

Fear without a dose-response: real-time crowdsourced psychometrics show a moderate earthquake's psychological footprint is decoupled from shaking intensity in an anticipation-primed megacity

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Fear without a dose-response: real-time crowdsourced psychometrics show a moderate earthquake's psychological footprint is decoupled from shaking intensity in an anticipation-primed megacity

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Abstract

Fear shapes how populations respond to earthquakes, yet it is almost always measured retrospectively, once it cannot be separated from the damage. On 23 April 2025 a MW 6.2 earthquake shook Istanbul – a megacity that has anticipated a major rupture for 25 years – at ground motions below design level, causing one death and light damage. Using a validated earthquake-fear instrument delivered in real time on a crowdsourced platform, we obtained 186 responses within hours, each linked to the respondent's reported intensity and location. Within the sample, fear barely tracks shaking: its correlation with reported intensity is weak ($r = 0.24$; 6% of variance), and respondents on Istanbul's European and Asian sides report indistinguishable fear (24.2 versus 24.5; $p = 0.85$) despite the European side shaking harder. Fear responds to being substantially shaken at all – a threshold – not to how hard the ground shook – a dose. The footprint was a chronic condition made vivid, not an acute reaction: it produced a behavioural response – 100,000 people outdoors, injuries dominated by panic – out of proportion to a one-fatality event. Real-time psychometric measurement through crowdsourcing is feasible at scale and uniquely separates fear from its physical cause.

Keywords: earthquake fear; Fear of Earthquake Scale; risk perception; crowdsourced seismology; Istanbul; moderate earthquake; behavioural response; real-time psychometrics

1. Introduction

The human cost of earthquakes is not exhausted by what buildings do. Populations that anticipate a major earthquake carry a chronic burden of fear, and when a felt event arrives that fear becomes behaviour – evacuation, flight, sheltering outdoors, and injury sustained in escaping rather than from the shaking itself. Understanding this response matters for emergency planning, risk communication and public mental health, yet it is unusually hard to measure. Fear is almost always assessed by survey, weeks or months after an event (e.g., Prizmić-Larsen et al., 2023; Sarı et al., 2023; Satıcı et al., 2024), once the acute response has passed and once it has become impossible to separate fear of earthquakes in general from the specific earthquake that prompted the study.

A central question is whether that fear is proportionate to the physical severity of the shaking – a dose-response, in which harder shaking produces more fear – or whether it behaves instead as a threshold, triggered by the fact of a felt earthquake and set by a standing baseline that the individual event does little to move. The two possibilities have opposite implications for planning. If fear scales with severity, the behavioural response to a moderate event should be correspondingly moderate; if it is a threshold on a high baseline, even a moderate event can trigger close to the full response a far more destructive one would, and models calibrated on physical damage will badly underestimate it.

The 23 April 2025 MW 6.2 Marmara Sea earthquake, together with a real-time deployment of a validated fear instrument, allows the question to be addressed directly. The event was the largest rupture of the Main Marmara Fault in over sixty years and struck 20–50 km from Istanbul, whose anticipated ‘big one’ has structured Turkish disaster policy since the 1999 Kocaeli earthquake and whose fear of it was renewed by the 2023 Kahramanmaraş catastrophe. Yet the 2025 event was moderate: ground motions stayed below code design levels at every station, and the toll was one fatality – a cardiac arrest attributed to shock – and 359 injuries, most behavioural (Aktas et al., 2026). The European-Mediterranean Seismological Centre integrated the Fear of Earthquake Scale (Prizmić-Larsen et al., 2023) into the mobile-web interface of its LastQuake crowdsourced reporting platform (Bossu et al., 2018) as a pilot; 186 users completed it in the hours after the mainshock, each response carrying the respondent’s own reported shaking intensity and geolocation. To our knowledge this is the first application of a validated earthquake-fear scale to data collected in real time, within hours, rather than by retrospective survey – and, crucially, the geolocation and self-reported intensity let us test whether fear tracks the shaking each person actually experienced.

