Supplementary Information for
"Association between Oklahoma earthquakes and anxiety-related Google search episodes"

Supplemental Methods.

Test transfer function:

We used Box-Jenkins methods (1) to identify and specify autocorrelation for our base model. These well-developed methods, which appear widely in the epidemiologic literature (2, 3), attribute autocorrelation to integration as well as to "autoregressive" and "moving average" parameters. Integration describes secular trends and strong seasonality. Autoregressive parameters best describe patterns that persist for relatively long periods, while moving average parameters parsimoniously describe less persistent patterns.

We estimated our test model by adding the monthly differences in *M* 4 earthquakes to our base model. We specified the model to include a "persistence" parameter that measured the proportion of the association, if any, between *M* 4 earthquakes and Oklahoma anxiety search episodes that carried into the month after the earthquakes. These steps yielded the following test transfer function:

$$\nabla Y_t^e = {}^{\omega_0}\!/_{(1-\delta B)}\,\nabla X_{1t} + \omega_1 \nabla X_{2t}^e + \omega_2 \nabla X_{3t}^e + {}^{(1-\theta B^{\mathrm{q}})}\!\big/_{(1-\phi B^{\mathrm{p}})}\, a_t$$

∇ is the difference operator that implies transforming Y_t^e to its first differences (i.e., value at t subtracted from that at t+1) to render a trended variable stationary in its mean. Y_t^e is the natural logarithm of the proportion of anxiety Google searches in Oklahoma for month t. ∇X_{1t} is the number of earthquakes exceeding *M* 4 in Oklahoma for month t. X_{2t}^e is the natural logarithm of the proportion of anxiety Google searches in the US for month t. X_{3t}^e is the natural logarithm of the proportion of toothache Google searches in Oklahoma for month t. ω_0 through ω_2 are the estimated coefficients of association, ω_0 is the primary coefficient of interest in our test. δ is the persistence coefficient that measures the proportion of ω_0 carried to month t+1. θ is the Box-Jenkins moving average parameter. ϕ is the Box-Jenkins autoregressive parameter. B is the "backshift operator" or value of Y_t^e at month t-p or of *a* at month t-q. a_t is the residual of the transfer function at month t. The residual series met the regression assumptions of independence, constant mean of 0, and constant variability around that mean. We hypothesized that ω_0 would be significantly greater than 0 ($p<0.05$; 2-tailed test).

Month	Year	US anxiety	OK anxiety	OK toothache
1	2010	1149.126	1368.288	250.7537
2	2010	1205.867	1674.979	190.7178
3	2010	1453.045	1663.688	660.7723
4	2010	1371.897	1957.559	301.5421
5	2010	1290.494	1234.506	310.7616
6	2010	1159.367	1235.986	240.3511
7	2010	1623.424	1865.333	236.5689
8	2010	1464.759	1826.469	307.6447
9	2010	1271.604	1483.285	170.2467
10	2010	1282.848	1443.681	261.2534
11	2010	1339.515	1817.383	359.4368
12	2010	1077.452	1334.498	205.4301
1	2011	1275.999	1307.045	251.9273
2	2011	1305.038	1318.908	216.4368
3	2011	1322.116	1237.391	189.2414
4	2011	1333.676	1550.214	197.1823
5	2011	1306.526	1166.361	252.077
6	2011	1286.001	1371.11	344.7319
7	2011	1306.312	1533.863	301.7317
8	2011	1315.27	1632.664	241.6276

9	2011	1374.292	1488.121	225.1638
10	2011	1390.015	1464.944	207.5576
11	2011	1351.835	1707.227	245.2805
12	2011	1239.527	1545.398	240.1345
1	2012	1563.932	1668.362	236.2152
2	2012	1548.018	1776.048	231.7717
3	2012	1513.587	1503.65	188.784
4	2012	1479.599	1595.026	299.1497
5	2012	1389.015	1199.222	273.8795
6	2012	1390.74	1410.88	193.8445
7	2012	1464.951	1718.908	197.9148
8	2012	1565.342	1995.617	250.0469
9	2012	1593.401	1770.501	237.3327
10	2012	1566.09	1748.025	206.8576
11	2012	1521.731	1731.177	213.147
12	2012	1455.943	1567.241	229.6956
1	2013	1583.156	1910.593	211.3188
2	2013	1576.039	1548.519	311.3442
Month	**Year**	**US anxiety**	**OK anxiety**	**OK toothache**
3	2013	1581.156	1643.775	225.6653
4	2013	1604.708	1842.071	210.6804
5	2013	1543.67	1676.234	200.9471
6	2013	1516.171	1799.24	244.3897
7	2013	1579.18	1949.189	170.6936
8	2013	1659.915	1875.803	260.153
9	2013	1693.587	1921.94	246.9671
10	2013	1631.573	1976.46	240.867
11	2013	1540.325	1801.042	252.6993
12	2013	1507.608	1662.382	295.8565
1	2014	1752.91	1957.454	253.7817
2	2014	1655.289	1825.917	284.0233
3	2014	1717.45	2007.736	227.9237
4	2014	1689.637	1955.583	227.7322
5	2014	1610.404	1990.833	233.4276
6	2014	1615.539	1955.619	338.8595
7	2014	1648.171	2172.537	266.7723
8	2014	1821.675	2202.284	240.021
9	2014	1756.95	1888.057	198.2557
10	2014	1784.519	2114.099	247.2223

