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Physiological Arousal or Social Influence: Which Better Predicts Pre-Evacuation Decision-Making?

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Delays during the pre-evacuation phase remain a leading cause of fire-related fatalities, yet the relative influence of emotional and social factors on pre-evacuation decision-making is not well understood. Previous studies show that fear heightens physiological readiness, but evidence is limited regarding whether such arousal directly leads to action or is moderated by social cues. This study addresses that gap by comparing fear-induced physiological activation and social influence in predicting evacuation behavior under simulated fire conditions. To model social influence, a trained research team member acted as a confederate, posing as a fellow participant so the real participant believed they were collaborating; during the alarm, the confederate either remained seated or exited. Twenty-two participants completed an autobiographical fear-recall task followed by a mock alarm while physiological responses were recorded using the Empatica E4 wristband. Results showed that fear induction significantly increased arousal, but physiological measures, electrodermal activity, heart rate, and temperature, did not predict evacuation decision. Participants were more likely to evacuate when the confederate left demonstrating that social cues outweighed internal activation. These findings show that emotional readiness alone is insufficient for action and highlight the importance of leadership, communication, and group modeling in improving emergency preparedness and safety training.

Keywords: Fear; Arousal; Social influence; Evacuation; Safety

Introduction

Fire remains a major global hazard, causing over 1.4 million incidents in the United States in 2024, with 3,790 deaths, 13,250 injuries, and $18.1 billion in losses (Hall, 2022). Globally, fire-related events cause about 180,000 deaths and 7 million injuries annually (World Health Organization, 2023). Despite advances in safety technologies, survival outcomes are largely shaped by human behavior. Many fatalities are linked to delays that occur in the pre-evacuation phase, the brief period between recognizing danger and beginning to move. Research shows this stage can last 30 seconds to more than five minutes, even when exits are accessible and alarms are working (Kuligowski, 2013; Ronchi et al., 2019). Such hesitation rarely stems from physical barriers but from how people interpret risk and decide when to act.

Among the psychological determinants of pre-evacuation delay, fear and social influence have emerged as the most powerful and interacting forces (Kinateder et al., 2015; Ronchi et al., 2019), yet their relative contributions remain unresolved. Fear heightens awareness and physiological readiness but, when excessive, can paralyze decision-making (Christianson, 1992; Aston-Jones & Cohen, 2005; Wichary et al., 2016). On the other hand, social influence, conversely, shapes interpretation through others' actions or inaction, often delaying response when uncertainty is high (Sime, 1992; Kinateder & Warren, 2016).

Despite substantial progress in evacuation research, the relative influence of physiological arousal and social cues on pre-evacuation decision-making remains unclear (Kinateder & Warren, 2016; Ronchi et al., 2019; Adetooto et al., 2025). Fear has often been examined through subjective reports or post-event recall, offering limited accuracy in capturing real-time physiological activation (Adetooto et al., 2025; Kim & Choi, 2025). Studies on social influence have relied on observational or virtual-reality contexts that omit concurrent physiological data (Nilsson & Johansson, 2009; Kinateder & Warren, 2016; Kinatedera & Shibanb, 2017; Rostedt & Andersson, 2019). Consequently, no integrated evidence demonstrates how physiological readiness (an objective indicator of fear) interacts with social context to shape evacuation timing. This gap limits understanding of which factor, physiological arousal or social influence, plays a more decisive role during pre-evacuation, underscoring the need for objective, time-resolved behavioral models. Given the small sample size, the study is positioned as an exploratory investigation that offers initial behavioral insight and informs future larger-scale research.

Pre-evacuation behavior is also relevant to construction environments. Jobsites change quickly, alarms are often ambiguous, and workers frequently look to supervisors or coworkers before acting (Lee et al., 2020; Pulver, 2021). Social dependence, noise, and crew structures can delay evacuation (Pulver, 2021). Understanding whether people rely more on internal arousal or social cues can therefore improve construction safety training and emergency communication on active jobsites.

