



Investigating the Relationship Between Psychological Safety, Role Ambiguity, and Adaptive Team Performance Among Firefighters and Emergency Responders During High-Stress Incidents

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Abstract

Firefighters and emergency responders operate in dynamic environments where uncertain responsibilities and acute stress can compromise coordinated action. This technical report develops an integrated, testable framework linking psychological safety, role ambiguity and adaptive team performance under high-stress incident conditions. An analytically grounded review synthesizes research on team psychological safety, role stress, adaptation, incident command, situational awareness and occupational demands. A prospective multiteam, multiwave design is specified to distinguish individual perceptions from team-level functioning and to reduce common-method bias. The proposed model assesses direct effects, the psychological-safety $\times$ role-ambiguity interaction, incident-stress contingency, and indirect pathways through communication and coordination. Multilevel structural equation modelling, measurement invariance, reliability tests, prespecified contrasts and clustered predictive validation are described using editable mathematical equations. Rather than fabricate a dataset, the results section develops theoretical propositions, directional expectations, falsification tests and a complete reporting template. Transferable insights from cybersecurity and infrastructure-risk literature are confined to the design of decision-support and training systems; finance literature is discussed solely as an indirect implementation and resource-mobilization analogy. The report specifies conditions in which psychological safety may enable error reporting and adjustment without replacing unambiguous command authority. Its contribution is a transparent empirical architecture for future assessment of how relational climate and role clarity jointly shape adaptive emergency-response behaviour.

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1. Introduction

1.1. Background and Operational Context

High-stress incidents demand rapid sense making, information exchange and disciplined reallocation of roles when hazards evolve. Firefighting, rescue and emergency medical operations are not simply individual performance tasks: they are coordinated activities in which omissions and delayed clarification can propagate across crews. The incident command system offers a mechanism for maintaining accountability in volatile tasks while permitting local adaptation (Bigley & Roberts, 2001) ^[3]. Fireground decision research also indicates the value of experience-based recognition under time constraints (Klein *et al.*, 1986; Klein, 1998) ^[26, 27]. Team adaptation is therefore best understood as appropriate alteration of coordinated actions after a change in task demands, rather than indiscriminate flexibility (Burke *et al.*, 2006; Waller, 1999) ^[5, 42].

Psychological safety concerns the shared belief that interpersonal risk-taking such as asking for clarification, speaking up about errors or reporting a hazard will not invite humiliation or retaliation (Edmondson, 1999; Edmondson & Lei, 2014) ^[11, 12]. Role ambiguity occurs when expectations concerning tasks, authority or responsibilities are insufficiently clear (Rizzo *et al.*, 1970; Jackson & Schuler, 1985) ^[23, 38]. Both may matter disproportionately when operational stress, noise, visibility constraints and interagency handoffs elevate the cost of communication failure.

1.2. Problem Statement and Research Gap

Team psychological safety predicts learning-related processes in numerous workplaces, and role ambiguity is linked to performance in the wider organizational literature (Frazier *et al.*, 2017; Tubre & Collins, 2000) ^[18, 41]. Yet neither body of evidence automatically establishes the size or direction of effects in firefighters responding to emergencies. An exploratory study of operational firefighter crews connects team effectiveness to interactional and adaptive processes (Jouanne *et al.*, 2017) ^[24], while incident-command research highlights the need to reconcile flexibility with standardized authority (Bigley & Roberts, 2001) ^[3]. The unresolved question is whether an interpersonal climate that encourages speaking up buffers the disruptive effect of ambiguous roles, particularly as incident stress rises, and through which team processes that relationship operates. Cross-sectional, single-source ratings risk confounding individual sentiment with operational team effectiveness (Podsakoff *et al.*, 2003) ^[35].