11	2014	1703.032	1985.334	217.5583
12	2014	1586.448	1706.955	229.2975
1	2015	1839.746	2047.004	229.3382
2	2015	1780.095	1889.947	230.9218
3	2015	1865.706	2110.256	176.369
4	2015	1901.433	2177.569	176.2277
5	2015	1813.026	2057.91	211.6951
6	2015	1838.536	2095.304	238.0718
7	2015	1941.547	2236.731	290.6044
8	2015	1974.576	2253.78	209.4959
9	2015	2088.621	2651.074	267.9362
10	2015	2089.183	2593.23	255.8388
11	2015	2000.286	2375.621	269.2541
12	2015	1881.969	2442.734	292.477
1	2016	2054.477	2720.393	248.8141
2	2016	2116.335	2607.3	273.092
3	2016	2136.062	2558.475	275.2412
4	2016	2204.857	2566.281	282.1523
Month	**Year**	**US anxiety**	**OK anxiety**	**OK toothache**
5	2016	2090.357	2555.845	276.4442
6	2016	1979.595	2536.916	255.785
7	2016	2159.241	2899.342	274.982
8	2016	2265.481	2670.229	274.6512
9	2016	2287.279	2782.073	307.8553
10	2016	2335.13	2801.564	302.131
11	2016	2161.458	2927.637	216.984
12	2016	2021.111	2696.493	332.0902
1	2017	2280.236	2722.682	306.4075
2	2017	2327.987	2955.815	280.3509
3	2017	2403.775	3013.169	277.2606
4	2017	2403.924	3184.315	278.9732
5	2017	2311.978	3016.841	319.6783

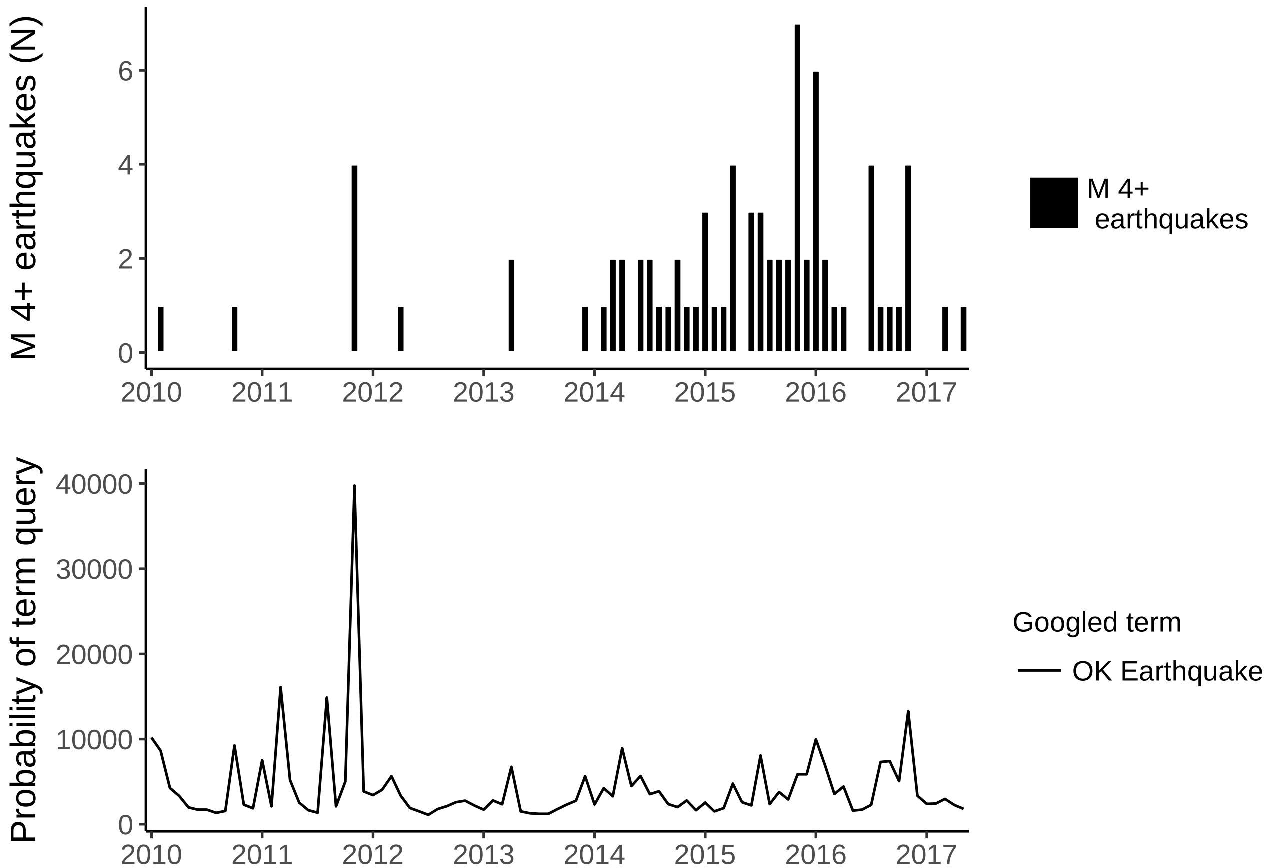
eTable 1. Monthly proportions of Google searches for specific terms from the Health category from January 2010 to May 2017.

