score limit was 40 eliminations, meaning that the first player (participant or computer) to reach 40 eliminations would win. Lastly, the top of the screen included a timer that began at 15 min and counted down to zero over the course of the game. Once the timer hit 14 min and 50 s (i.e. 10 s into the phase), both the participant and their opponent would be able to start shooting at one another. This prevented participants from being caught off guard, since it allowed the participant to locate the opponent in the level before it started shooting. Lastly, we asked participants not to speak to the other participant in the room (if there was one), since this could distract them from their task and produce unrepresentative data. We then asked if participants had any questions prior to starting phase 1.

After delivering the instructions, we loaded participants into phase 1 using one of the corresponding workshop map codes (see below). Both phases 1 and 2 took place on the level 'Workshop Chamber'. Participants loaded into the level on the character Soldier: 76. Shortly afterwards, their computerized opponent loaded in. The computerized opponent also used Soldier: 76. Once the game timer hit 14 min and 50 s, the participant and their opponent began fighting one another in the game. After 15 min or 40 eliminations, whichever came first, we loaded the participants out of phase 1 and told them that they could begin phase 2, which we said was against a different participant than they had played against in phase 1. However, phases 1 and 2 were identical with the exception of the computer opponent. We then loaded participants into phase 2, which they played for 15 min or up to 40 eliminations.

In our Workshop game mode, participants could only walk using W-A-S-D and shoot using the left mouse button. We disabled all other abilities (keys E, Q, L-Ctrl, L-Shift) to avoid disadvantaging less experienced participants. All participants played at a standardized mouse sensitivity of 20 cm per 360° on 800 dpi. To account for dpi deviation, we tuned the in-game sensitivity until 20 cm on the desk surface equalled a full 360° rotation in the game. We also disabled the so-called 'kill-cams', as they would have revealed to participants that their opponent was a computer (since computers do not aim like humans).

We coded the computer opponent identically for all Workshop codes, except for one variable: damage dealt by the computer opponent towards the participant. For the easier treatments (e.g. phase 1 winner for the least experienced participants), we reduced the amount of damage the computerized opponent did to the participant. For the harder treatments (e.g. phase 1 loser for the most experienced participants), we increased the amount of damage the computerized opponent did to the participant. This manipulation kept participants blind to the opponent's artificialness, since participants would believe that the difficulty of their opponent (or lack thereof) was due to the opponent's skill at aiming with the computer mouse.

Table A1
Output table for the generalized linear model we used to analyse the results of the video game experiment

Source	Type III sum of squares	*df*	Mean square	*F*	*P*
Corrected model	3932.223	3	1310.741	19.848	0.000
Intercept	191.902	1	191.902	2.906	0.090
Treatment	875.901	1	875.901	13.263	0.000
Sex	2980.000	1	2980.000	45.125	0.000
Treatment*sex	114.539	1	114.539	1.734	0.189
Error	14198.407	215	66.039		
Total	18131.000	219			
Corrected total	18130.630	218			

Table A2
Output table for the generalized linear model we used to analyse the results of the reading comprehension experiment

Source	Type III sum of squares	*df*	Mean square	*F*	*P*
Corrected model	9546.877	11	867.898	1.494	0.139
Intercept	345775.810	1	345775.810	595.381	0.000
Treatment	2421.601	1	2421.601	4.170	0.043
Sex	30.310	1	30.310	0.052	0.820
Experience	930.278	2	465.139	0.801	0.451
Treatment*sex	5.470	1	5.470	0.009	0.923
Treatment*experience	4522.965	2	2261.483	3.894	0.022
Sex*experience	1978.130	2	989.065	1.703	0.186
Treatment*sex* experience	2132.352	2	1066.176	1.836	0.163
Error	89437.605	154	580.764		
Total	853568.000	166			
Corrected total	98984.482	165			

