Geopsychology of instrumental aggression: daily concurrence of global terrorism and solar-geomagnetic activity (1970-2018)

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Geopsychology of instrumental aggression: daily concurrence of global terrorism and solar-geomagnetic activity (1970-2018)

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ABSTRACT

Formal scientific study of the geopsychology of human aggression dates back at least a century and has consistently demonstrated a positive association between solar-geomagnetic activity and aggressive behaviour. Advances in the theories, methodologies, and practical applications of geopsychology could therefore contribute to collective efforts to comprehend, to forecast, and to develop interventions for aggressive behaviours such as those seen in terrorism. This requires a rigorous and precise estimate of the magnitude of association between solar-geomagnetic activity and aggression using a representative, contemporary sample of strictly-operationalized behaviour. Here we show that days in recent history (1970-2018) with the lowest levels of instrumental human aggression (number of casualty-associated terrorism incidents) also had the lowest levels of solar and geomagnetic activity, and that stepwise increases in human aggression were mirrored by progressive increases in solar activity. We used Bayesian methods robust to outliers and heterogeneity of variance to analyze the most comprehensive and contemporary global database of terrorism incidents available, which included more than 105,000 unique instances of instrumental aggression spanning 48 years. We conclude that there is a small, nonzero promotional effect of solar-geomagnetic activity on terrorism-related aggression. This may reflect the fact that solar-geomagnetic activity serves as a *zeitgeber* that coordinates the expression of instrumental aggression across an aggregation of susceptible individuals. We propose that many behaviours – even instrumental acts such as terrorism which are presumed to involve a degree of planning and intention – may be subject to subtle geopsychological induction or suppression.

Keywords: biophysics; geophysics; behavioural ecology; aggregate human behaviour; Bayesian data analysis.

A Brief History of the Geopsychology of Aggression

Geopsychology, or geo-neuroscience, denotes the manifold impacts of the Earth's physical environment on biology and behaviour [1,2]. Interest in the geopsychology of aggression originates prior to recorded history, with indigenous peoples inhabiting northern regions of the globe. Displays of *aurora borealis* – visible light phenomena reflecting transient disturbances in the geomagnetic field [3] often linked to variations in solar activity [4] – were in some cases likened to ancient warriors or considered omens foretelling of war, famine, and disease [5].

In 1924, A.L. Chizhevski first published (in Russian) the seminal scientific work on the geopsychology of aggression. His statistical analyses of historical data from 500 BCE to 1914 CE demonstrated that the most acute/severe human conflicts and violent revolutions occurred around maxima of 11-year solar activity (sunspot) cycles and that cultural development tended to flourish at solar minima [6]. In 1928, Chizhevski described a comparable association between Russian terrorism and solar activity for the period 1902 to 1911 [7]. Later (1999), M.A. Persinger demonstrated that higher yearly levels of solar-geomagnetic activity similarly predicted higher levels of armed human conflict for the years 1904 to 1950 [8]. Then, in 2015, Vares and Persinger showed that daily solar activity predicted 4% to 10% of the variance in the daily number of force and confrontation events occurring in the years 2009 to 2013 [9].

While both innovative and informative, existing naturalistic geopsychology of aggression studies are limited by sample size/representativeness, operational definitions of aggression, and data analysis methodology. For one, some prior studies have tended to examine relatively small samples of data and/or datasets with low time-resolution (e.g. yearly data). Considering that solar and geomagnetic activity are known to show substantial variation at a period of 11 years (as well as shorter- and longer-period cycles of varying magnitudes), geopsychological studies should at minimum include data spanning more than one 11-year cycle. Furthermore, larger datasets and those with higher time-resolution provide the high precision necessary to detect and generate meaningful statistical estimates of geopsychological effect sizes, which tend to be small (i.e. ~0.1-0.2 SD group differences or ~5-15% shared variance) [2, 7]. Second, existing studies have tended to employ relatively broad or non-specific operational definitions of aggressive behaviour. However, reactive/impulsive and instrumental subtypes of aggressive behaviour involve differences in the nature of the aggressive behaviour as well as its social context and neuroanatomical underpinnings [10, 11]. Because geopsychological effects may operate via multiple distinct and behaviour-specific geo-neurobiological mechanisms [1, 2, 12, 13], effects could be diluted by tallying multiple distinct subtypes of aggressive behaviour under a common metric. Finally, previous studies of the geopsychology of aggression have tended to rely on methods of data analysis that are not robust to outliers or heterogeneity of variance across groups or factor levels, which could confound effect size estimates.

