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Cybernetic combatants support the importance of duels in the evolution of extreme weapons

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A current evolutionary hypothesis predicts that the most extreme forms of animal weaponry arise in systems where combatants fight each other one-to-one, in duels. It has also been suggested that arms races in human interstate conflicts are more likely to escalate in cases where there are only two opponents. However, directly testing whether duels matter for weapon investment is difficult in animals and impossible in interstate conflicts. Here, we test whether superior combatants experience a disproportionate advantage in duels, as compared with multi-combatant skirmishes, in a system analogous to both animal and military contests: the battles fought by artificial intelligence agents in a computer war game. We found that combatants with experimentally improved fighting power had a large advantage in duels, but that this advantage deteriorated as the complexity of the battlefield was increased by the addition of further combatants. This pattern remained under the two different forms of the advantage granted to our focal artificial intelligence (AI) combatants, and became reversed when we switched the roles to feature a weak focal AI among strong opponents. Our results suggest that one-on-one combat may trigger arms races in diverse systems. These results corroborate the outcomes of studies of both animal and interstate contests, and suggest that elements of animal contest theory may be widely applicable to arms races generally.

1. Introduction

It has been suggested recently that animal weapon exaggeration (the evolution of extremely enlarged or elaborate forms, beyond that which is usual among similar species) is more likely to occur in species where combatants face each other in duels [1]. This is because in duels, the outcome is expected to be more deterministic, with stronger or better-armed contestants consistently winning fights [1]. Thus, it is suggested that arms races are more likely to occur in duel-based systems, leading to the evolution of elaborate weaponry such as the exaggerated structures wielded by many male animals in fights over females (e.g. [2–7]). A key observation supporting this hypothesis is that among dung beetles (Scarabaeidae), those species that fight in duels tend to bear large and elaborate horns, while those that fight in skirmishes do not [8,9]. By contrast, systems where combatants face each other en masse (e.g. horseshoe crabs [10] and Dawson's burrowing bees [11]) may have less predictable outcomes, and weaker or less well-armed individuals may sometimes be victorious [1,12,13]. In such a scenario, selection may instead favour adaptations relating to energy efficiency, agility, endurance, learning or behaviour, instead of direct fighting power and extreme weaponry [14–17]. Duels may be just as important for weapon escalation in military technologies, for precisely the same reasons as described above in animal systems [1,18–20]. New technologies (e.g. battering rams on oared galleys, closeable gun ports on sailing galleons, machine guns on early aircraft) that aligned military vehicles in close-range one-on-one

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engagements (i.e. duels) have long been considered catalysts of military arms races [18,19]. If true, then this would point to an exciting parallel between animal and military forms of conflict. Experimentally testing for the importance of duels in human conflicts has obvious practical and ethical drawbacks, but there are additional non-animal systems in which there is severe conflict, without those obstacles. One example is computer-simulated warfare, where programmed combatants attempt to destroy each other in a digital behavioural medium.

Helpfully, the realm of computerized war gaming has provided many highly tuned, adaptable and diverse conflict simulators with massive effort spent perfectly tuning the models for high-stakes E-sports competition [21–24]. In addition, the user interfaces of these programs are developed to allow detailed customization of factors such as arena layout, combatant characteristics, motivation, victory conditions and countless more. These advantages have made war games a favourite basis for research in artificial intelligence (AI), statistics, human cognition, machine learning and strategy (e.g. [25–29]). We feel that war games can have as much or an even greater benefit to understanding biological concepts such as animal contests and weapon evolution.

Here, we set the programmed AI combatants provided by the real-time strategy (RTS) war game Starcraft 2 against one-another to test whether duels favour superior combatants disproportionately more than skirmishes. Similarly to the animals used extensively for contest research, including insects, spiders and crustaceans (e.g. [30–32]), the AI's senses are limited to their local environment, they operate according to a set of simple rules, they use resources from their environment in order to grow, and they can trade off developmental speed with size or elaboration at maturity. As such, we consider them an appropriate subject for the extension of theory based on animal study species, while being different enough to be informative in regard to the generality of the hypothesis.