2. Results

2.1 A high-quality real-time fear signal

The 186 respondents returned a mean total score of 22.6 of 35 (median 22.0, sd 7.9), with high internal consistency (Cronbach’s $\alpha = 0.92$, matching the 0.90 of the instrument’s own validation; Prizmić-Larsen et al., 2023). The first response arrived 3.1 minutes after the mainshock and the median at 39.6 minutes. That a psychometrically coherent fear signal can be captured this quickly, through the same channel that collects shaking reports, is what makes the tests below possible. These 186 responses are distinct from, though drawn from among, the event’s felt reports. A felt report is the brief, picture-based testimony through which a LastQuake user indicates how strongly they felt the shaking – the basis of the reported intensity used throughout this paper – and takes only seconds; the Fear of Earthquake Scale questionnaire is a separate, longer instrument, offered to the user after their felt report, on which they rate seven statements about their fear of earthquakes. Of the felt reports submitted through the mobile-

web interface, roughly one in eight ($\approx 12\%$, 186 of 1,549) went on to complete the fear questionnaire, and the responses span the felt footprint from the Aegean to the Balkans, concentrated in Istanbul (Figure 2). Beyond the felt report – whose thumbnail-based method is described by Bossu et al. (2017) – LastQuake also collects free-text comments and geolocated photographs and videos, the latter published only after manual validation; the images analysed in Section 2.3 are drawn from this stream. Such crowdsourced platforms have supported rapid impact assessment for numerous earthquakes (Finazzi, 2016; Bossu et al., 2024).

We do not interpret the absolute level of fear against external norms. The instrument exists in several near-identical adaptations – Croatian and Turkish – validated on different samples with differing means, so no single external benchmark cleanly applies; our own reliability ($\alpha = 0.92$) simply matches the scale's validation (0.90). The analysis therefore rests entirely on within-sample contrasts, which require no such benchmark.

2.2 Fear is a threshold response, not a dose-response

The central finding for this event is that fear does not scale with the shaking each respondent experienced. Across the 186 respondents, the correlation between total fear and the respondent's own reported felt intensity is $r = 0.24$ ($p = 0.001$; Spearman $\rho = 0.23$), so experienced shaking accounts for only 6% of the variance in fear (Figure 1b). Two caveats make clear this is a weak relationship rather than a dose-response. It is small (6% of variance), so the tight error bars on the binned means in Figure 1b reflect bin sizes, not predictive strength: the individual scatter behind them is large. And it uses each respondent's own reported intensity, which is subjective and shares variance with fear – a frightened person may both feel and report stronger shaking – so the apparent trend is best read against the objective, matched test below. The weak trend that exists is coarse: mean fear rises from those who barely felt the event (intensity I–II) to those who clearly felt it (III and above) and then flattens. Fear distinguishes 'felt it substantially' from 'barely felt it', but resolves little beyond that.

The sharpest test removes the confounds of distance and population by comparing two halves of the same city. Within the Istanbul metropolitan area, respondents on the European and Asian sides of the Bosphorus report statistically indistinguishable fear – 24.2 against 24.5 out of 35 ($p = 0.85$) – even though the European side experienced systematically stronger shaking in this event, a difference resolved by both the instrumental record and the felt-intensity field (Aktas et al., 2026). Two matched urban populations, one demonstrably shaken harder than the other, were equally frightened (Figure 1c). There is a coarse geographic step – respondents inside the Istanbul window score higher than those in the wider felt footprint (24.3 against 21.2; $p = 0.007$), consistent with fear responding to gross proximity – but within the strongly-shaken city, the fine intensity gradient that instruments resolve leaves no trace in the fear scores. Objective shaking severity thus explains almost none of the fear, and the weak self-

reported association does not survive a matched, objective test: fear behaves as a threshold rather than a dose. The faint residual sensitivity to proximity may itself owe less to the shaking than to perceived exposure to the anticipated major rupture – people further from the Marmara fault have less reason to fear the long-expected ‘big one’, independent of how hard this particular event shook them.

2.3 The behavioural and physical signature of a threshold response

A fear response decoupled from physical severity is exactly what the event’s impact record shows. Of 359 recorded injuries across the Marmara region, the overwhelming majority arose from panic behaviour rather than structural failure: the Istanbul Governor’s Office attributed 151 of Istanbul’s 236 injuries to people jumping from height in panic, and the single fatality was a cardiac arrest attributed to shock (Aktas et al., 2026). Roughly 40,000 people sheltered outdoors on the first night and an estimated 100,000 across the event period, despite no inhabited building having collapsed. These are behavioural and physiological responses – flight, cardiac events, nights outdoors – at population scale, generated by an event that barely damaged the building stock.