Aims and Purposes of the Present Study

To address these limitations and contribute to advances in the geopsychology of aggression, we used contemporary datasets and analysis methods to produce representative, rigorous, and precise geopsychological effect size estimates (e.g. for use in the design and interpretation of experimental studies). As such, we used the most complete and representative terrorism dataset available (Global Terrorism Database, GTD) [14], reflecting the global occurrence of a narrowly-defined subtype of instrumental aggressive behaviour and spanning 48 years of recent history (1970-2018). We also employed Bayesian methods of data analysis that provided informative detail about the range of credible parameter values (i.e. geopsychological effect sizes) and that accommodated for outliers and for heterogeneity of variance across groups/levels [15].

In addition to the theoretical and methodological aims just outlined, we chose to study the geopsychology of terrorism for humanistic reasons. Terrorism has far-reaching and long-lasting detrimental physical, social, psychological, and economical impacts [16-18]. We thus aspired to re-examine and to enhance the current understanding and conceptualization of the phenomenology of terrorism-related aggression in order to better anticipate and disrupt intended acts of violent coercion before they occur; we aimed to facilitate development of just economic and social policy to redress modifiable biopsychosocial risk factors underlying terrorism [19, 20].

Study Methods

3.1 Instrumental Aggression (Terrorism) Data

The Global Terrorism Database (GTD) [14] is in ongoing, active development; is freely available for non-commercial use; currently includes information on more than 190,000 terrorism incidents; and presently spans complete years 1970 to 2018 (all data from 1993 were irretrievably lost). There are 4 data collection epochs in the GTD wherein distinct methodologies were employed: 1 January 1970 to 31 December 1997; 1 January 1998 to 31 March 2008; 1 April 2008 to 31 December 2011; and 1 January 2012 to present. As such, the GTD project leaders recommend treating each epoch distinctly when conducting statistical analysis [21].

After retrieving the GTD, any terrorism incident with an unknown/missing value for date, month, year, or casualties (number of wounded or killed persons) was omitted. For the purposes of the present study, all GTD terrorism incidents associated with at least one casualty (≥1 wounded or killed persons) were considered *casualty-incidents*. The number of such casualty-incidents was then counted within each day, where days with no terrorism casualty-incidents were assigned a score of zero. The total number of distinct terrorism casualty-incidents occurring on each day from 1970 to 2018 served as our daily metric of global instrumental human aggression.

There was a disproportionate number of days with zero terrorism casualty-incidents, giving the distribution of daily casualty-incident counts a pronounced positive skew. Casualty-incident counts were hence indexed to quintiles within each study epoch using the *quantcut* function [22]. In other words, each day was assigned to a subgroup (nominal factor level) corresponding to its epoch-wise instrumental aggression (terrorism casualty-incident) quintile.

3.2 Solar-Geophysical Data

Solar-geophysical data for years 1970 to 2018 (spanning solar cycles 20 through 24) were obtained from GFZ German Research Centre for Geosciences (www.gfz-potsdam.de/en/kp-index/) and then matched by date and merged with the terrorism casualty-incident dataset. Daily (sum) K_P index (a measure of global geomagnetic activity) [23] and daily 10.7 cm radio flux (a measure of solar activity) [24] were each separately regressed on case (day) number and the standardized residuals were saved for use as predicted variables in our analyses. (This was done in order to unit-normalize and linearly detrend the solar and geomagnetic data series prior to analysis.)

