Scale Invariance in Global Terrorism

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Traditional analysis of international terrorism, now an endemic feature of the modern era, has not sought to explain the emergence of rare but extremely severe events. Using the tools of extremal statistics, we analyze terrorist attacks worldwide between 1968 and 2004, as compiled in the National Memorial Institute for the Prevention of Terrorism (MIPT) database [1]. We find that international terrorism exhibits a "scale-free" behavior [2] with an exponent close to two. We conjecture that such power-law behavior is an extension of the still unexplained scale invariance between the frequency and intensity [3] of wars [4, 5, 6, 7]. Finally, we briefly consider the reasons why such scaling may exist and its implications for counter-terrorism policy.

Although terrorism has a long historical relationship with politics [8], only in the modern era have small groups of motivated individuals had access to extremely destructive weapons [9, 10], particularly chemical or explosive agents. This dramatic increase in destructive power has allowed severe terrorist attacks such as the March 20 1995 release of the Sarin nerve agent in a Tokyo subway which injured or killed over 5000, the August 7 1998 car bombing in Nairobi, Kenya which injured or killed over 5200, or the more well known attack on September 11 2001 in New York City which killed 2823 [1]. Over the course of modern history, such attacks have been treated as outliers. We show here that discounting these events as special cases ignores significant patterns in terrorism over the past 37 years.

To extract and understand these patterns, we use extremal statistics to characterize the relationship between the *severity* and frequency of terrorist events. By severity, we simply mean the number of individuals injured or killed by an attack. Although many organizations track terrorism worldwide, few provide their data publicly or in anything but an aggregate form. The MIPT database appears to be unique in its comprehensive detail as it contains, as of January 2005, records of over 19 907 terrorist events in 187 countries worldwide between 1968 and 2004. Of these, 7 088 resulted in at least one person being injured or killed. It is itself the compilation of the RAND Terrorism Chronology 1968-1997, the RAND-MIPT Terrorism Incident database (1998-Present), the Terrorism Indictment database (University of Arkansas & University of Oklahoma), and DFI International's research on terrorist organizations. Each record includes the date, target, city (if applicable), country, type of weapon used, terrorist group responsible (if known), number of deaths (if known), number of injuries (if known), a brief description of the attack and the source of the information.

Tabulating the event data as a histogram of severity (injuries, deaths and their aggregation greater than zero), we show the cumulative distribution functions $P(x > X)$ on log-log axes in Figure 1. That the distributions are highly right-skewed is immediately obvious, and is exemplified by the fact that the means of the distributions are 14.60 ± 114.82, 5.13 ± 43.37 and 12.70 ± 103.38 respectively, while the largest corresponding events are 5000, 2823 and 5291. The regularity of the scaling illustrates that the extremal events are not outliers, but are instead in concordance with a global pattern in terrorist attacks. Surprisingly, this scaling exists in spite of strong heterogeneity in the types of weapons, the perpetrating organizations, locations and political motivations.

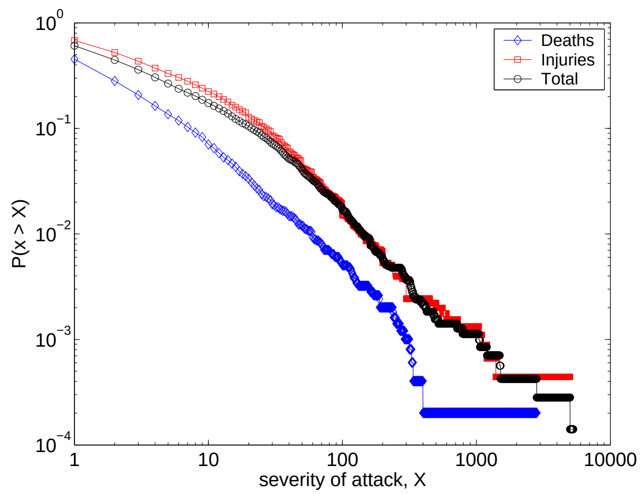

FIG. 1: The distributions $P(x > X)$ of the severity (injuries, deaths and their aggregation) of terrorist attacks worldwide between 1968 and 2004, from [1]. These distributions are well-modeled by power laws with scaling parameters of $\alpha = 1.867 \pm 0.002$, $\alpha = 1.842 \pm 0.002$ and $\alpha = 1.878 \pm 0.001$ respectively.