What people were fleeing is documented directly. Of 25 geolocated files submitted through the platform, the 17 images uniformly record non-structural damage and displaced contents – objects thrown from shelves, broken glassware, a toppled television, cracked plaster at wall–ceiling junctions – and not one records structural damage (this classification is our own, from visual inspection). The hazard people experienced indoors was falling objects in structurally intact apartments, and the injuries were sustained overwhelmingly by people leaving those apartments rather than by people struck within them. A threshold-triggered fear, on a high standing baseline, sent a population out of buildings that were, on this event’s evidence, more dangerous to flee in panic than to occupy.

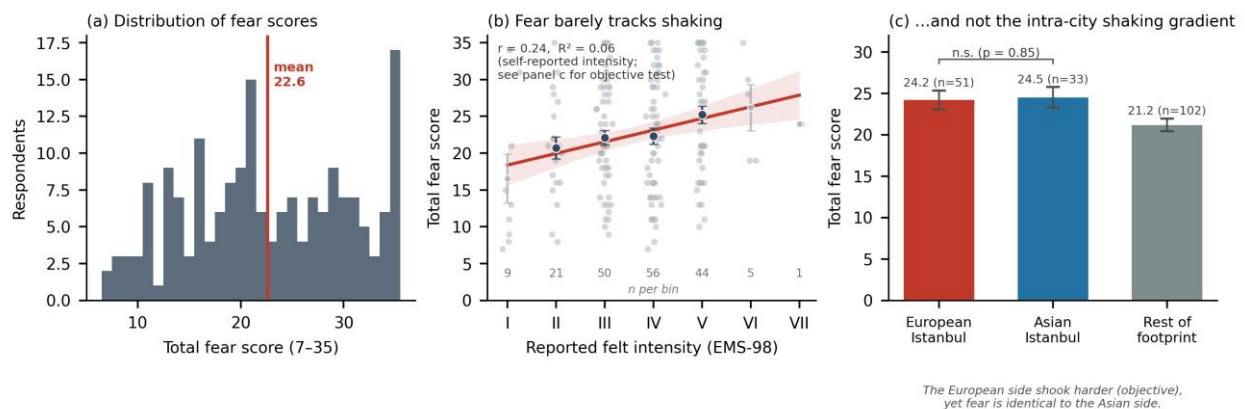


Figure 1. Fear is a threshold response, not a dose-response. (a) Distribution of Fear of Earthquake Scale total scores (n = 186), with the sample mean (22.6) marked. (b) Total fear against the respondent’s own reported felt intensity, with per-intensity means; fear rises weakly and coarsely ($r = 0.24$). The fitted regression line and its 95% confidence band are shown with the individual responses and the per-bin sample sizes; the slope is shallow relative to the scatter ($R^2 = 0.06$), and the two highest-intensity bins

(VI, VII) rest on very few respondents. (c) Total fear by location: respondents on Istanbul's European and Asian sides are indistinguishable ($p = 0.85$) despite the European side shaking harder, while both exceed the wider felt footprint – a coarse proximity step but no fine intensity gradient.