For the purposes of this approach, we consider duels and skirmishes fought by the AI to be comparable to various biological scenarios, including actual one-on-one fights between individuals, as featured in the many animal mating systems where rival males clash head-to-head (e.g. [4,33–35]) as opposed to the chaotic multi-combatant fights that occur in other species (e.g. [11,36,37]). In addition, because of the format of the game we consider the AI matches to also serve as models of competition over resources among colonies of individuals, which may similarly unfold in colony-to-colony or multi-colony conflicts, as competition unfolds for example in many species of social Hymenoptera (e.g. [38]) or microbes (e.g. [39]). Those similarities aside, the purpose of this study is to examine armed conflict in an entirely new system. Consequently, we do not expect the AI combatants used here to precisely model any specific system (animal or otherwise). Also note that we did not seek to simulate ecological conditions that might lead animals to fight in duels or not. Instead we experimentally created duel or skirmish scenarios in order to examine the relative advantages of weaponry in these contrasting forms of conflict.

To examine our general hypothesis, we specifically tested: (i) whether AI with improved weaponry fared better than expected in duels than in skirmishes, (ii) whether AI that invested more than their competitors in weapon technology were more likely than expected to win matches when facing fewer opponents and (iii) whether AI given an 'artificial' weaponry advantage were more likely than expected to win matches when facing fewer opponents.

2. Material and methods

(a) Defining 'individuals' and 'weapons' in a war game

We used the RTS war game Starcraft 2 (v. 4.2.0, released 20 February 2018—the most recent version at the time) to set the built-in AI combatants against one-another. Ordinarily, these programmed agents serve as opponents for human players, but in this case we set up matches between the AIs only, without any human players involved. In this game, competitors are simultaneously spawned in separate locations on an arena containing resources, which are harvested and spent in order to buy damage-dealing components referred to as units. The units comprising each combatant are graphically represented as soldiers or fighting creatures, and have the ability to deal damage or use abilities that affect the battle in various ways. Although the units are graphically represented as independent creatures moving in a spatial medium (figure 1), this is for human interpretation only. In fact, the constellation of units controlled by each AI might be better interpreted as the constitutive parts (cells, appendages) available for allocation by the AI at any point in time. Similarly, other dynamic traits of the AI, such as their stockpile of harvested resources, their roster of upgrades achieved and their growth on the arena could be thought of as analogous to forms of animal condition. For example available energy, developmental maturity or body size. However, these are not strict equivalents and we do not seek to treat them as such here. Rather we recognize that, like animals, the AIs have a wide variety of traits that they could allocate resources to, and we seek to test whether weapon elaboration is particularly favoured in duels. We consider the units and their presence in the arena as the AI's equivalent to weaponry because it is through the units and the manoeuvring of them that the AI deal damage to each other.

Consequently, the combatant individuals in this system are the AI—they accumulate resources, select strategies, decide when to attack or retreat, develop weaponry (units) and ultimately win or lose the battle by fighting until destroyed. Graphically, the AIs are represented as having an army of units. Mechanically, however, each AI is an individual. It is these AI individuals that we set against one-another for the experiments outlined below. This is similar to animal systems, in which the individual combatants are recognized as such despite being comprised multiple subservient components at different scales, such as appendages, organs, cells, organelles and so on. As such, in our experiments outlined below, duels refer to battles between two AI, and skirmishes to battles with more than two AI.

(b) Increasing (or decreasing) weapon superiority

The ability of AI to accumulate new and/or better units follows a branching, hierarchical 'tech-tree', such that technology investment by the combatant unlocks more advanced units and weaponry over the course of the match. In this way, an arms race is built in to the game design, with a large advantage generally going to the side with superior weapons [40]. The game includes three tech-tree subsets (hereafter named 'P', 'T' and 'Z'), each of which features a unique suite of buildable units and a slightly different method of producing them. A huge and ongoing amount of game design effort is applied by the developer (e.g. [41]) to ensure that these subsets are perfectly balanced (i.e. none has an inherent advantage over either of the others).