Hypothesizing that these distributions are power laws of the form $P(x) \sim x^{-\alpha}$, we bootstrap the numeric maximization of the likelihood function 50 times to estimate the scaling parameter α. We find that all three distributions are well-modeled over several decades in the tail by a power law with $\alpha \approx 2$. Further, the relevant Kolmogorov-Smirnov goodness-of-fit test [11] indicates that there is insufficient evidence to reject this hypothesis ($p_{KS} > 0.05$). On the other hand, we may reject the hypothesis ($p_{KS} < 0.05$) that the tail is distributed as a lognormal [12]. It is worth pointing out that we have not considered mixtures of heavy-tailed distributions, which may result in a better fit. In support of our results here, an analysis of the International Policy Institute for Counter-Terrorism's (ICT) event database [13], with only 1417 events between May 1980 and December 2002, yields similar results. Table I summarizes the power laws for the three distributions.

Type	α	σ_B	range
Injuries	1.867	0.002	$x > 39$
Deaths	1.842	0.002	$x > 3$
Total	1.878	0.001	$x > 36$

TABLE I: A summary of the power law distributions for the severity of terrorist attacks between 1968 and 2004.

Of the 7 088 attacks which killed or injured at least one person, 4 784 (67%) correspond to attacks since 1998, when the MIPT assumed maintenance of the database. This increase may be due, in part, to more efficient recording. However, we find only a 3% difference between the scaling of the total severity distributions before and after January 1 1998. This suggests that the scaling is neither a recent phenomenon, nor the result of changes in data collection.

We conjecture that this scale invariance in terrorism worldwide is an extension of the power law observed by Richardson in 1948 [4] for the frequency versus intensity of wars. Using similar statistical tools on the data of Small and Singer [14], Newman found a scaling parameter of $\alpha = 1.80 \pm 0.09$, which is evocatively close to that which we measure for global terrorism.

Although it has been suggested that Richardson's scaling law is the result of a metastability in a self-organized critical (SOC) [15] system of geopolitics [16, 17], this hypothesis seems ill-suited to explain the scaling in the severity of terrorist attacks. However, we find it plausible that Richardson's scaling law and the one we document here may both be related to the exponentially decreasing economic cost of inflicting death or injury [10]. When combined with other factors like a growing number of players interested in inflicting such damage and a preference for attacking targets with dense populations, these scaling laws may emerge naturally. Further study is needed to substantiate this theory.

Because the most likely scaling parameter for the total severity distribution is in the range $\alpha < 2$, the mean and maximum values will be infinite. Thus, if this scaling governs the patterns of global terrorism in the future, we will continue to see increasingly more severe attacks. On the other hand, a severity-proportional reduction in frequency of terrorist attacks at all scales would increase the scaling parameter, thus making the mean, and ultimately the variance, finite. Inhibiting the generative mechanism, perhaps by reducing either the number of players or increasing the cost of inflicting injury/death, may also lead to similar scaling changes.

Finally, over the course of the 37 years of data, the mean inter-event interval has been dropping steadily. In 1980, it was 96 hours, while since 1998, the average interval has been only 17.3 hours. Historically, the probability of seeing an event of at least the total severity of the attacks on September 11 2001 is $P(x > 2823) \approx 3 \times 10^{-4}$. Thus, if this distribution continues to govern the severity of attacks in the future and the sampling rate remains constant, we may expect that to see another catastrophic attack of at least that severity within 7 years, or by 2012.

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