This study advances understanding pre-evacuation decision-making by comparing physiological fear responses and social influence cues under controlled emergency simulations. By integrating behavioral observations with biosensor data, it examines how emotional and social factors jointly shape the timing of protective action and determines which factor better predicts pre-evacuation decisions under threat.

Background

Human Decision-Making in Pre-Evacuation

Pre-evacuation decision-making involves interpreting cues, assessing threat credibility, and deciding when to act under uncertainty (Kuligowski, 2013). The Protective Action Decision Model (PADM) conceptualizes this as cue recognition, threat appraisal, and response initiation (Lindell & Perry, 2012). Delays often occur not because of physical barriers but due to internal evaluations about whether action is necessary or justified (Kinateder et al., 2015). These judgments depend on perceived risk, situational ambiguity, and confidence in social or environmental information (Kinateder & Warren, 2016). However, decision processes are not purely cognitive; emotional arousal plays a defining role in how threat information is interpreted, linking perception to physiological readiness and behavioral choice. However, existing models such as PADM primarily emphasize cognitive appraisals and situational cues but insufficiently capture how emotional or social states dynamically alter decisions during the pre-evacuation phase (Lindell & Perry, 2012; Kuligowski, 2013; Kinateder et al., 2015). Because decision-making is not purely cognitive, it is necessary to examine the emotional processes that accompany it.

Emotional and Physiological Responses to Fear

Fear is the most dominant emotional response during fire emergencies, shaping how people appraise risk and initiate protective action (Ronchi et al., 2019). It activates sympathetic arousal, increasing electrodermal activity, heart rate, and skin temperature through locus-coeruleus–norepinephrine and hypothalamic–pituitary–adrenal mechanisms (Aston-Jones & Cohen, 2005; Wichary et al., 2016). While this activation prepares the body for rapid response, excessive arousal can narrow perception and delay decision-making (Sjouwerman et al., 2020). Fear-induced arousal alters individual readiness for action, but its interaction with social cues during pre-evacuation remains unclear. Understanding these physiological signatures is essential, as they reveal real-time emotional states that self-report methods often overlook, thereby improving the accuracy of behavioral prediction during pre-evacuation. Beyond internal emotional activation, external social cues also strongly influence behavioral choice.

Social Influence in Emergency Contexts

Social influence determines how individuals interpret uncertain cues and decide whether to act (Nilsson & Johansson, 2009; Rostedt & Andersson, 2019). People often look to others for behavioral validation; passive bystanders can inhibit movement, while active evacuees encourage it (Kinateder & Warren, 2016). Experimental findings show that exposure to non-moving confederates substantially reduces the likelihood of evacuation (Adetooto et al., 2025). Nonetheless, existing research mainly relies on observational contexts that capture behavioral conformity but neglect concurrent physiological data (Nilsson & Johansson, 2009; Kinateder & Warren, 2016; Adetooto et al., 2025). As a result, the combined effect of observable social cues and internal physiological arousal on evacuation timing remains empirically untested. Since emotional and social cues co-occur during emergencies, an integrated approach is necessary.

Integrating Emotion and Social Influence

Although prior studies suggest that emotional arousal and social influence may jointly shape decision-making under uncertainty (Wichary et al., 2016; Ronchi et al., 2019), this relationship has not been systematically examined within evacuation contexts. Physiological arousal may heighten vigilance but also intensify conformity when social cues appear stable, whereas strong activation may override group inaction (Kinateder & Warren, 2016; Wichary et al., 2016). These potential interactions highlight the need to move beyond treating emotion and social influence as independent predictors. Integrating real-time physiological and behavioral data enables researchers to test these hypothesized dynamics and improve the predictive validity of evacuation models, shifting from rational-choice assumptions toward biologically and socially grounded realism.

Point of Departure

Although previous studies have examined emotional and social determinants of pre-evacuation behavior, their combined influence has never been objectively measured using physiological data during real-time emergency simulation. Existing research has primarily relied on self-reports, recall surveys, or observational data, limiting insight into how fear-related physiological arousal and social influence jointly shape actual evacuation decisions (Nilsson & Johansson, 2009; Kinateder & Warren, 2016; Adetooto et al., 2025). The absence of synchronized physiological and behavioral evidence leaves a fundamental gap in understanding which factor, emotional readiness or social context, plays the more decisive role when individuals face ambiguous threat cues.