3.3 Statistical Analysis

Bayesian MCMC (Markov Chain Monte Carlo) simulation was used to estimate a credible range of solar and geomagnetic activity values (metric-scale predicted variables) for days grouped according to their terrorism casualty-incident quintile (a nominal factor with 5 levels). To account for differing methodologies and sample sizes across the 4 GTD study epochs, epoch was included as a second nominal factor (with 4 levels) in the models. Distinct means and standard deviations were estimated for each casualty-incident quintile within each epoch (i.e. there was no assumption of homogeneity of variance across epochs or aggression factor levels). Noise in the data was represented with a *t*-distribution that included a normality parameter to prevent bias of geopsychological effect estimates as a result of extreme values [15].

Prior distributions for all parameters were selected to be broad on the scale of the data and to exert minimal influence over the posterior distributions. Broad normal priors were used for baseline solar/geomagnetic estimates and for estimates of deflections from baseline associated with each casualty-incident factor level. Standard deviation parameters were given broad gamma prior distributions and the prior for the normality parameter was a broad exponential distribution. Our main interest lie in examining and reporting the magnitude of differences in solar/geomagnetic activity between instrumental aggression factor levels. This was estimated by examining factor-level contrasts (relative differences) in the posterior distribution of estimated solar-geomagnetic activity parameter values (with a conservative approach that compared, in turn, values from each individual casualty-incident quintile to those from all other quintiles combined).

Data analyses were conducted in *R* [25] with *JAGS* [26] and *runjags* [27] for Bayesian MCMC simulation. We employed functions and a modified script for analysis of metric predicted variables with two nominal factors made available and extensively described by Kruschke [15]. All of the MCMC chains were checked for convergence. Effective sample size (ESS) was examined and reported as a measure of estimate stability/accuracy for parameters of interest. Further detail regarding data processing and analysis can be obtained from the corresponding author.

Results

The GTD (downloaded 6 November 2020), spanning the 17,532 days from 1970 to 2018 (data from 1993 missing), contained 191,464 unique terrorism incidents. After omitting those with missing date or casualty information, 172,579 incidents remained for analysis. Of those, 106,998 (~62%) incidents were associated with ≥1 wounded or killed persons and so were considered terrorism casualty-incidents. Daily tallies of terrorism casualty-incidents varied from 0 to 56, with a mean (SD) of 6.10 (7.55) terrorism casualty-incidents per day. Upper and lower limits for casualty-incident quintiles (i.e. casualty-incident factor levels), computed separately for each of the 4 GTD study epochs, revealed qualitative across-epoch differences (Table 1).

Examination of terrorism casualty-incident factor-level differences in the posterior distributions showed that solar activity levels were credibly lower (i.e. the 95% HDI for the estimated differences excluded zero) on days falling in the 1st and 2nd terrorism casualty-incident quintiles, and credibly higher for days in the 3rd, 4th, and 5th quintiles. In fact, point estimates of solar activity showed a rank-ordered stepwise increase across casualty-incident quintiles. And while geomagnetic activity was likewise credibly lower on days in the 1st casualty-incident quintile and credibly elevated on days falling in the 4th quintile, estimates of differences in geomagnetic activity for days in the 2nd, 3rd, and 5th casualty-incident quintiles had 95% HDIs that included zero (i.e. null contrasts). These results are summarized in Table 2 and in Figures 1 and 2.

Discussion

Results from our original study examining the daily concurrence between incidents of global instrumental (terrorism-related) aggression included in a large, historically-representative dataset and contemporaneous solar-geomagnetic conditions were consistent with prior naturalistic-observational research [6-9, 28]: the geopsychological effects observed in the present study were nonzero, small (lowest/highest levels of aggression associated with ~0.1 to 0.2 SD relative deviations in solar-geomagnetic activity), and in the expected direction (i.e. increasing aggression with increasing solar-geomagnetic activity).

5.1 How Does Geopsychology Contribute to Instrumental Aggression?

Efforts to understand, anticipate, and preempt incidents of terrorism have rightly tended to highlight chains of more-or-less modifiable genetic, biological, psychological, cultural, and economic mechanisms that precede coercive acts of actual or threatened violence [19]. The present findings suggest that, in addition, features of the concurrent solar-geophysical milieu can effect aggregate (global) alterations in terrorism-related aggression [7]. Solar-geomagnetic variations may thus serve as *zeitgebers* that trigger synchronized expression of instrumental aggression among persons whose behaviour is prone to geopsychological influence [13], contributing to the emergent aggregation of human aggressive behaviour [8, 29].