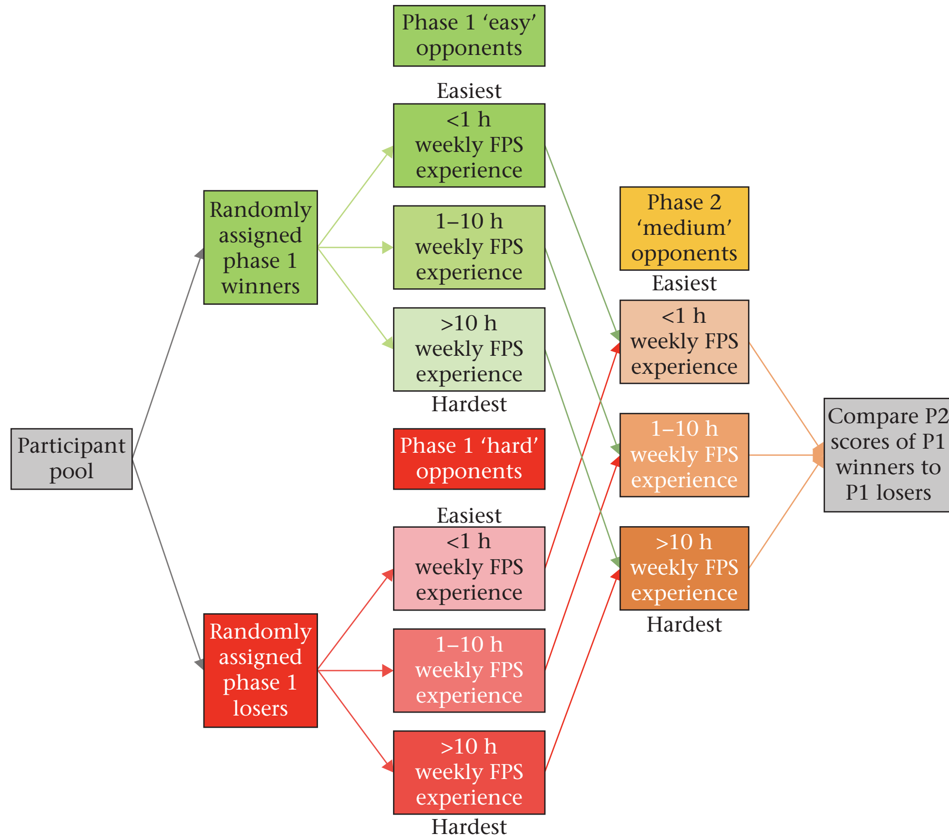


Figure A1. Design of the video game experiment. We randomly assigned all participants to either a phase 1 win or a phase 1 loss. We then matched winners and losers to phase 1 opponents (centre column) based on the participant's self-reported first-person shooter (FPS) experience. After phase 2, all opponents played a 'medium' opponent in phase 2, which was also adjusted for the participant's FPS experience. 'Easiest' and 'Hardest' refer to the difficulty of the computerized opponent within the treatment.

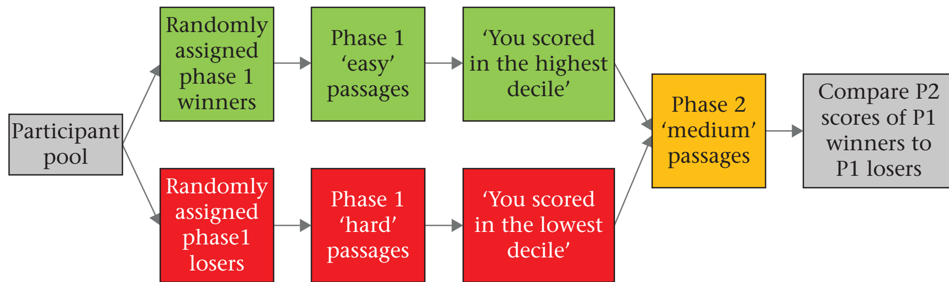


Figure A2. Design of the reading comprehension experiment. We randomly assigned participants to two conditions: phase 1 high score or phase 1 low score. We influenced experience in two ways: passage difficulty (phase 1 high scorers had easier passages; phase 1 low scorers had harder passages) and feedback (phase 1 high scorers received feedback indicating they scored in the highest decile; phase 1 low scorers received feedback indicating they scored in the lowest decile). We believed the feedback, which provided a measure of social comparison through relative score, could account for the absence of overt competition. After feedback, all participants read two phase 2 passages, which were of 'medium' difficulty and were identical for all participants.