To address this gap, the present study integrates biosensor-based measures of electrodermal activity, heart rate, and temperature with controlled social manipulation in a simulated fire scenario. This approach enables an objective, time-resolved assessment of how physiological arousal and social influence interact to predict pre-evacuation decisions, advancing behavioral models beyond cognitive or observational limitations. This study therefore poses the following research question: *Which factor more strongly predicts pre-evacuation decision-making during a fire emergency, fear-*

related physiological arousal or social influence? To answer this question, three hypotheses were tested:
H_{01}: Fear induction does not affect physiological arousal.
H_{02}: Physiological arousal does not influence evacuation decisions.
H_{03}: Social influence does not have a stronger effect on evacuation decisions than physiological arousal.

Research Methodology

Experimental Design

This study employed a controlled laboratory experiment to examine how fear-related physiological arousal and social influence cues shape pre-evacuation decision-making. A mixed-factor design was adopted, incorporating a within-subject emotion manipulation (baseline, fear induction, and alarm exposure) and a between-subject social condition (confederate leaves vs. stays). The primary dependent variables were physiological indicators of arousal, electrodermal activity (EDA), heart rate (HR), and skin temperature (TEMP), recorded via the Empatica E4 wristband (see Figure 1). The behavioral outcome was the participant's evacuation decision (leave vs. remain) following the simulated fire alarm.

Participants and Study Setting

Twenty-two participants (11 male, 11 female), all healthy adults over 18 years old, were recruited from Purdue University through voluntary sign-up. Individuals with severe anxiety, PTSD, trauma-related conditions, or pregnancy were excluded to ensure participant safety. Each subject completed one experimental session lasting approximately 90 minutes in a controlled room within Grissom Hall, at Purdue University. Seating, temperature, and lighting conditions were kept constant across sessions. All participants provided informed consent, were exposed to mild deception to preserve natural responses, and were fully debriefed after the session. Given that the sample consisted of university students, generalization to broader populations should be made with caution.

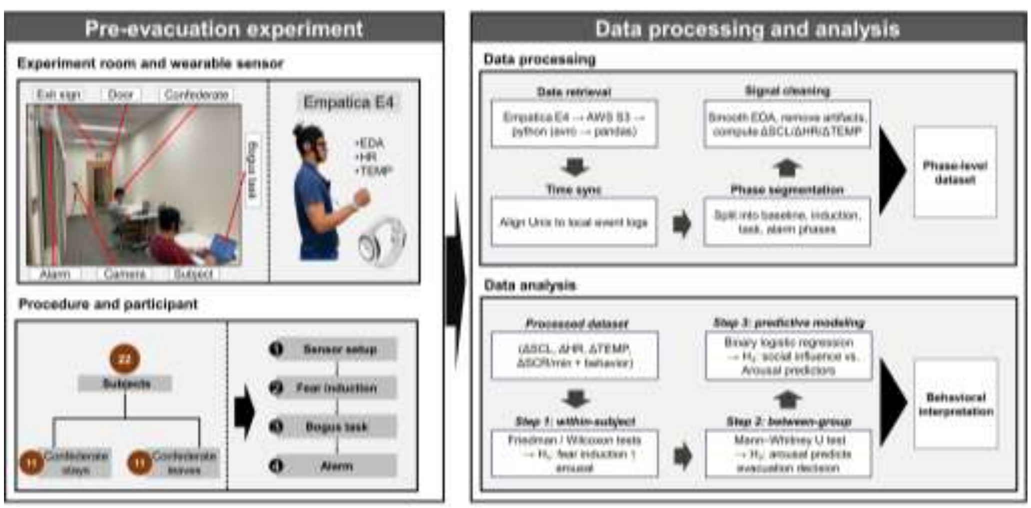


Figure 1. Methodological framework.