1.3. Aim, Objectives and Hypotheses

The aim is to specify and empirically test an integrated, multilevel model of psychological safety, role ambiguity and adaptive team performance under variable incident stress. The objectives are to validate context-specific measures; estimate direct associations; test the psychological-safety buffering hypothesis; evaluate communication and coordination as mechanisms; assess whether incident stress alters these paths; and contrast explanatory and out-of-team predictive performance against simpler models.

H1: Team psychological safety is positively associated with adaptive team performance. H2: Role ambiguity is negatively associated with adaptive performance. H3: The negative role-ambiguity slope is less pronounced at higher psychological safety. H4: Greater incident stress strengthens the adverse role-ambiguity association. H5: Communication quality and coordination partially mediate the psychological-safety association. H6: The integrated model adds predictive value beyond additive baselines. All hypotheses are prospective and untested in this report.

1.4. Scope and Practical Significance

The unit of substantive inference is the operational team or crew, with responses nested within personnel, teams and, where feasible, incidents. Volunteer and career fire services, ambulance services and multiagency rescue units may be sampled with discipline-specific controls rather than assumed equivalent. The emphasis is on adaptation without sacrificing procedural compliance, command integrity or safety. Results could inform role briefings, safety-critical speaking-up routines, simulations and after-action reviews, subject to observed evidence rather than the present expectations.

2. Literature Review and Theoretical Integration

2.1. Psychological Safety and Team Voice

Psychological safety enables interpersonal risk-taking that can support learning and error communication (Edmondson, 1999) ^[11]. Reviews identify associations with information sharing, learning and performance, although construct level and organizational context qualify interpretation (Newman *et al.*, 2017; Frazier *et al.*, 2017) ^[18, 33]. Inclusive leadership and professional status shape whether individuals believe it is safe to contribute (Nemphard & Edmondson, 2006) ^[32]. In the emergency setting, this framework predicts more timely

challenges to unsafe assumptions and clearer disclosure of information gaps. It does not imply unbounded debate during a life-critical command decision; the expected advantage lies in concise, task-relevant voice embedded within protocols (Salas *et al.*, 2005; Marks *et al.*, 2001) ^[30, 40].

2.2. Role Ambiguity, Stress and Command

Classic role theory defines ambiguity in relation to clarity of expected behaviour, while differentiating it from competing demands or role conflict (Kahn *et al.*, 1964; Rizzo *et al.*, 1970) ^[25, 38]. Meta-analyses have linked role stressors to a range of organizational outcomes, including reduced performance, but effect sizes vary across occupations and measurement approaches (Jackson & Schuler, 1985; Gilboa *et al.*, 2008; Tubre & Collins, 2000) ^[19, 23, 41]. At an incident, ambiguity may arise from uncertain sector responsibility, unclear handoff ownership, multiple incident leaders, or an incomplete operational picture. The proposed measurement separates task, authority and priority ambiguity (Breugh & Colihan, 1994) ^[4] and distinguishes these from legitimate dynamic reassignment. High reliability requires both local sensitivity and clear command roles (Roberts, 1990; Bigley & Roberts, 2001) ^[3, 39].

2.3. Adaptive Performance and Team Processes

Adaptive performance includes responding to emergencies, managing uncertainty, solving novel problems and learning new procedures (Pulakos *et al.*, 2000) ^[36]. At the team level, monitoring, backup behaviour, shared mental models and leadership are mechanisms through which groups revise task execution (Burke *et al.*, 2006; Salas *et al.*, 2005; Mathieu *et al.*, 2008) ^[5, 31, 40]. Temporal models distinguish transition, action and interpersonal processes, suggesting that adaptation should be studied before, during and after incident escalation (Marks *et al.*, 2001) ^[30]. Situation awareness contributes to coordinated responses but should not be inferred from confidence alone (Endsley, 1995) ^[13]. Adaptive outcome indicators should combine observer-rated coordination with time-sensitive, context-adjusted process indicators and safety-critical deviations.