We increased the combat advantage of a focal AI in two ways; a 20% increase in all unit hit-points (thereby increasing the damage-dealing potential of the AI's weaponry relative to enemies), or increasing a difficulty setting to one higher than

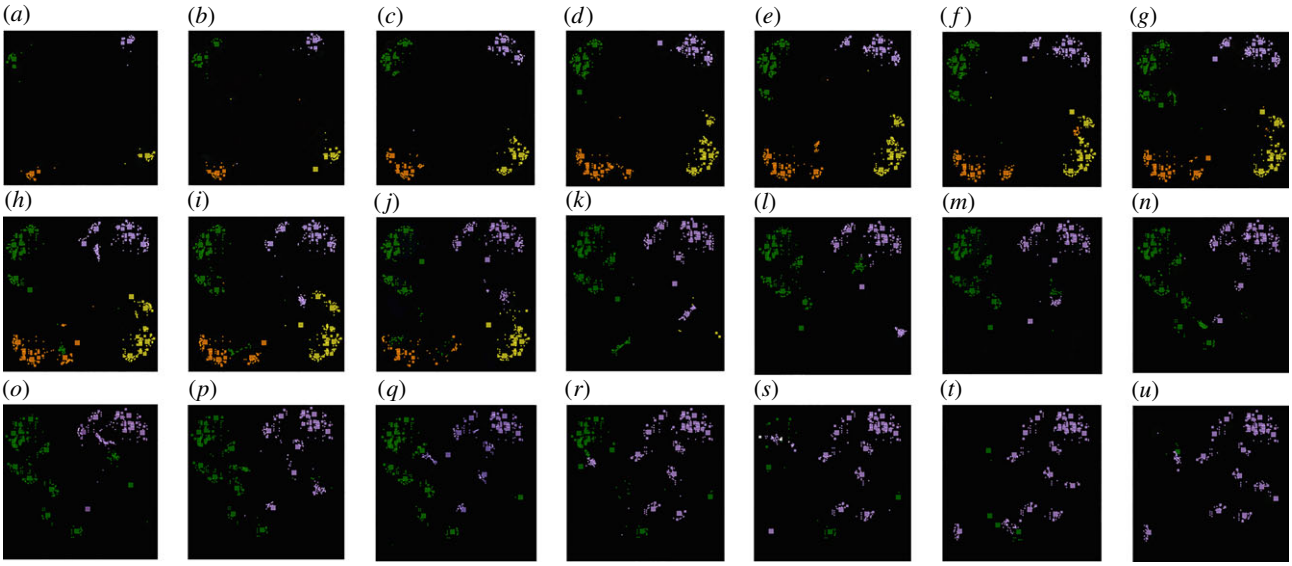

Figure 1. Example of a typical four-way battle, in birds-eye snapshots of the arena taken every 2 min. Black panels indicate the limits of the arena, and coloured dots are units controlled by each of four AI Note that the representation of a swarm is a graphic for human representation only—each unit is intrinsically a part of the AI individual to which it belongs, represented by the four colours. (*a*) The AI start in opposite corners of the arena. (*b–d*) The AI use local resources to grow, expanding into the nearby territory. (*e*) Orange AI makes the first military excursion and (*f*) attacks the yellow AI unsuccessfully, while the pink and green AI continue to focus on growth. (*g–i*) The green AI attacks the now weakened orange AI (*j–k*) The green AI finishes destroying orange, while pink expands territory, attacks and destroys the weakened yellow AI (*l–n*) The green and pink AI continue to grow, expanding into the territory of their defeated opponents, and exchanging minor battles. (*o–p*) The green AI makes an unsuccessful attack against pink, losing most of its fighting forces. (*q*) The pink AI counter-attacks the green peripheral territory, largely destroying it. (*r–u*) Pink attacks the green core territory, destroying it and consolidating dominance of the arena. (Online version in colour.)

all other opponents (focal AI 'elite' versus 'very hard' combatants).