Experimental Procedure

Participants were individually escorted to the laboratory from another floor to avoid prior interaction and preserve the study's deception protocol. After providing informed consent, each participant was introduced to a confederate, who was presented as a fellow volunteer to mimic a shared task environment. A trained member of the research team served as the confederate during the sessions, and no participants expressed suspicion during the study or debriefing. The Empatica E4 wristband was placed on the participant's non-dominant wrist for continuous measurement of electrodermal activity, heart rate, and skin temperature throughout the session.

Figure 2. Experimental procedure timeline showing sequential phases and durations.

As illustrated in Figure 2, the experimental procedure consisted of sequential phases, including baseline calibration, fear induction, bogus task, and alarm exposure, each with defined durations and transition criteria. Following calibration, participants completed a 12-minute autobiographical writing task designed to evoke fear by recalling a personal event associated with strong anxiety (Fakhrhosseini & Jeon, 2017). This self-referential method has been shown to reliably elicit discrete emotional states and maintain sustained arousal compared with standardized visual stimuli. Immediately afterward, participants performed a neutral grammar task lasting four minutes to stabilize attention before the emergency simulation. During this task, an unexpected fire alarm of approximately 100 dB was activated. The confederate enacted one of two behaviors, either remaining seated and continuing the task (stay condition) or promptly exiting the room (leave condition), while the participant was free to decide whether to stay or evacuate. No verbal cues or prompts were given. The experimental session ended immediately if the participant left the room, or four minutes after alarm onset if the participant remained seated. Physiological data were continuously recorded across all stages, capturing transitions from baseline to induction, neutral task, alarm, and post-alarm periods. Following completion, participants were fully debriefed, informed of the confederate's role and the simulated nature of the alarm, and given the option to withdraw or reconfirm consent for data inclusion.

Data Processing and Analysis

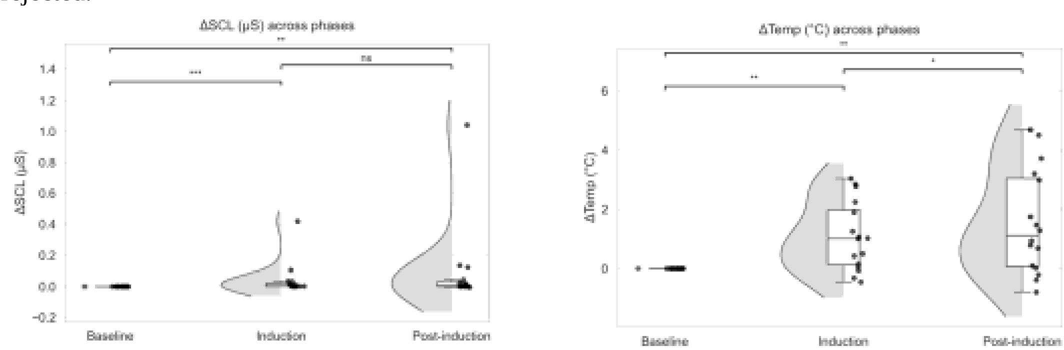
Physiological data were collected through Empatica E4 and downloaded from the cloud using a secure Python-based pipeline interfacing with the Amazon Web Services Simple Storage Service (AWS S3) Application Programming Interface (API). The raw .avro files contained timestamped streams of electrodermal activity (4 Hz), blood-volume pulse (64 Hz), and skin temperature (4 Hz). Files were decoded and synchronized using avro and pandas' libraries, with timestamps converted to both Unix and local time to preserve temporal precision. Event logs defined six consecutive time windows: baseline (2 min pre-induction), induction (12 min), post-induction (2 min), bogus-task (4 min), alarm (variable), and post-alarm (1 min). Each signal was aligned and cropped to these intervals for analysis. Electrodermal activity was smoothed with a one-second rolling mean to remove transient artifacts. The tonic component (skin-conductance level, SCL) was computed as the median for each experimental phase. The phasic component (skin-conductance responses per minute, SCR/min) was then extracted separately to capture transient sympathetic activations. These responses were quantified using adaptive peak thresholds at the 70th percentile to ensure consistent detection across participants. Heart rate was derived from blood-volume pulse by detecting valid inter-beat intervals (0.3–2.0 s) and converting the median interval to beats per minute, and temperature values were averaged per phase.

