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Scrolling Through the Heat: Evaluating User Engagement in an Interactive Map-Based Narrative of Urban Heat In Europe

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Abstract:

In 2022, 61 000 deaths were heat-related due to an extreme heatwave (Gallo et al., 2023), and in 2023, it was 47 000 (Ballester et al., 2024), making the last few years record-breaking for climate mortality on the continent over the last decade. The effect of the Urban Heat Island (UHI) increases physical pressure on citizens: in densely populated, built-up areas, air temperatures may exceed those in suburban areas by up to 8°C (Oke, 1982). At the same time, heat stress as a specific urban risk remains systematically underrepresented in public discussions compared to its real mortality burden: despite climate change being among the top-3 concerns of European citizens, surveys show that respondents often name floods and storms as the main threats, but not the extreme heat (European Commission, 2024). An independent proxy-indicator of public attention supports this assumption. Based on the Wikimedia Pageviews API, the "Heat wave" article in June 2023 was viewed about 11 times more than in the non-summer period (baseline is a median figure of views for November-February); the "Urban heat island" article, even in its historical peak, surpassed the non-summer baseline only by 2 times, and it was in 2019, coinciding with any documented heat waves. Altogether, these indicators reveal systematic issues in climate communication.

The goal of this study is to design, develop, and evaluate a climate-focused interactive map-based storytelling prototype using open-source web technologies, and to synthesize design guidelines for prototyping storytelling maps. For this purpose, three research objectives were defined: ***RO1* –** develop a three-level prototype (free exploration, authored narrative, immersive experience) based on the FOSS4G stack; ***RO2* –** assess user engagement through a between-subjects mixed-methods user study; ***RO3* –** synthesize empirically based recommendations on developing climate-focused storytelling maps through literature triangulation, documented design decisions, and research results.

The literature review reveals three interconnected gaps forming a problematic funnel. Communication gap ***(A):*** scientific data about heat stress are extensive and reliable; however, public risk perception remains reactive and unsystematic. Cartographic gap ***(B):*** scroll-based storytelling is widely used in data journalism; however, its use in climate cartography is practically unstudied from a user-experience perspective. Tool gap ***(C):*** The potential of the FOSS4G approach for narrative cartography is weakly documented, and there are no empirically based recommendations for designing climate story maps. Gaps create a cascade: poor climate communication ***(A)*** partially is because of narratively ineffective visualizations, such as overused choropleth maps ***(B),*** which remain a dominant format with a lack of documented open tools for narrative cartography and empirical-based reasons about how narrative storytelling is better than free explorative alternatives ***(C)***.

In order to systematically address these gaps, this research is grounded in five theoretical pillars. "Narrative visualization and cartographic storytelling" (Segel & Heer, 2010; Roth, 2021; Song et al., 2022) and "Interactive web cartography and FOSS4G" (MacEachren & Kraak, 2001; Roth, 2012) together form the design basis of the prototype ***(RO1)***. "Climate communication and risk perception" (Weber, 2006; Spence et al., 2012; Moser, 2010) provides a basis for hypotheses about engagement and psychological proximity. "Usability assessment and user engagement (O'Brien & Toms, 2008; O'Brien et al., 2018; Braun & Clarke, 2006) defines user study tools ***(RO2)***. "UHI science and geospatial data" (Oke, 1982; Arnfield, 2003; Fiala et al., 2012) sets visualization variables. The synthesis of all five pillars defines an evidence chain for design recommendations ***(RO3)***.

The prototype employs the narrative structure of "Martini glass": from the global view through the European scale to the three anchor cities - Vienna, Athens, and Berlin, with the main story focus on Vienna, which was chosen based on

four criteria: climate diversity, UHI intensity, data availability, and representability of three European archetypes of heat stress (mediterranean extreme, transitional central european, north-central). Narrative structure is built on the “Hero’s journey” approach: a 71-year-old citizen of Vienna residing in the Favoriten district, without AC, is introduced at the beginning and is presented from time to time in the story. The story ends with a message about small actions people can take to address urban heat, actions that blur the gap between reading the story and taking real action.

Three-level prototypes share the same thematic coverage, styling, and cartographic data, differing only in delivery method and interaction logic. Tier 1 is an independent, interactive heat atlas with exploration tasks and an informational side panel for each layer (an ecologically valid alternative delivery format and a non-traditional control condition). Tier 2 - authored narrative (scroll-based storytelling) with editorial text, graphs, and other multimedia. Tier 3 is Tier 2 plus the bundle of four experience-enhancing functions: audio narration, animated transitions, 3D elements, and personalization by the Vienna district. Comparison of Tier 1 and Tier 2 compares two ecologically valid delivery formats - controlled cartographic exploration and authored narrative scrolling-based storytelling; Tier 2 and Tier 3 isolate bundle experience effect. The whole stack, MapLibre, deck.gl, etc., is built around FOSS4G; in the context of climate communication, the choice of open-source software is not only a technical decision but also an ethical one, ensuring reproducibility and public access.

Evaluation is conducted through an intergroup experiment (A/B/C, between-subjects, n = 30, each with at least 10 participants per tier), with initial recruiting via social media. Recruiting source is treated as a covariate in all sensitivity analyses. Three primary endpoints were adjusted using the Holm-Bonferroni method: (H1) the total UES-SF score (O'Brien et al., 2018) differs across tiers (Tier 3 > Tier 2 > Tier 1); (H2) knowledge gain Δ (pre-/post-test, 6 items K1–K6) differs across tiers; a directional hypothesis regarding Tier 3 versus Tier 2 is not formulated due to theoretical ambiguity between dual coding (Paivio, 1986) and extraneous cognitive load (Sweller, 1994); (H3) the psychological proximity index (adapted from Spence et al., 2012) is higher in the narrative tiers (Tier 3 > Tier 2 > Tier 1), in accordance with Weber’s (2006) experiential information processing theory. Secondary methods: SUS (Brooke, 1996), UEQ-S (Schrepp et al., 2017), behavioral logs (Supabase), cognitive load (PAAs scale), self-efficacy (SE-1, SE-2), open questions (Braun & Clarke, 2006). The power at n = 60 is ~80% for large effects (Cohen's f ≈ 0.40). Main constraints: Tier 3 is being tested as a single bundle without isolating each feature; the prototype is optimized mostly for the desktop version; a single-session format limits the assessment of long-term attitudes; a novelty effect is possible among Tier 3 participants; self-selection via social media limits generalizability.

Upon completion of the research, a functional three-level interactive climate storytelling web prototype will be created, and empirically reasoned design guidelines will be derived. Scientific contribution consists of conducting empirical research comparing the influence of narrative delivery format on user engagement and climate risk perception in the context of mapping heat stress, and of demonstrating the FOSS4G stack's suitability for narrative climate cartography. The study aligns with the UN Sustainable Development Goals: SDG 3, SDG 11, SDG 13, and SDG 4.

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