Increasing unit hit-points represents an improvement to the AI's weaponry in a number of ways, for example:

(a) It allows units to persist for longer, thereby increasing their lifetime damage output because damage occurs over time.
(b) It increases the value of abilities that restore hit-points, by increasing the pool of hit-points available to be restored. This then feeds back into (a), above.
(c) It increases the value of the unit's own traits that interact with their hit-points, such as upgrades that iteratively reduce incoming damage, by multiplying the benefit across more hit-points.
(d) It decreases the number of units likely to be lost in a given point of contact with the enemy, thereby avoiding their replacement cost (which can then be spent on further increasing weaponry), and reducing the recovery time between attacks, allowing the AI to make more attacks per unit-time.
(e) It increases the chances that units persist until damage-boosting upgrades are added to them, thereby increasing the total damage advantage granted by those upgrades by multiplying it across more units.
(f) It increases the number of times that units can use abilities or manoeuvres that sacrifice hit-points for damage benefits.
(g) It decreases the ability of opponents to avoid damage by selectively eliminating parts of the AI with low hit-points and high damage-dealing ability.
(h) It relatively weakens opponent weaponry (because damage is dealt to hit-points).

Increasing an AI's difficulty setting increases its resource collection rate, developmental speed and progression up the tech-tree, making them a stronger fighter more likely to acquire superior weaponry earlier than an opponent AI.

We also tested the inverse scenarios with a focal AI given a 20% decrease in unit hit-points or a difficulty setting one lower than all other opponents (focal AI 'very hard' versus 'elite' combatants).

We observed battles with the focal AI facing between one and six other AI in free-for-all (FFA) battles (i.e. no allegiances, any contestant able to win by elimination of all others), and tested whether stronger fighters were more favoured in duels relative to skirmishes by comparing the win–loss ratio achieved by a focal AI to the expected null win–loss ratio (i.e. 0.5 in a duel, 0.33 in a three-way battle and so on). We carried out 30 battles under each scenario (tabulated for clarity in electronic supplementary material, table S1), for a total of 720 battles. All battle simulations were carried out on a custom-made, radially symmetrical arena with unlimited resources to fuel the AI Starting positions, AI strategies and AI tech-tree subset selection were randomized in each trial. We considered the type of battle (i.e. duel, three-way and so on) as an ordinal variable and performed a χ^2- test for trend in proportions (function *prop.trend.test* in R, v. 3.3.1, [42]). Because we expected a negative trend in win–loss ratio under the null hypothesis, we artificially modified the argument 'number of trials' to equal double the expected number of victories under the null hypothesis (i.e. 15 for duels, 10 for three-way, 7.5 for four-way) instead of being fixed at 30 (e.g. duels: $15 \times 2 = 30$, three-way: $10 \times 2 = 20$ and so on). That way for each number of opponents, we had an appropriate null expected number of wins against which to compare the focal AI's observed number of wins.

(c) Relative advantage of upgrade spending in duels versus skirmishes

To examine whether weaponry advancement in particular provided an advantage in duels relative to skirmishes, we observed further battles with all AI starting on an equal footing, and compared the weaponry investment of eventual contest winners with that of losers in duels, four-way FFAs and eight-way FFAs. Weaponry investment was extracted from the in-game record of

combatant's military research expenditure, referred to as 'upgrade spending'. We carried out 52 of each battle type, for a total of 156 battles. Arena layout and settings were kept as above, except that no advantage or disadvantage was granted to any AI Post-battle upgrade spending scores for each contestant were recorded as a proportion of the highest upgrade spending score in the game over time.