All variables were baseline-normalized (ΔSCL, ΔSCR/min, ΔHR, ΔTEMP) to control for individual variability. Phase-level metrics were aggregated into a single dataset for inferential testing. Non-parametric Friedman and Wilcoxon tests evaluated within-subject phase differences, Mann–Whitney U tests compared alarm-phase physiology between participants who stayed versus evacuated and repeated-measures ANOVA with Greenhouse–Geisser correction examined parametric contrasts. Binary logistic regression assessed whether standardized physiological changes predicted evacuation decisions beyond the influence of social condition. Statistical significance was set at $\alpha = 0.05$, with Holm corrections applied for multiple comparisons and effect sizes (Cliff's δ or η^2) reported for magnitude interpretation.

Results

H_{01}: Fear induction does not affect physiological arousal.

To test H_{01}, physiological data were analyzed across baseline, induction, and post-induction phases. As illustrated in Figure 3, skin conductance level (ΔSCL) increased from baseline (mean = 0.000, standard deviation = 0.000 µS) to induction (mean = 0.040, standard deviation = 0.100 µS) and post-induction (mean = 0.090, standard deviation = 0.260 µS). This change was statistically significant, $Q(2) = 17.750$, $p < 0.001$, leading to rejection of H_{01}. Heart rate rose slightly from baseline (mean = 0.000, standard deviation = 0.000 bpm) to induction (mean = 8.440, standard deviation = 21.370 bpm) and post-induction (mean = 8.440, standard deviation = 23.490 bpm), but the difference was not significant, $F(2,30) = 2.040$, $p = 0.167$. Temperature followed a similar increasing trend from baseline (mean = 0.000, standard deviation = 0.000 °C) to induction (mean = 1.090, standard deviation = 1.160 °C) and post-induction (mean = 1.540, standard deviation = 1.770 °C), showing a significant effect, $F(2,30) = 12.330$, p = 0.003, $\eta^2 = 0.451$. Collectively, these findings demonstrate that the autobiographical recall task effectively triggered and sustained physiological arousal across phases, confirming that H_{01} was rejected.

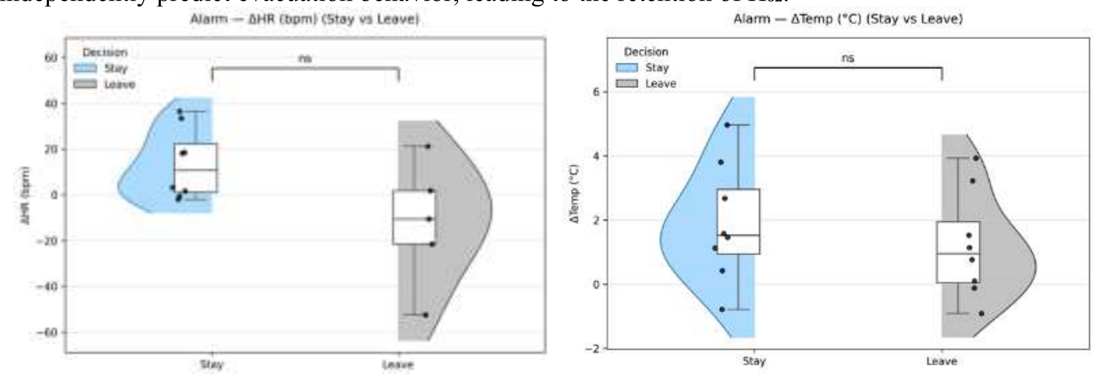


(a) Skin conductance level (b) Temperature

Figure 3. Changes in physiological arousal across experimental phases

H_{02}: Physiological arousal does not influence evacuation decisions.