2.4. High-Stress Incidents and Resource Demands

Acute stress can narrow attention and compromise aspects of complex performance, although the direction of its effects depends on task demands and individual preparedness (Driskell & Salas, 1991; LeBlanc, 2009) ^[10, 29]. The job demands-resources perspective predicts that demanding contexts deplete resources while support, training and procedural clarity can preserve functioning (Bakker & Demerouti, 2007; Demerouti *et al.*, 2001) ^[2, 7]. Evidence on firefighters connects social support, self-efficacy and trauma exposure (Regehr *et al.*, 2003; Doe Gadekah, S. B. & Enyejo, J. O. (2026); however, trauma-related symptoms are distinct from the short-duration demands of a particular incident. The proposed study records event-level operational stress separately from longer-term burnout or psychological morbidity.

2.5. Cross-Domain Risk Systems, Training and Resourcing: Bounded Analogies

An auxiliary literature on cybersecurity risk management illustrates how early warning, threat classification, formal escalation and resilient staffing might be engineered in other time-critical contexts. Akanni *et al.* (2026) ^[1] integrate

business intelligence with threat modelling; Idowu, Leslie, *et al.* (2026) address real-time cyberattack detection; and Idowu, Cherotich, *et al.* (2025) consider AI-assisted risk management in critical utilities. These publications offer analogies for data pipelines, escalation protocols and decision-support system design not evidence of psychological safety among firefighters. Odozor *et al.* (2025)^[34] discuss practical workforce training in cybersecurity, which can motivate comparison with simulation-based emergency-response training. Folorunso *et al.* (2025)^[14] examine ensemble risk forecasting, a methodological comparator only if algorithmic prediction is prospectively implemented.

Financing research is even more peripheral to the causal research question. Frank, (2026) addresses blended finance for clean energy, examines renewable-energy partnerships, Doe Gadekah., & Enyejo, (2025) focuses on crowdfunding, and addresses industrial energy infrastructure; Frank (2026)^[15] examine blended capital for strategic-sector startups. These sources are mentioned solely to illustrate that funding and infrastructure constraints can affect the feasibility of

training facilities, data systems and responder-capacity investments. They do not test psychological safety, role ambiguity or incident-team adaptation and are excluded from hypothesis justification.

2.6. Integrated Theoretical Model and Falsifiable Predictions

The model combines interpersonal risk climate with role stress and an input–mediator–outcome sequence. Psychological safety and role ambiguity may be correlated without being interchangeable. The key test is an interaction: an open voice climate may help members clarify unclear tasks and raise emerging concerns before errors compound. A competing prediction is that ambiguous command authority overwhelms the benefits of voice; therefore, the buffering effect may approach zero under extreme incident severity (Frank, 2026)^[15]. Additional competing explanations include experience, incident complexity, leadership quality, staffing, team familiarity and training (Cannon-Bowers *et al.*, 1993; Kozlowski & Ilgen, 2006)^[6, 28].

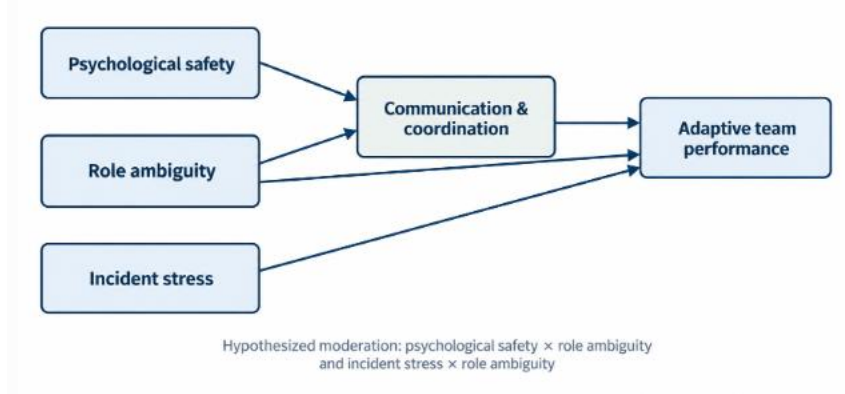


Fig 1. Proposed multilevel conceptual relationships among psychological safety, role ambiguity, incident stress and adaptive performance.