While our study is descriptive and correlational, causal direction is implied by the relative determinants of solar/geomagnetic as opposed to human activities; below, we examine our results in light of the available experimental research in this area and consider geopsychological mechanisms that could be implicated in direct causal effects of solar-geomagnetic signals on alterations in brain function. It is however possible that the historical association between solar/geomagnetic and global terrorism activity reported above was instead and/or in addition mediated by other unexamined variables [30-32]. Whatever the causal mechanism(s), historical precedent suggests that terrorism activity is likely to increase as solar cycle 25 progresses from its initial minimum in 2020 to its peak in 2023-2025 [33, 34]. However if there is in fact a direct physical, dose-response effect of solar and/or geomagnetic activity on the neurobiology underlying human instrumental aggression, then it may also be germane that some have predicted solar cycle 25 will attain a historically high maximum [35].

5.1.1 Classical and/or Quantum Geopsychological Transduction Mechanisms?

We found support for similar promotional effects on instrumental aggressive behaviour of both solar and geomagnetic activity. This concordance is unsurprising given the strong coupling between solar and geomagnetic activities [36]. However, we also found a quasi-linear, dose-dependent terrorism-promoting effect of solar activity specifically, whereas the effect of geomagnetic activity on aggression appeared to be nonlinear (*i.e.* compare Figures 1 and 2). Both weak (Earth-strength) magnetic fields and radio-frequency electromagnetic noise are known to influence intra-cellular electron transfer reactions (*e.g.* involving human cryptochrome; [37, 38]), in qualitatively different ways, via a quantum (radical pair) intra-cellular mechanism [39, 40]. There is evidence that the radical pair mechanism underlies behavioural effects of solar-geomagnetic activity in non-human species: for instance, radio-frequency noise (*e.g.* solar activity) may disrupt sensitivity to orientational information in the geomagnetic field, leading to navigational errors in birds and whales [40, 41]. Our finding that instrumental human aggression (terrorism) was subject to influence by both solar and geomagnetic activity similarly suggests mediation via a quantum intra-cellular mechanism. That said, recent experimental evidence indicates that some human brain responses to geomagnetic perturbations depend not on a quantum but on a classical (ferromagnetic) intra-cellular transduction mechanism [42].

It is also important to consider that qualitative differences in the observed effects of solar versus geomagnetic activity may have in part been artifacts of our study design. Two aspects of our methodology may have obfuscated the behavioural effect of geomagnetic activity by failing to capture biologically-salient components of this geophysical signal. First, we aggregated terrorism incidents by day, though individual incidents occurred at differing times and at locations distributed across the globe. This is relevant because the local strength of global geomagnetic disturbances varies by latitude and longitude [43, 44] and because human physiological responses to geomagnetic activity depend on local/contemporaneous meteorological conditions (*i.e.* temperature, pressure, humidity; [32]). Second, we analyzed absolute levels of solar/geomagnetic activity occurring on each day and thus did not account for relative short-term (inter- and intra-day) changes or fluctuations. A prior study of terrorism-suicides examined 11-day periods centered on the time of occurrence of individual incidents and indeed found that terrorism-suicides occurred at relative across-day peaks in geomagnetic activity [28], while within-day deviations in geomagnetic flux from the expected diurnal variation could serve as *zeitgebers* for biological and behavioural rhythms [13].

5.1.2 Neurobiology Underlies Geopsychological Susceptibility

We examined a very narrowly-defined manifestation of instrumental aggression (terrorism). Instrumental aggression is unlike reactive-impulsive-type aggressive behaviours. These are typically a (defensive) response to immediate threat mediated by brainstem- and diencephalic-level neuroanatomical structures (*i.e.* periaqueductal grey and hypothalamus). In contrast, instrumental aggressive behaviours (e.g. terrorism) are by definition premeditated, often removed in space and time from the instigating event(s), and depend primarily on limbic and orbito-frontal/pre-frontal cortices [10, 11]. As such it is notable that prior rat and human research from our group and others has implicated both (right) limbic-temporal [45-49] and (right) pre-frontal brain regions [50-53] in geopsychological effects.