To test H_{02}, Mann–Whitney U tests were conducted on *delta (Δ)* values, representing within-person change from baseline, to compare physiological arousal between participants who evacuated and those who stayed during the alarm phase. As shown in Figure 4, there were no statistically significant group differences in electrodermal response (ΔEDR: $U = 26.500$, $p = 0.599$), heart rate (ΔHR: $U = 9.000$, $p = 0.127$), or temperature (ΔTemp: $U = 24.000$, $p = 0.442$). Although evacuees exhibited slightly higher, heart rates and lower temperatures, these differences were small and not statistically meaningful. These findings indicate that while fear induction increased physiological arousal, such activation did not independently predict evacuation behavior, leading to the retention of H_{02}.



(a) Heart rate (b) Temperature

Figure 4. Physiological comparison between stayers and leavers during the alarm phase.

H_{03}: Social influence does not have a stronger effect on evacuation decisions than physiological arousal.

To test H_{03}, a binary logistic regression was performed to determine whether social influence or physiological arousal better predicted evacuation decisions. As shown in Table 1, the overall model was statistically significant, $\chi^2(2) = 9.370$, $p = 0.045$, correctly classifying 77.300% of cases. Social influence emerged as the only significant predictor ($\beta = -3.091$, $p = 0.030$), indicating that participants were substantially more likely to evacuate when the confederate left than when they stayed (Exp(B) = 0.045, 95% CI [0.003, 0.743]). In contrast, physiological arousal, represented by changes in temperature (zΔTemp), did not significantly predict evacuation behavior ($\beta = 0.547$, $p = 0.450$, Exp(B) = 1.727, 95% CI [0.417, 7.139]). Neither skin conductance nor heart rate reached significance in earlier regression models and were excluded from the final analysis. These findings confirm that social behavior, rather than physiological activation, was the key determinant of evacuation outcomes, leading to the rejection of H_{03} and highlighting the dominant role of social influence in pre-evacuation decision-making.

Table 1. Logistic regression predicting evacuation decisions from physiological arousal and social condition

Variable	**Estimate (β)**	**Exp(B)**	**95% CI Low**	**95% CI High**	**Inverse Exp(B)**	**p-value**
Const	1.200	3.319	0.680	16.191	0.301	0.138
Social influence (Stay)	-3.091	0.045	0.003	0.743	22.012	0.030
z(ΔTemp)	0.547	1.727	0.417	7.139	0.579	0.450

Discussion

The results confirmed that autobiographical recall significantly increased physiological arousal, evidenced by elevated skin conductance and temperature values across phases. This finding demonstrates that self-referential emotional recall effectively induces sympathetic activation consistent with established models of stress and decision-making (Aston-Jones & Cohen, 2005; Wichary et al., 2016). By eliciting emotion through personal memory rather than standardized stimuli, the study replicates authentic fear responses within a controlled laboratory environment. Such induction mirrors the subjective anxiety that individuals may experience before clear confirmation of danger, enhancing the ecological validity of the manipulation (Sjouwerman et al., 2020).

Having established that autobiographical recall reliably induced physiological arousal, the next question was whether this activation influenced evacuation behavior once the alarm was triggered. The results for Hypothesis 2 showed that physiological arousal, measured through electrodermal responses (ΔEDR), heart rate (ΔHR), and skin temperature (ΔTemp), did not significantly differ between those who evacuated and those who stayed during the alarm phase. This suggests that while participants experienced heightened arousal following fear induction, these physiological changes did not directly drive the behavioral decision to evacuate. Rather than serving as a behavioral trigger, physiological activation represented an internal state of vigilance and uncertainty. In real-world emergencies, autonomic responses such as increased heart rate or skin conductance prepare the body for potential action, but the actual decision to move depends on cognitive interpretation and environmental validation (Aston-Jones & Cohen, 2005; Lindell & Perry, 2012). For example, individuals often pause to interpret whether an alarm is genuine or a false trigger, seeking additional cues such as smoke, crowd behavior, or verbal confirmation before acting (Kinsey et al., 2019). During the alarm, participants were not explicitly told the alarm signified danger, mirroring the ambiguity common in real emergencies where individuals await confirmatory social cues before acting. The non-significant differences observed here align with prior findings that fear alone can heighten awareness without necessarily prompting immediate evacuation (Kinateder & Warren, 2016; Ronchi et al., 2019). Therefore, physiological arousal in isolation may be a necessary but insufficient precursor to protective behavior during uncertain emergencies.