Searches included anxiety search episodes across the United States and within Oklahoma and toothache search episodes within Oklahoma. Search probabilities were multiplied by 10 million for readability. Because Google uses a uniformly distributed random sample of 5-15% of Google web searches to calculate probabilities, updated once per day, the values in the table represent the average of 75 unique samples.

	Proportion monthly change in Oklahoma anxiety searches, B (95% CI)[a]		
Variable	**Base model**	**Test model**	**Binary *M* 4 model**
Moving average at t-1	0.66 (0.47, 0.85)	0.58 (0.38, 0.78)	0.618 (0.42, 0.81)
Autoregression at t-12	0.38 (0.21, 0.54)	0.42 (0.23, 0.61)	0.45 (0.26, 0.63)

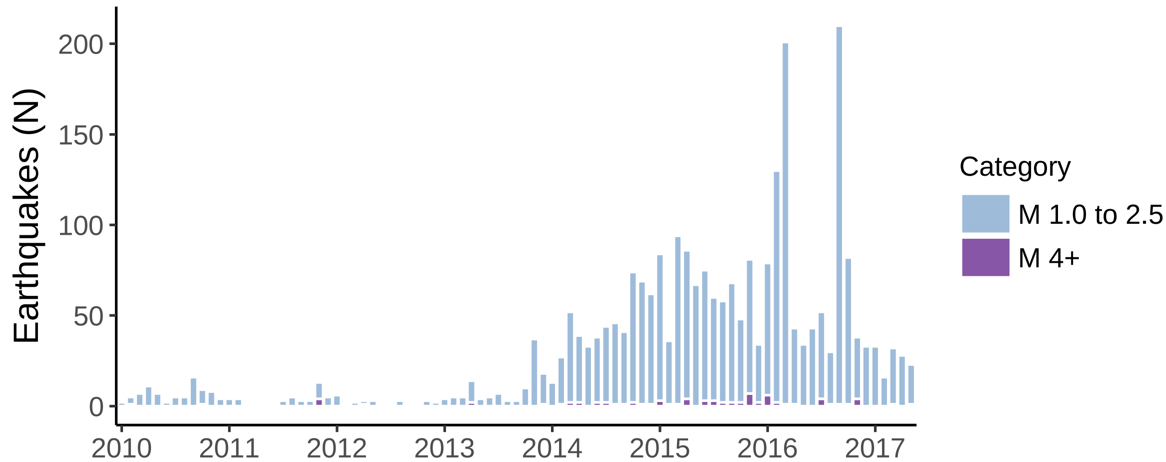
eTable 2. Moving Average and Autoregressive Parameters from Time Series Analysis[a]

[a] Estimates from a time series model for the proportion change in monthly Google anxiety search episodes per additional earthquake ≥ magnitude 4 in Oklahoma (Models presented in Table 1); n = 89 months (January 2010 to May 2017)



eFigure 1. Monthly total of $\geq M$ 4 earthquakes and Proportion of Google Searches in Oklahoma for the Term "earthquake" from January 2010 to May 2017.

We present the proportion of searches for earthquake, which we multiplied by 10 million for readability.



eFigure 2. Earthquakes per Month in Oklahoma During the Study Period.
The slate blue bars represent the number of *M* 1 to *M* 2.5 earthquakes[a] per month and the purple bars the number of ≥ *M* 4 earthquakes per month as identified from the USGS Advanced National Seismic System catalog from January 1, 2010 to May 31, 2017.

[a] The United States Geological Survey reports the magnitude of these smaller earthquakes using the Richter scale, also known as the local magnitude. ML and moment magnitude estimates are often similar. See: https://www.usgs.gov/faqs/moment-magnitude-richter-scale-what-are-different-magnitude-scales-and-why-are-there-so-many for additional details.

References

1. Box G, Jenkins G, Reinsel G. Time Series Analysis: Forecasting and Control. 4th ed. Hoboken, NJ: Wiley; 2008.
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3. Zeger SL, Irizarry R, Peng RD. On time series analysis of public health and biomedical data. Annu Rev Public Health 2006;27:57-79.