We did not collect data on upgrade spending in the last 60% of the elapsed match time, because in the late-game, combatants which have already gained the upper hand will almost always acquire more resources and invest those in further tech-tree development, creating a feedback between success in the contest and upgrade spending. Because of that, we only wanted to measure early-game investment, and examine how that translated into eventual victory.

We fitted a linear mixed-effects model (function *lmer* in 'lme4' [43]) with winner relative upgrade spending as the response variable, time (in % of elapsed match time) and battle type (duel, four-way or eight-way) as explanatory variables. We included game identity as a random factor because these measures at different times are not independent from one another (as they are associated with the same game). Type III *F*-tests using the Satterthwaite's method to estimate degrees of freedom (function *anova* in 'lmerTest' [44]) were then used to specifically test the significance of the effects of battle type, elapsed game time and their interaction on winner's upgrade spending. Finally, *post hoc* tests were used to compare intercepts (function *emmeans* in 'emmeans' [45]) and slopes (function *emtrends* in 'emmeans') between each battle type.

(d) Relative advantage of advanced units in duels versus skirmishes

In addition, we observed matches between two to seven combatants, with a focal AI given a selection of high-tech units, while all others were restricted to the three most basic units for their tech-tree subset. By contrast to the previous trials, we did not observe 'natural' battles with AI following the usual scenario of resource collection and development, culminating in a self-produced set of weaponry. Instead, we set the starting conditions of the match such that each AI began the game with a predetermined, fixed set of military units from the same tech-tree subset, in close proximity to one another. In this way, the experiment was more similar to a classical ethological experiment staged in a laboratory with mature animals in a small arena. This approach, therefore, removed the stochastic influences of resource acquisition, strategy selection, arena exploration and research decision differences between the AI. Instead, they appeared fully formed and adjacent to one-another at the start of the match, and immediately fought to elimination. We repeated this process for each of the three tech-tree subsets, with 30 battles at each number of combatants (between two and seven), thus observing a total of 540 battles. At first we carried out battles with all AI having a number of units that granted them equal total supply (the in-game measure of a unit's value), however, this gave our focal combatant an overwhelming advantage, removing all variation from battle outcomes. We therefore increased the total unit supply of the low-tech AI, to equal 150% of the focal AI unit supply. In this way, the combatants were more balanced for total fighting ability, while the focal AI still had a weapon technology advantage. These contests were carried out on a flat, featureless arena, with opponents starting in contact with each other. The units were arranged as columns (one column for each combatant) in a spoke formation, such that a duel started as a straight line of units, half belonging to each combatant, and a multi-way battle started as a star or asterisk-shaped array, with each arm belonging to a different combatant. Similarly to our first experiment, we compared trend in win–loss ratios achieved by the focal AI as a function of the number of combatants, to the expected null trend using a χ^2-test for trend in proportions for each tech-tree.

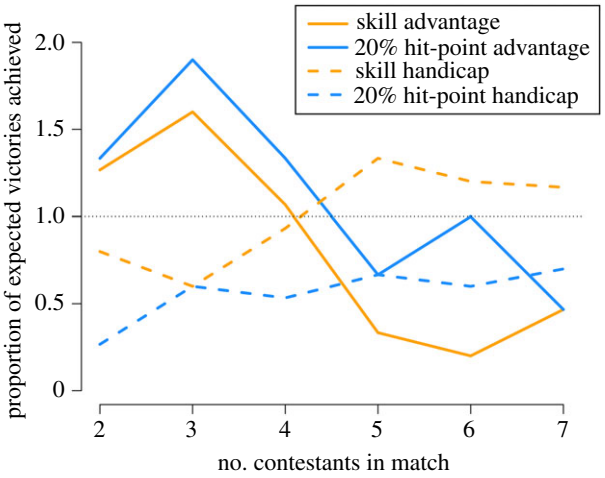

Figure 2. Number of victories achieved by focal AI with an advantage or disadvantage, relative to the expected number under the null hypothesis (i.e. each combatant has the same chances to win), in FFA battles of varying combatant number. The dotted line indicates expectations under the null. (Online version in colour.)