Given that internal arousal alone did not predict evacuation, the next analysis examined whether external social cues better explained participants' behavioral choices. The third hypothesis examined whether social influence would exert a stronger effect on evacuation behavior than physiological arousal, and the results supported this prediction. The logistic regression model showed that social influence significantly predicted evacuation outcomes ($\beta = -3.091$, $p = 0.030$), whereas physiological arousal (ΔTEMP) did not. Participants were more likely to evacuate when the confederate left, indicating that observable social cues exerted greater influence than internal physiological states. This pattern aligns with previous research showing that, under ambiguous threat conditions, individuals often interpret risk through the behavior of others (Kinateder & Warren, 2016). Social influence thus provided the clearest behavioral signal, while emotional arousal primarily reflected internal readiness. Together, these findings suggest that evacuation decisions are shaped more by social context than by individual physiological activation, underscoring the importance of communication and group modeling in pre-evacuation planning.

Contributions to Theory

This study provides new empirical insight into the relationship between emotion and behavior in evacuation contexts. Self-generated fear induction increased physiological arousal. However, this response did not directly lead to protective action, distinguishing emotional readiness from behavioral execution. This finding clarifies that while fear heightens vigilance and bodily preparedness, actual evacuation decisions are strongly impacted by cognitive appraisal and social validation. By experimentally contrasting internal arousal with external social influence, the study shows that emotional and social processes interact to shape decision timing under uncertainty. These results deepen our understanding of how human responses unfold in the critical moments before evacuation, highlighting the dynamic interplay among emotional activation, perception, and social context.

Contributions to Practice

The findings of this study have clear implications for emergency planning and safety management. These findings also relate to construction safety, where workers often make evacuation decisions in noisy and rapidly changing environments. Jobsite alarms can be unclear, and workers frequently look to supervisors or nearby coworkers before deciding to move. Results show that physiological arousal alone does not predict evacuation, meaning that fear or stress by itself is not enough to prompt movement. Instead, visible social cues, such as when others begin to move, play a stronger role in driving action. Training and evacuation plans should therefore include designated first movers or supervisors who model response behavior during alarms. Communication systems should combine sound and visual prompts to clarify what action is expected. Communication systems should integrate auditory and visual prompts to reduce ambiguity and ensure that individuals clearly understand the required response. Drills should also incorporate controlled uncertainty to simulate real decision-making conditions and improve independent response readiness. Finally, physiological monitoring tools such as wearable biosensors (e.g., wrist-worn electrodermal and heart rate sensors) can be used in training to assess when high stress does not lead to movement, helping safety managers identify hesitation patterns and improve response readiness.

Conclusion and Limitations

This study contributes to the growing understanding of pre-evacuation behavior by experimentally distinguishing between physiological arousal and social influence as predictors of evacuation decisions. Using autobiographical recall as a novel emotion-induction method, the current study demonstrates that personally generated fear reliably elicits measurable sympathetic activation, validating its use as an ethically sound and ecologically relevant approach to studying emotional states in controlled evacuation research. However, the findings reveal that such physiological activation alone does not directly translate into evacuation behavior. Instead, observable social cues, particularly the behavior of others, emerged as the dominant driver of decision-making under ambiguous threat conditions. These results emphasize that fear may prime readiness but that collective action cues determine behavioral execution, underscoring the social nature of protective decision-making.

Despite its contributions, this study has several limitations. The controlled laboratory setting may not fully capture the complexity and intensity of real emergencies, and the small, university-based sample limits generalizability. The autobiographical recall, though effective, induced generalized fear rather than event-specific evacuation fear, which may differ in field contexts. Physiological measures were limited to three indicators; future studies should integrate multimodal metrics (e.g., respiration, EEG) and group-level dynamics to capture interactive effects. Nonetheless, the findings establish a methodological and conceptual foundation for future research combining affective physiology, social modeling, and real-time analytics. Practically, they highlight that enhancing visible leadership, social modeling, and communication clarity is more critical for effective evacuation than fear elevation alone.

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