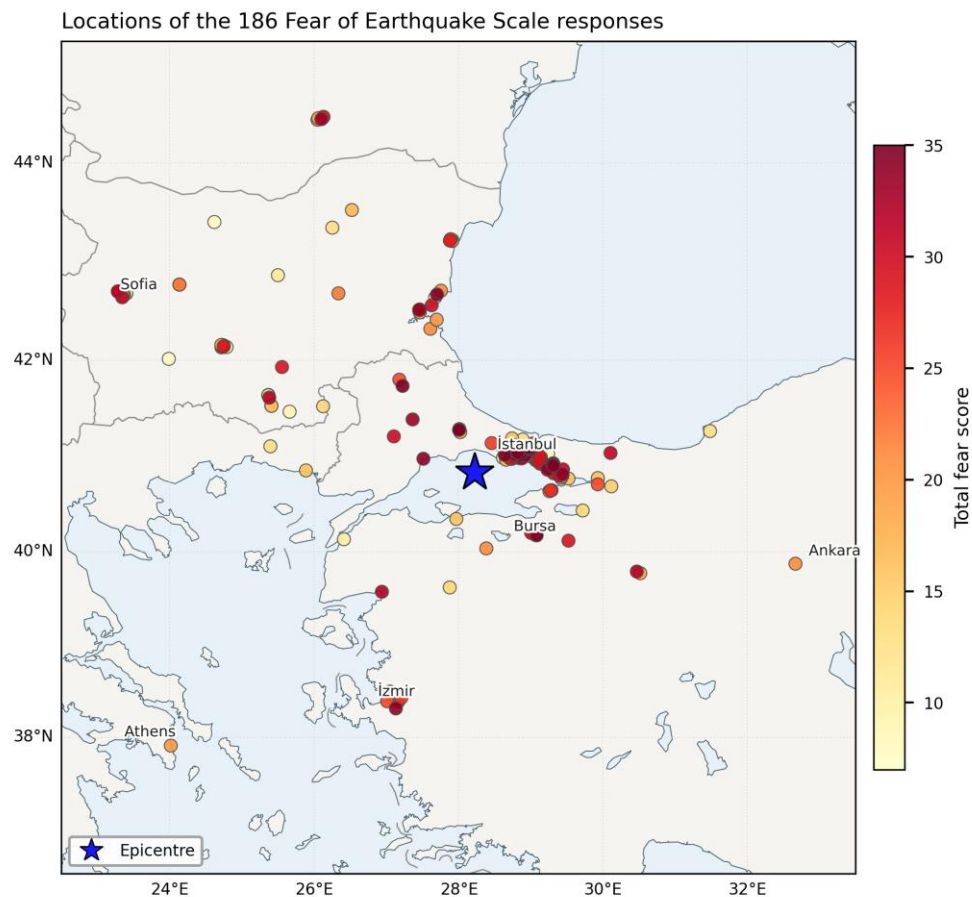


Figure 2. Locations of the 186 Fear of Earthquake Scale responses, coloured by total score; the blue star marks the epicentre. Responses concentrate in Istanbul (45%) but extend across the felt footprint into the Aegean, western Anatolia and the Balkans. High fear scores occur far from the epicentre as well as close to it.

3. Discussion

The result is simple and, we think, consequential: in an anticipation-primed megacity, the fear provoked by a felt earthquake is a threshold phenomenon, not a dose-response. It is triggered by the fact of substantial shaking and set by a standing baseline, and it does not resolve the intensity gradient that instruments and felt reports both record within the city. The cleanest evidence is the matched comparison of Istanbul's two sides: the European side shook harder, yet its residents were no more frightened than those across the Bosphorus. Because that comparison is between two halves of the same population, it requires no external benchmark and is immune to the sampling and instrument

caveats that attend cross-study comparison. Whether this holds elsewhere is an open and testable question. In a region without a looming anticipated event, the same shaking might instead produce a dose-like response, with fear scaling with severity; the threshold may therefore be a signature specifically of anticipation-primed populations – a hypothesis the growing multi-event record of this instrument is well placed to test.

This decoupling explains the event's most striking feature – a behavioural response grossly out of proportion to its physical severity. One hundred thousand people outdoors, mass departure attempts and an injury toll dominated by panic were generated by an earthquake that killed one person and left the building stock essentially intact. If fear scaled with shaking, a moderate event would produce a moderate response. Because it is instead a threshold on a high baseline, a moderate event that crosses the perceptual threshold triggers close to the full behavioural response. The practical implication is direct: models of post-earthquake displacement, evacuation and communication demand calibrated on physical damage will systematically underestimate the response to moderate events in primed populations – which are the events such populations most often experience. More broadly, a real-time fear measure adds a dimension to how risk itself is characterised: not only how strongly the ground shook, but how a population reacts and behaves during and immediately after it – a 'human-reaction layer' that carries its own consequences for risk, and that could be built by combining these responses with eyewitness comments and imagery.

That fear is a standing condition rather than a product of this event follows from the threshold result itself: if fear barely responds to how hard the ground shook, the fear a moderate event elicits is largely the fear the population already carried. The event did not create it; it made a chronic disposition acute enough to act on. This reading rests on the within-sample evidence and needs no comparison of absolute level against external norms. These conclusions are bounded by the sample and by the instrument, and we state both plainly. The 186 respondents are self-selected – they chose to complete a psychometric instrument moments after an earthquake – and are therefore likely more engaged, and plausibly more fearful, than the population at large; they are geographically concentrated and not demographically characterised. Self-selection compresses the range of the outcome, which would attenuate the fear–intensity correlation; we therefore treat $r = 0.24$ as a lower bound on an association that is, in any case, weak, and note that the matched European–Asian null does not depend on it. On the instrument, the deployed seven items are the Fear of Earthquake Scale (Prizmić-Larsen et al., 2023), a one-factor scale; we therefore analyse the total score and do not treat it as having subscales. The same seven items have been re-validated in Türkiye with differing results (two-factor in Sarı et al., 2023; one-factor in Satıcı et al., 2024) and on different populations, so no single external norm cleanly applies; we make no

normative comparison of absolute level and rest the analysis on within-sample contrasts. None of these caveats touches the central, within-sample finding.