3. Results

The AIs fought each other to elimination in all cases except for $n = 2$ draws in the first experiment, which were discarded and re-run. FFA battles were more chaotic than duels, with multi-way skirmishes and flanking manoeuvres commonly occurring (figure 1).

AIs that were granted an advantage in either difficulty or unit hit-points relative to their competitors achieved a greater proportion of their null expected victory count in battles with fewer participants (difficulty advantage: $\chi^2 = 16.31$, $p < 0.0001$; hit-point advantage: $\chi^2 = 10.14$, $p = 0.001$), while this trend was reversed when focal AIs were weakened by applying difficulty or hit-point handicaps (difficulty handicap: $\chi^2 = 3.55$, $p = 0.06$; hit-point handicap: $\chi^2 = 2.26$, $p = 0.13$; figure 2).

In battles without experimental alterations made to the AI, we found that elapsed game time ($F_{1,1089} = 10.42$, $p = 0.001$), battle type ($F_{2,720.3} = 55.6$, $p < 0.0001$) and their interaction ($F_{2,1089} = 34.6$, $p < 0.0001$) had a significant effect on winner relative upgrade spending. Specifically, duels were won more often by combatants with superior technology in the early game (higher intercept, electronic supplementary material, table S2) relative to their opponents, than were FFAs with four or eight combatants (figure 3).

Additionally, when focal AI with relatively more advanced weapon technology were set against less advanced competitors, the focal AI won a greater proportion of their expected number of battles in duels relative to multi-way skirmishes. This was the same for each of the three tech-tree subsets (tech-tree 'P': $\chi^2 = 9.06$, $p = 0.003$; tech-tree 'T': $\chi^2 = 26.71$, $p < 0.0001$; tech-tree 'Z': $\chi^2 = 24.61$, $p < 0.0001$, figure 4).

4. Discussion

The dyadic nature of animal contests has long been taken for granted. Models of conflict resolution, staged contests and

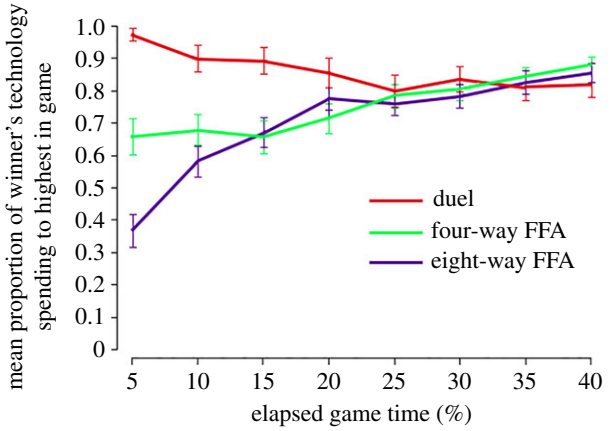

Figure 3. Mean relative weaponry investment of eventual contest winners in duel, four-way and eight-way FFA matches. Elapsed contest time is cut off at 40% due to feedback of contest-winning onto ubiquitous weaponry investment in later stages. Error bars represent standard error of the mean. (Online version in colour.)

