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Fight the power: Lanchester's laws of combat in human evolution

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ABSTRACT

Lanchester's "Laws of Combat" are mathematical principles that have long been used to model military conflict. More recently, they have been applied to conflict among animals, including ants, birds, lions, and chimpanzees. Lanchester's *Linear Law* states that, where combat between two groups is a series of one-on-one duels, fighting strength is proportional to group size, as one would expect. However, Lanchester's *Square Law* states that, where combat is all-against-all, fighting strength is proportional to the *square* of group size. If conflict has been important in our evolutionary history, we might expect humans to have evolved assessment mechanisms that take Lanchester's Laws of Combat into account. Those that did would have reaped great dividends; those that did not might have made a quick exit from the gene pool. We hypothesize that: (1) the dominant and most lethal form of combat in human evolutionary history (as well as among chimpanzees and some social carnivores) has been asymmetric raids in which multiple individuals gang up on a few opponents, approximating Square Law combat; and (2) this would have favored the natural selection of an evolved "Square Law heuristic" that correlated fighting strength not with raw group size but with group size *squared*. We discuss the implications for primate evolution, human evolution, coalitionary psychology, and contemporary war.

1. Introduction

> "Words are inadequate to describe the emotion aroused by the prolonged movement in unison that drilling involved. A sense of pervasive well-being is what I recall; more specifically, a strange sense of personal enlargement; a sort of swelling out, becoming bigger than life, thanks to participation in a collective ritual."
>
> [William McNeill (1995, p. 2)]

> "We've got them!"
>
> George Armstrong Custer, at the Battle of the Little Bighorn.
>
> [Stephen Ambrose (1975, p. 438)]

On 2 August 1867, Crazy Horse led a force of one thousand Sioux warriors in an attack on a US Army outpost near Fort Phil Kearny in northern Wyoming. Captain J. N. Powell gathered 26 soldiers and a handful of armed civilians in a corral of wagons, and they prepared to defend themselves. The Sioux initially circled Powell's position on horseback, firing arrows, intending to exhaust the cavalrymen's ammunition, but to no avail. Powell had stockpiled several thousand rounds, and the soldiers kept up a constant hail of fire. Eventually, Crazy Horse pulled his warriors back into a ravine, where they were partially protected from the gunfire. From here, the Indians attempted to attack on foot. The ravine was narrow which, as Stephen Ambrose describes, meant that "the men in front masked the mass of warriors in the rear, making it impossible for them to fire … Powell only had to deal with a handful of Indians, Crazy Horse and his fellow shirt-wearers [Sioux leaders] at the apex of the charge" (Ambrose, 1975, pp. 294–295). At this point, the outcome of the battle remained far from certain to those present. As one soldier recounted, "It chilled my blood … Hundreds and hundreds of Indians swarming up a ravine about ninety yards [away]… Our fire was accurate, coolly delivered and given with most telling effect, but nevertheless it looked for a minute as though our last moment on earth had come" (Ambrose, 1975, p. 295). Against their volleys of arrows and some astonishingly brave charges, the withering fire from the cavalry's new breech-loading rifles wore the Indians down and, after several hours' fighting, they withdrew to the mountains.

Against the backdrop of the earlier Fetterman massacre of 1866, when Crazy Horse and two thousand Sioux had surrounded Captain William Fetterman's force of 81 cavalrymen and annihilated them to a man, Powell's victory against the odds seemed nothing less than a miracle. But the reason Powell lived to see another day may well have been down to some fundamental mathematical principles of battle. Crazy Horse's congested attack up the ravine meant he was not able to bring his superior numbers and their deadly arrows to bear—even on a tiny enemy force. Meanwhile, Powell's concentrated fire on the lead ranks of Indians meant that, despite Powell's force being outnumbered 25 to 1, any Indian that squeezed onto the frontline fell into the sights of several American soldiers at once. Despite Crazy Horse's numerical

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supremacy and the advantage of surprise, the deck was stacked against him.

The "Wagon Box Fight" of 1867 reflects the mathematical patterns of Lanchester's Laws of Combat (Lanchester, 1916). These "laws" are mathematical equations that model the dynamics of conflict and its outcomes, and were originally developed with modern human warfare in mind. Although they have long been used in military operational research (for reviews, see MacKay, 2006; Wrigge, Fransen, & Wigg, 1995), they have only recently been applied to explain variation in the patterns of conflict in animals such as ants, birds, lions, and chimpanzees (Franks & Partridge, 1993; Mosser & Packer, 2009; Plowes & Adams, 2005; Shelley, Tanaka, Ratnathicam, & Blumstein, 2004; Whitehouse & Jaffe, 1996), including manipulation experiments showing variation in fighting behavior as parameters were changed (McGlynn, 2000; Wilson, Britton, & Franks, 2002).