Figure 1 maps the prespecified direct, mediated and interaction hypotheses. Solid arrows represent proposed processes, not established causal effects; the dotted path marks a direct association. The stress path represents an anticipated change in the role-ambiguity slope, which requires an explicit interaction test.

The conceptual specification separates an interpersonal climate from the formal allocation of operational authority. A team may freely report hazards yet still lack an agreed task owner; conversely, roles may be clearly assigned in a climate where responders conceal errors. Their joint contribution must therefore be tested as distinct factors rather than collapsed into a composite measure. Psychological safety may strengthen the effectiveness of challenge and clarification, whereas role clarity establishes the responsibilities that can be challenged or clarified.

The hypothesized buffering mechanism requires a positive cross-product coefficient for psychological safety $\times$ role ambiguity in the performance equation. This is a conditional association, not proof that psychological safety neutralizes poor incident command. When an incident requires immediate accountability, high voice climate without a recognized command hierarchy may be insufficient. The proposed contrasts should be estimated at plausible observed percentiles and accompanied by uncertainty intervals.

3. Research Methodology and Mathematical Model

3.1. Design, Population and Sampling

A multicentre, prospective explanatory study is recommended. At baseline, team members complete validated or adapted scales for psychological safety, role ambiguity and controls. Across subsequent simulations or routine incidents, trained observers and incident logs measure adaptive team performance, communication and workload. A minimum of two waves reduces simultaneous reporting, while repeated incident observations allow within-team comparisons. Sample planning should be simulation-based for the interaction and mediation hypotheses, with team count—not simply individual count—governing power. As a provisional recruitment target rather than a power claim, 50–80 operational teams with 4–8 members each may be considered; the final target must follow assumptions about intraclass correlation, effect sizes, incidents per team, missingness and attrition.

Participating agencies should vary by crew type, shift, incident volume and area served. Exclude situations where consent or observation would interfere with operations. Obtain ethics approval, agency authorization, confidential identifier management and explicit prohibition on using survey results for disciplinary action. Capture critical incident characteristics (hazard class, scale, staffing ratio,

duration and interagency coordination burden) without identifying patients or affected residents.

A prospective two-wave field design offers a stronger temporal structure than a one-time questionnaire. At baseline, responders can report perceived psychological safety, role ambiguity, training history, experience and team membership. Following a defined incident or standardized exercise, participants can report communication and coordination, while trained observers independently score adaptive actions using anchored behavioural criteria. Incident severity, exposure duration, staffing, shift, team size and

mutual-aid participation should be recorded as contextual descriptors.

The sampling frame should be constructed at the crew or shift level and a priori power analysis should reflect the number of independent teams, expected intraclass correlations and planned interaction effects. Recruiting many individuals from a small number of crews does not provide the same inferential precision as sampling additional crews. Consent must be voluntary, data must be de-identified, and reports to commanders should avoid person-level rankings or punitive interpretation.

3.2. Variables and Measures

Table 1. Operational Definitions, Measurement Domains, and Data Sources

Construct	Operational indicator	Source / unit
Psychological safety (PS)	Adapted team psychological-safety items; referent-shift “In this crew...”	Team-member survey; team aggregate if justified
Role ambiguity (RA)	Task, priority and authority clarity; reverse-coded clarity items	Member survey + brief observer checks
Incident stress (IS)	Workload, threat urgency, uncertainty and time pressure	Incident-level observer/log + short survey
Communication (COM)	Timely hazard reporting, read-backs, closed-loop messages	Trained observer rating
Coordination (COO)	Role reassignment, mutual monitoring and backup behaviour	Observer / incident after-action rating
Adaptive performance (ATP)	Response adjustment quality, tactical recovery and compliance	Independent rater; team-incident level

Item wording should undergo content validity review by firefighters, emergency medical services personnel and organizational psychologists. Prespecify directional scoring, ordinal item estimators, missing-data handling and the conditions for team aggregation. Investigate within-group agreement and intraclass correlations before construing individual PS ratings as a team-level property. Record performance independently from the PS/RA questionnaire wherever possible (Podsakoff *et al.*, 2003) [35].