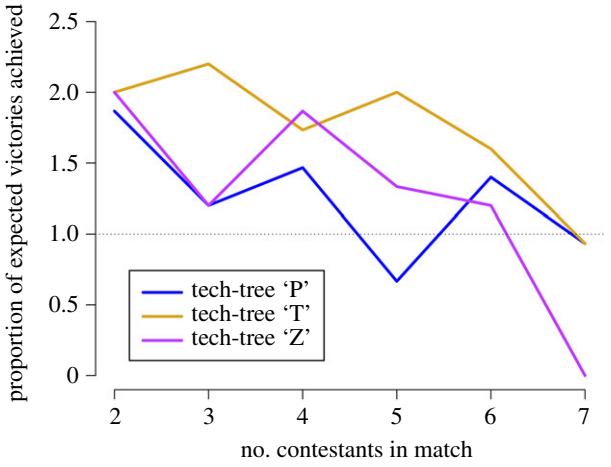

Figure 4. Number of victories achieved by focal AI with a technology advantage, relative to the expected number under the null hypothesis (i.e. each combatant has the same chances to win), in FFA battles of varying combatant number. The three different tech-tree subsets in the game are represented by the different line colours. The dotted line indicates expectations under the null. (Online version in colour.)

field observations of species bearing weapons all focus on the one-on-one confrontations of rival males (reviewed by Briffa & Hardy [46]). Although the outcome of multi-player scrambles was known to be less predictable than duels [13,47], the transition to dyadic fighting was never considered to be a potential driver of animal weapon evolution.

The importance of duels was recognized first by military historians, who noted that new technologies which brought opponents or vehicles into close contact often sparked an arms race, and that interstate conflicts were most likely to escalate when they coalesced around a pair of evenly matched foes (reviewed by Dupuy [18] and O'Connell [19]). This idea borrowed from the military literature cast animal contests in a new light, and since then the importance of third-party intervention and the possibility of multi-way combat has been gaining attention. In species in which animals live in social groups, but in which conflict arises over resources or social dominance, third-party intervention has been shown to influence coalition formation and dominance hierarchies (spotted hyenas [48]; baboons [49]; ravens [50]). Even in systems that have been thought of as classic examples of duels, such as in contests between male deer during the rut, third-party intervention has been shown to be important [51]. In fallow deer (*Dama dama*), around 10% of contests between stags are disrupted by interveners [51] and interveners improve their mating success [52], while those suffering intervention, have reduced mating success [53].

Clearly, not all animal contests are duels, and the proportion of contests occurring as duels may help explain population and species differences in relative weapon size (e.g. [13,54]). If true, then the behavioural transition from scrambles to duels could underlie the initiation of arms races in both animal and military weapons, highlighting a simple property of confrontations with far-reaching consequences for all types of conflict. Here, we tested whether dyadic encounters are important for weapon evolution using a system analogous to, yet nonetheless distinct from, both animals and military technologies; cybernetic combatants in computer war games.

We found that increasing numbers of cybernetic combatants reduced the benefits of weaponry or power that occur in dyadic contests. In duels, combatants with greater power (as granted in two different forms) had a large advantage, but that advantage deteriorated as the number of competitors increased. Conversely, experimentally weakened contestants suffered less of a disadvantage in multi-way skirmishes, winning relatively more often in contests with more combatants. In particular, combatants with the highest early-game investment in weaponry often went on to win duels, but in FFAs, this trend was reduced. Furthermore, when we experimentally granted focal AIs a weaponry advantage in the form of high-tech units, they enjoyed a greater benefit in duels relative to multi-way skirmishes. Therefore, our results suggest that the evolutionary hypothesis regarding the role of duels in animal and military weapon evolution may accurately reflect underlying natural laws of conflict, and possibly explain the occurrence of arms races in disparate duel-like systems.

It is interesting that strengthened AIs won fewer than their null expected number of victories in skirmishes with more than four combatants, because it suggests that in contests against multiple combatants, their greater power actually became a disadvantage in some way. This could be due to early-game dominance granting them large territories which became hard to manage at later stages, or through hyper aggressive strategies causing them to 'burn out' against multiple opponents while more passive tactics endured longer. Assessment of these possibilities was beyond the scope of the current study, but they open interesting questions for future examination. It may be that similar feedbacks restrict strategies based on high aggression or weapon specialization in biological systems where interactions between more individuals at any given time are common. Animals with exaggerated weapons are known to suffer metabolic, biomechanical and locomotory costs [55–59]. Likewise, there is growing evidence that weapons show developmental trade-offs with testes [60,61] and other morphological structures that grow in proximity to weapons [62]. Exaggerated weapons that convey an advantage in one context (fights) have also been shown to be a disadvantage in another context (races through tunnels) in the dung beetle *Onthophagus taurus* [14].