Much of the literature on Lanchester's Laws looks at models and data with regard to combat *outcomes*. In this paper we make a rather different kind of argument. First, we argue that Lanchester's Square Law, under which imbalances in numbers are disproportionately advantageous to the larger side, is especially applicable to pre-military human conflict, and is likely to have influenced its dynamics for several million years. This provides substantive support to theories about the importance of human groups and coalitions in early warfare (Alexander, 1987; Bingham, 2000; Pitman, 2011; Wrangham, 1999a).[1]

Second, the question then naturally arises: Have we evolved corresponding assessment strategies that influence when (and how) we choose to fight? Violent conflict is argued to have played a major role in our ancestral past (Buss & Shackelford, 1997; Ferguson, 2012; Gat, 2006; Guilaine & Zammit, 2004; Keeley, 1996; LeBlanc & Register, 2003; Potts & Hayden, 2008; Wrangham & Peterson, 1996, though for an earlier, contrasting view see Knauft 1991). Empirical studies suggest that warfare accounted for around 15% of male deaths among archeological and ethnographic data (and much more in some societies Bowles, 2006; Keeley, 1996; Otterbein, 1989), implying strong selection pressure on adaptations for fighting—and winning. We therefore hypothesize that natural selection should have favored assessment mechanisms that take the Square Law into account, leading to an evolved "Square Law heuristic" in the context of coalitionary conflict. Thus the Square Law becomes more than a *post hoc* model of conflict outcomes: rather it may be an evolved heuristic that influences decisions about whether or not to fight in the first place, continuing to affect decisions about conflict today. If so, this carries major implications for understanding human conflict in our past, present, and future.

2. Lanchester's Laws of Combat

Although there are variations in how the models are set up, and in real life there are many complicating factors (Adams & Mesterton-Gibbons, 2003; Johnson & MacKay, 2011; MacKay, 2011), the underlying logic of Lanchester's Laws capture the essence of conflict processes irrespective of species or setting—"elementary principles", as Lanchester called them, "which underlie the whole science and practice of warfare in all its branches" (Lanchester, 1916, p. 39). The key insight is the distinction between the Linear Law and the Square Law.

2.1. Lanchester's Linear Law

Consider two opposing sides with m individuals in the blue force and n individuals in the red force (we follow the notation of Adams & Mesterton-Gibbons, 2003), in hand-to-hand combat along a battle line. If α denotes the fighting ability of individuals, then the attrition rate for the blue force is

$$\mathrm{d}m/\mathrm{d}t = -\alpha_n l, \tag{1}$$

while for the red force

$$\mathrm{d}n/\mathrm{d}t = -\alpha_m l, \tag{2}$$

where l is the length of the battle-line, representing the number of individuals on each side actually engaged in the fighting. The crucial feature is that this is the same for each side, for example $l = \mathrm{Min}(m,n)$ (*i.e.* the number in the smaller of the two forces, though it may be constrained by some other factor such as the available space in which to fight). Nor do we need to know the precise form of l in order to predict the battle's outcome. If we divide Eq. (1) by Eq. (2), the explicit time-dependence disappears, as does the dependence on l, and we have

$$\mathrm{d}m/\mathrm{d}n = \alpha_n/\alpha_m, \tag{3}$$

so that the casualty ratio $\mathrm{d}m/\mathrm{d}n$ is constant.[2] Rearranging and integrating (which corresponds to summing over all the small changes that combine to determine the outcome) we obtain

$$\alpha_m(m_0 - m) = \alpha_n(n_0 - n), \tag{4}$$

where m_0 and n_0 are the initial numbers of blue and red soldiers. Thus m wins if

$$\alpha_m m_0 > \alpha_n n_0. \tag{5}$$

Following Lanchester, we call this combination of numbers and prowess (in this case, simply their product) the "fighting strength" of a given group, so that the force with the greater fighting strength wins the battle. In this, Lanchester's Linear Law, fighting strength is *proportional* to fighting ability (α) and *proportional* to group size (m).

2.2. Lanchester's Square Law

Here's where it gets interesting. Consider two opposing sides as before. This time, attrition rates for the blue force are

$$\mathrm{d}m/\mathrm{d}t = -\alpha_n n \tag{6}$$

and for the red force

$$\mathrm{d}n/\mathrm{d}t = -\alpha_m m. \tag{7}$$

The difference is that, in this fight, combat is not restricted—there is no battle line, no set of duels, no one unable to get into the fight. Rather, each force can engage all its soldiers, and thereby cause enemy losses in proportion to its own numbers. For Lanchester, this was the defining property of war characterized by accurate, aimed projectile fire (such as rifles). But such conditions occur more generally whenever some form of "ganging up" is possible.

Now we again divide one equation by the other, obtaining

$$\mathrm{d}m/\mathrm{d}n = (\alpha_n/\alpha_m)(n/m). \tag{8}$$

In contrast to Eq. (3), the casualty ratio is not constant, but rather is proportional to the force ratio (to be clear, the "force ratio" being n/m). This has stark effects when we rewrite Eq. (8) as

$$\alpha_m m \,\mathrm{d}m = \alpha_n n \,\mathrm{d}n, \tag{9}$$

[1] For recent collections on the evolution of human violence more generally see Shackelford and Hansen (2014) and Fry (2013).

[2] Of course, in real hand-to-hand pitched battles casualty numbers often are hugely asymmetric, usually because most casualties occur in the rout of fleeing troops rather than in the battle line, a point recognized by Lanchester. They also depend on the skill of the soldiers, as detailed below.