Two extensions would strengthen the picture, and both are in progress. EMSC has now collected the scale for several hundred earthquakes through the same platform; a comparison across events of different size and in different populations would establish whether the threshold behaviour seen here is general or specific to anticipation-primed megacities. And the same platform records the fear and reporting response to the aftershock sequence, allowing the persistence of the response to be tracked directly over the days after a mainshock. Both are left to future work.

4. Methods

4.1 Event and setting

The earthquake occurred on 23 April 2025 at 09:49:12 UTC (12:49 local time) on the Kumburgaz segment of the Main Marmara Fault, at 15.2 km depth, MW 6.2, predominantly strike-slip, with a source duration of about 13 s. Recorded ground motions remained below the DD-2 code design level at every station.

The event caused one fatality and 359 recorded injuries across the Marmara region, the latter dominated by panic behaviour; full seismological and engineering documentation is given in the reconnaissance report (Aktas et al., 2026), which this paper does not reproduce.

4.2 The instrument and its administration

The instrument deployed is the Fear of Earthquake Scale (Prizmić-Larsen et al., 2023), a seven-item, one-factor measure of earthquake fear on a 1–5 Likert scale (1 = strongly disagree, 5 = strongly agree), giving a total of 7–35, adapted from the Fear of COVID-19 Scale (Ahorsu et al., 2020). The seven items – (1) “I am very fearful about earthquakes”, (2) “Thinking about the earthquake disturbs me”, (3) “My hands shake when I think about the earthquake”, (4) “I am very afraid of losing my life in an earthquake”, (5) “I get anxious and worried when I watch news and stories about earthquakes in the media”, (6) “Worry about being caught in an earthquake keeps me awake”, and (7) “My heartbeat speeds up when I think about being caught in an earthquake” – are each rated from 1 (strongly disagree) to 5 (strongly agree). The deployed questionnaire cites this scale as its source, and its items were confirmed against its verbatim. Because the scale is unidimensional, we analyse the total score and do not treat it as having subscales. The same seven items have since been re-validated in Türkiye (Sarı et al., 2023, as a two-factor scale; Satıcı et al., 2024, as one-factor), with differing norms; we treat the family as a single instrument and make no normative comparison of absolute level. EMSC integrated the questionnaire as a pilot into the mobile-web interface of the LastQuake platform, offered to users after they submitted a felt report (it was not available in the app), with no time restriction. The interface presents the questionnaire in the

respondent's browser language; the per-respondent language is not recorded. Because the sample lies overwhelmingly within Türkiye – roughly three-quarters of respondents, including the 45% in Istanbul – most are estimated to have seen the Turkish version, while the remainder in the Greek and Balkan parts of the felt footprint saw automatic translations into their own languages. This leaves the central, within-sample results unaffected: the matched European–Asian comparison is drawn entirely from within Istanbul, so both groups completed the same instrument. For the 2025 Marmara event, 186 complete responses were collected, each carrying a timestamp, geolocation, and the shaking intensity the respondent had reported.

4.3 Analysis

Total scores were computed as the item sum. Internal consistency was assessed by Cronbach's α . The association between fear and experienced shaking was assessed by Pearson and Spearman correlation of total score against the respondent's own reported EMS-98 intensity, and by comparison of mean fear across intensity levels. Geographic contrasts used the Istanbul metropolitan window 40.8–41.3°N, 28.0–29.5°E, divided at 29.0°E along the Bosphorus with two-sample t-tests (unequal variance). Analyses used Python (pandas, statsmodels, scipy).

Data availability

In keeping with EMSC's open-data policy, the fear-scale responses and associated felt-report data for EMSC event 1798415 are available in anonymised form; the data were extracted on 12 May 2026. Analysis code will be deposited (Zenodo) on acceptance.

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Author contributions

YDA: conceptualisation, analysis, writing – original draft. RB: LastQuake system and scale integration, methodology, writing – review. SI: crowdsourced data products and scale integration, data provision, writing – review. RS: data curation and platform products, writing – review.

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