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Indications of (not so clear) Gender Differences in VR-based Urban Fear Spaces

Katrin Reichert [a,*], Julian Keil [a], Dennis Edler [a], Frank Dickmann [a]

[a] *Institute of Geography, Ruhr University Bochum, Bochum, Germany, katrin.reichert@rub.de, julian.keil@rub.de, dennis.edler@rub.de, frank.dickmann@rub.de*

* Corresponding author

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Abstract:
Fear in public spaces is shaped by environmental and social factors such as poor lighting, overcrowding, and bias (Kelling & Wilson, 1982). From a cartographic perspective, such factors can be conceptualized and analyzed as spatial attributes of urban environments, enabling the mapping and simulation of fear-relevant spaces. Lighting quantity (brightness and distribution) and quality (color temperature and directionality) strongly influence perceived safety, with poor lighting heightening insecurity, whereas well-designed lighting enhances comfort (Lis et al., 2024). Previous studies report gender differences in fear perception and call for more gender-sensitive approaches in urban design (Dellenbaugh-Losse, 2024; Peterson, 2024). Most research relies on self-report questionnaires and finds that women report higher levels of fear than men, a pattern that may by influenced by social desirability bias and gender norms (Krauß & Schwimmer, 2021). This highlights the need for methodological approaches that go beyond self-report to examine gender-based fear perceptions more comprehensively. Virtual reality (VR) with head-mounted displays enables immersive assessment of fear-related spaces, extending cartographic approaches towards experimental mapping through increased emotional engagement and sense of presence (Felnhofer et al., 2015). As individuals are not always consciously aware of fear triggers, combining self-reports with implicit physiological measures provides a more comprehensive perspective. Electrodermal activity (EDA) reliably captures unconscious stress responses linked to emotional arousal (Braithwaite et al., 2015), while the Self-Assessment Manikin (SAM) assesses arousal, dominance and valence (Bradley & Lang, 1994). Thus, SAM captures conscious emotional experience, whereas EDA reflects autonomic arousal, thereby indexing distinct dimensions of emotional responding. Although differences between subjective and objective fear measures are well documented, their gender-specific expression in VR contexts remains underexplored. In this study, a virtual "space of fear" was developed from urban data, translating a real-world site into a spatially accurate VR environment that preserves key cartographic properties such as scale and layout, while integrating visual and auditory cues. The experiment included one dusk baseline and two nighttime scenes differing only in lighting: two localized cold-white spotlights versus a distributed, warmer scheme (see Figure 1). After each scenario, participants rated their emotional state using an adapted SAM scale. Following Keil et al. (2023), participants explored the environments using a head-mounted display while wearing skin conductance sensors to record EDA, with the SAM task embedded directly in VR.

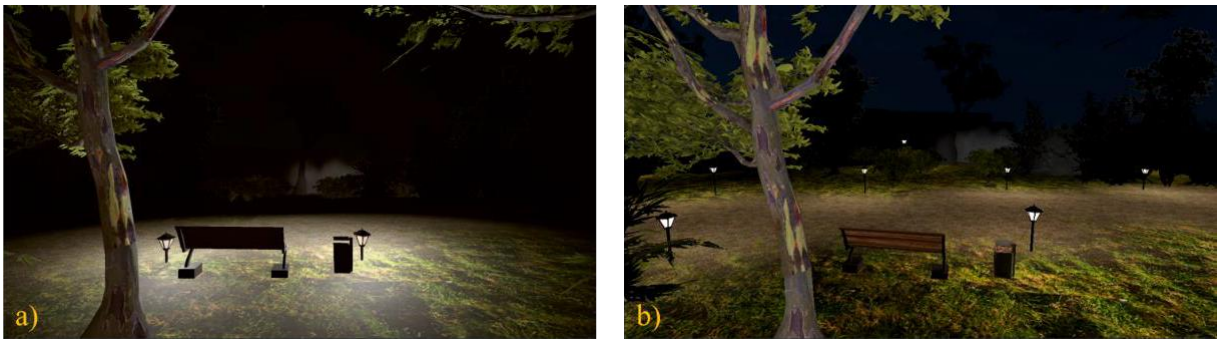

Figure 1. Virtual 3D model of the self-built urban green space at nighttime: a) punctual condition: localized cold-white spotlights; b) distributed condition: distributed warmer lighting with softer distribution.

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Results indicate that both nighttime scenes elicited fear responses, as confirmed by significant correlations across the SAM dimensions and by significant differences between the two conditions (Arousal: $W = 287.5$, $p = .014$; Dominance: $W = 1010$, $p < .001$; Valence: $W = 853.5$, $p < .001$, $n = 57$). Gender comparisons (29 females, 28 males) showed significant differences in subjective ratings (see Figure 2), whereas no significant differences were observed in EDA data. These findings reveal a discrepancy between physiological and self-reported fear responses, suggesting that gender differences are reflected in subjective evaluations rather than in physiological reactions. Possible explanations include social desirability, gender norms, differences in interpreting arousal as fear, and variability in EDA. Further analyses with larger samples are needed to confirm these results and to better interpret EDA responses. Overall, this study illustrates how VR-based geovisualizations can serve as testbeds for examining urban perceptions and affective cartography. Such approaches may help uncover subtle gender-based differences and inform spatially explicit and more inclusive urban design strategies.

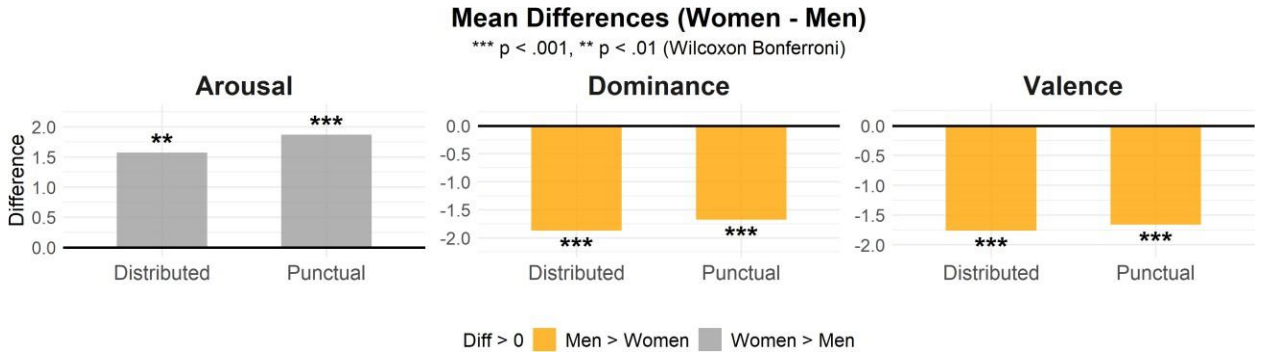

Figure 2. Mean differences (women minus men) in SAM dimensions arousal, dominance, and valence for the two conditions punctual and distributed with significant differences between the genders (***p < .001; **p < .01).

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