As with the manifold established biological effects resulting from exposure to Wi-Fi and related anthropogenic microwave-frequency electromagnetic fields [54], there are likely to be multiple distinct solar-geophysical signals and biological transduction substrates implicated in the spectrum of geopsychological phenomena [1, 2, 7, 12, 13, 40, 42]. We assume that a combination of molecular, cellular, and neuroarchitectural/neuroanatomical characteristics underlies the primary susceptibility of a particular behaviour to solar-geophysical influence. Moreover, “energetic environmental phenomena affect psychophysical processes that can affect people in different ways depending on their sensitivity, health status, and capacity for self-regulation” [55; p.1], and some individuals show evidence of extreme susceptibility to geopsychological induction [49, 56]. Further studies are required to elaborate our understanding of phenotypes that increase the risk of geopsychological induction of aggressive behaviours, and how these relate to the broader framework of biopsychosocial factors implicated in terrorism.

Conclusion and Practical Implications

In undertaking this study we sought to contribute to theoretical and methodological advances in the geopsychology of aggression by illustrating a robust and historically-representative manifestation of an ecologically-embedded geopsychological phenomenon. We also sought to address an unmet societal need for “tools for understanding, predictions, alerts, and the rational design of countermeasures of societal cataclysms, such as terrorism and war” [20; p. 327]. The direct and indirect causal mechanisms through which solar-geomagnetic activity impacts human instrumental aggression have yet to be fully elucidated. Nonetheless, the findings presented herein indicate that the approach of solar cycle 25 maximum (in 2023-2025) is likely to herald a progressive increase in the frequency of global instrumental aggressive behaviour. Broader consideration of this fact may aid in identifying avenues to address the major modifiable causes and mitigate the detrimental global impacts of terrorism, in all its forms.

Author Declarations

7.1 Data Availability

Terrorism data can be obtained from Global Terrorism Database (www.start.umd.edu/gtd/access/) and solar-geophysical data can be obtained from GFZ German Research Centre for Geosciences (www.gfz-potsdam.de/en/kp-index/).

7.2 Code Availability

Relevant code can be obtained from the corresponding author upon reasonable request.

7.3 Acknowledgments

Dedicated to Michael A. Persinger (1945-2018) and Alexander Leonidovich Chizhevsky (1897-1964), whose lives and works continue to teach us valuable lessons. Thanks to Kevin Saroka for inspiration and guidance.

7.4 Author Contributions

BPM and SAK conceived and designed the study; BPM performed data processing and analysis; BPM and SAK interpreted the data; BPM wrote the manuscript; BPM and SAK revised the manuscript.

7.5 Competing Interests

The authors declare no competing interests.

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Table 1. Epoch-wise terrorism casualty-incident quintile ranges.

	Global Terrorism Dataset (GTD) data-collection epoch							
	1 January 1970- 31 December 1997		1 January 1998- 31 March 2008		1 April 2008- 31 December 2011		1 January 2012- 31 December 2018	
Casualty quintile	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
1st	0	0	0	1	0	5	0	14
2nd	1	1	2	2	6	7	15	18
3rd	2	3	3	3	8	9	19	22
4th	4	5	4	5	10	12	23	27
5th	6	30	6	36	13	34	28	56

Each day from 1970 to 2018 was assigned a quintile rank based on the number of terrorism casualty-incidents occurring on that day. Upper and lower limits of casualty-incident quintiles were computed separately for each of the 4 data collection epochs (reflecting methodological differences) included in the Global Terrorism Database (GTD).