Here, we have shown that although the exaggerated weapons of AIs conveyed an advantage in duels, that advantage

deteriorated in multi-opponent skirmishes. In the context of our second experiment, this could be due to the AI's investment in weapon technology trading off with alternative strategies that may increase their chances of victory against multiple opponents. This trade-off may therefore favour different resource allocation strategies depending on the number of opponents. Our third experiment also suggested that another trade-off may occur entirely within the context of fights themselves as the advantage of superior weaponry declined with greater numbers of opponents, even with the potential for alternative strategies (such as rushing or sneaking) removed. In that experiment the only variable other than weaponry was the number of opponents, so it could be that choices such as how many different opponents to engage at a time, or who among them to engage, might overshadow weaponry differences at high contestant numbers. We hope that studies of animal contests between varying numbers of competitors might evaluate whether such a trade-off also occurs in nature.

Because our results arose in a non-biological system, they suggest that duels may feed arms races not only in the context of exaggerated weaponry and animal contests but also in other systems as well. These might include evolutionary arms races such as those between parasites and hosts, or arms races in non-biological systems such as human technology, business, military escalation, trade wars or cyber warfare. In many of these scenarios, conflicts can be played out in a duel-like fashion (such as between a specialist parasite or predator and its crucial host or prey species) or more skirmish-like (such as between generalists). Indeed, this logic tracks closely with the idea of 'hot spots' and 'cold spots' in the geographical mosaic theory of coevolution [63]. In any scenario where the only way to win (or survive, or reproduce) is to outcompete a single rival that is in the same situation, we might expect extreme development of something analogous to weaponry or resource holding potential.

Although game theory has been critical to explaining various evolutionary phenomena (e.g. [64]), the use of actual games to test evolutionary theory has not been employed to our knowledge, beyond the use of pure mathematical models. Our results highlight the potential to examine complex biological contests with the pre-existing conflict simulators that are provided in the form of consumer war games. In this way, other aspects of contests could also be examined. Various evolutionary and ecological concepts have equivalents in war gaming—resident versus intruder status in animal contest research [65] is analogous to the 'defender's advantage' in war gaming, assessment of rivals [12] occurs during 'scouting' in war gaming and rock–paper–scissors-style alternative strategies (e.g. [66]) are paralleled in the concept of 'build-order-wins'. Fighting technique also has an effect on the type of weaponry that evolves [67,68], and war games also usually feature a range of possible techniques that can be employed, some focused on quickly acquiring certain weapon technology, and some focused on making efficient use of low-tech units. Another area which is beginning to be incorporated into evolutionary models of contests is the potential for offense to result in damage to self as well as damage to the opponent [69,70]. This is also something that could be easily examined with war game simulations, as aggressive forces suffer clear losses while attacking (in fact, these data are specifically quantified and reported by software designed to aid match analysis and commentary).

Finding that the predictions of hypotheses can apply to diverse systems suggests a match between the underlying theory and the laws of nature. Thus, we should seek to test predictions in systems different to those for which they were developed. We have done so with the current study, examining a hypothesis relating to the evolution of animal weaponry in a completely separate context. We ultimately found that in contests between AIs in a computer war game, the advantages of exaggerated weaponry in duels were negated in multi-opponent battles. We are unaware of studies of animal contests that specifically test whether third-party interventions negate or reduce any benefits of larger weaponry or other measures of resource holding potential, but our results suggest that they would, and that this could be a fruitful area for future research.

Data accessibility. This article has no additional data.

Competing interests. We declare we have no competing interests.

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