Table 2. **Bayesian geopsychological parameter estimates.**

	Parameter	Solar Activity				Geomagnetic Activity			
			95% HDI Limits				95% HDI Limits		
		Mode	Lower	Upper	ESS	Mode	Lower	Upper	ESS
Baseline and quintile-wise deflections	*Baseline*	-0.112	-0.127	-0.097	16061	-0.129	-0.146	-0.111	29671
	1st quintile	-0.147	-0.168	-0.127	40873	-0.061	-0.090	-0.031	31712
	2nd quintile	-0.038	-0.061	-0.012	41630	0.005	-0.028	0.036	40005
	3rd quintile	0.041	0.017	0.068	39916	0.009	-0.023	0.041	33951
	4th quintile	0.058	0.033	0.086	40109	0.052	0.020	0.084	36148
	5th quintile	0.083	0.055	0.111	40658	-0.002	-0.036	0.030	36918
Contrasts (quintile-wise differences)	*1st quintile*	**-0.183**	**-0.210**	**-0.159**	40873	**-0.077**	**-0.112**	**-0.039**	31712
	2nd quintile	**-0.047**	**-0.077**	**-0.015**	41630	0.006	-0.036	0.045	40005
	3rd quintile	**0.051**	**0.021**	**0.085**	39916	0.011	-0.029	0.051	33951
	4th quintile	**0.073**	**0.041**	**0.108**	40109	**0.065**	**0.025**	**0.105**	36148
	5th quintile	**0.104**	**0.069**	**0.139**	40658	-0.002	-0.045	0.038	36918

Parameter estimates derived from Bayesian posterior distributions for baseline solar/geomagnetic activity as well as for deflections from baseline in solar/geomagnetic activity associated with each casualty-incident quintile (nominal factor level). Contrasts represent posterior distribution difference scores (such as those presented in the figures) between each individual casualty-incident quintile and all other quintiles combined. Contrasts deemed credibly non-null (with 95% HDI limits that do not overlap zero) are bolded. (HDI = highest density interval; ESS = effective sample size).

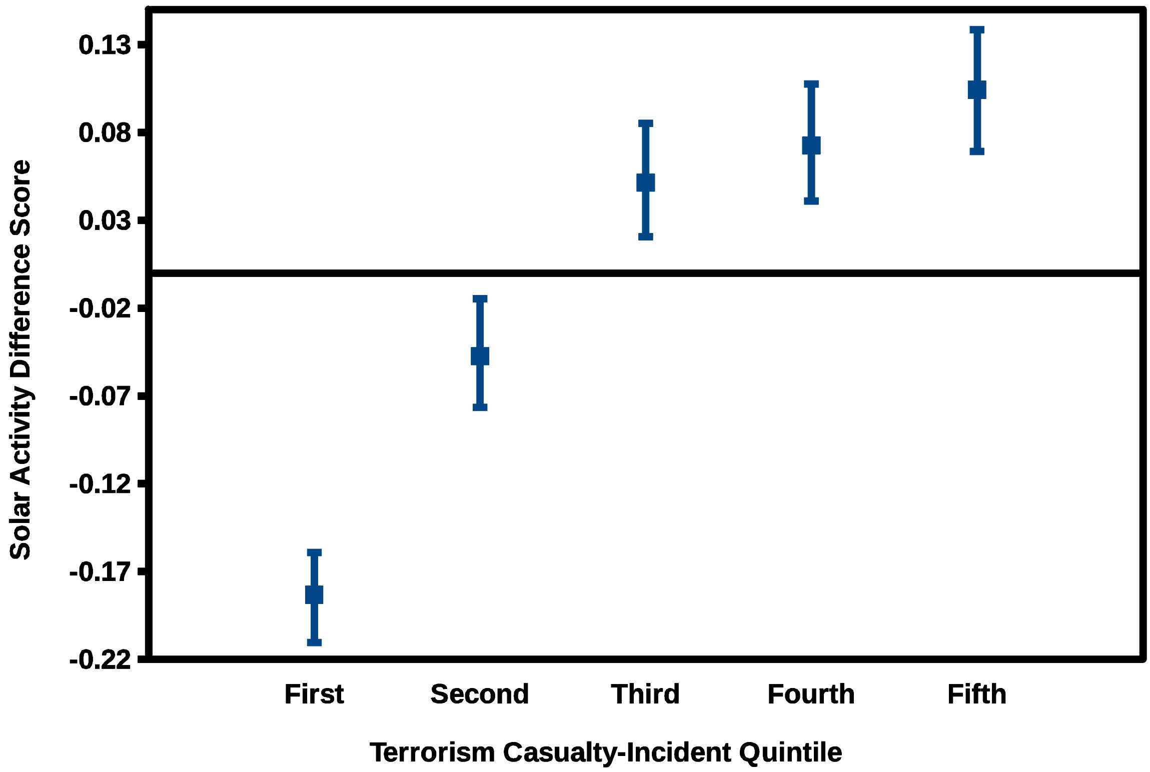

Fig. 1 Bayesian solar activity difference scores across levels of instrumental aggression (terrorism). Posterior solar activity difference scores (mode ±95% HDI) for each terrorism casualty-incident quintile relative to all other quintiles combined. (HDI = highest density interval)

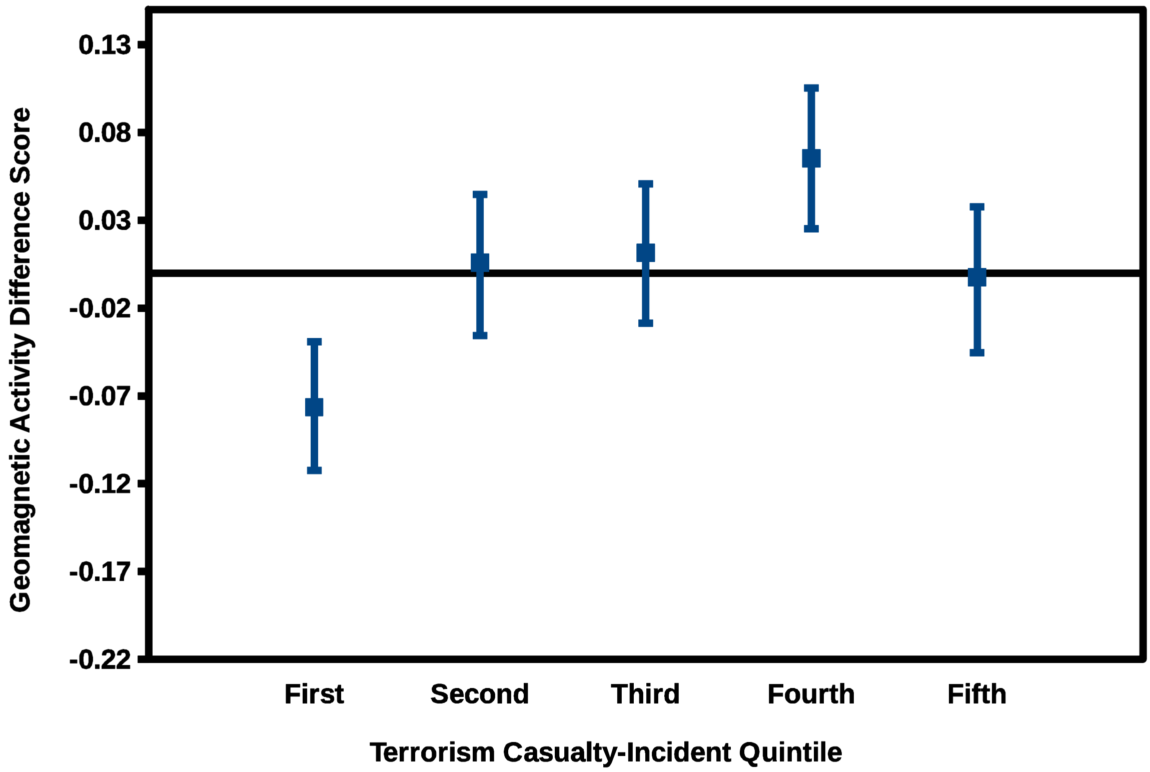

Fig. 2 Bayesian geomagnetic activity difference scores across levels of instrumental aggression (terrorism). Posterior geomagnetic activity difference scores (mode ±95% HDI) for each terrorism casualty-incident quintile relative to all other quintiles combined. (HDI = highest density interval)