Psychological safety should be measured using context-adapted indicators of speaking up, requesting support, acknowledging mistakes and challenging unsafe actions. Role ambiguity should be represented by uncertainty about priorities, boundaries, reporting lines and decision rights. Adaptive performance should distinguish timely re-planning, reassignment, shared situational awareness and containment of escalating operational risk. A pilot study should verify that firefighters, ambulance personnel and rescue specialists interpret questions similarly.

Common-method risk arises if the same respondent rates both the predictors and the outcome immediately after an emotionally demanding event. The preferred design separates measurement occasions and sources, while retaining a limited self-report outcome for sensitivity analysis (Podsakoff *et al.*, 2003) [35]. Agreement indices and intraclass correlations should be reported before assigning team-level meaning to individual ratings.

3.3. Measurement and Structural Equations

For respondent *i* in team *j*, the latent measurement model for item *k* is:

$$y_{ijk} = \nu_k + \lambda_{khj} + e_{ijk} \quad (1)$$

where ν is the item intercept, λ is the loading, η is the relevant latent construct and ε is measurement error. Estimation should account for the ordinal response scale where applicable. At team–incident level, an illustrative structural

equation is:

$$ATP_{jt} = b_0 + b_1PS_{jt} + b_2RA_{jt} + b_3IS_{jt} + b_4(PS_{jt} * RA_{jt}) + b_5(RA_{jt} * IS_{jt}) + gTX_{jt} + u_j + e_{jt} \quad (2)$$

The coefficient β_1 captures the conditional psychological-safety association, β_2 role ambiguity, β_4 moderation by psychological safety and β_5 stress amplification. Center continuous predictors before interaction estimation, inspect multicollinearity and use robust uncertainty estimates reflecting clustering. The simple conditional slope of role ambiguity is:

$$dE[ATP | X] / dRA = b_2 + b_4PS + b_5IS \quad (3)$$

H2 predicts a negative ambiguity slope at representative conditions; H3 predicts $\beta_4 > 0$, and H4 predicts $\beta_5 < 0$. The communication and coordination paths may be represented as:

$$COM_{jt} = a_0 + a_1PS_{jt} + a_2RA_{jt} + a_3IS_{jt} + z_{jt} \quad (4)$$

$$COO_{jt} = d_0 + d_1PS_{jt} + d_2COM_{jt} + d_3RA_{jt} + x_{jt} \quad (5)$$

$$ATP_{jt} = q_0 + c'PS_{jt} + b_1COM_{jt} + b_2COO_{jt} + qTZ_{jt} + w_{jt} \quad (6)$$

An illustrative sequential indirect effect for $PS \rightarrow COM \rightarrow COO \rightarrow ATP$ is $a_1d_2b_2$. The causal interpretation of a product of paths requires stronger assumptions than association, especially no unmeasured mediator–outcome confounding and correct temporal ordering.

$$IE_{seq} = a_1 * d_2 * b_2 \quad (7)$$

3.4. Reliability, Validity, Identification and Robustness

Prespecify acceptable item functioning, composite reliability and factor structure. Examine convergent/discriminant validity, cross-disciplinary and wave-level measurement invariance, and alternative-factor solutions (Hair *et al.*, 2019) [20]. Use multilevel confirmatory factor analysis or multilevel SEM when between-team measurement is identified; if team numbers are insufficient, transparently restrict inference to clustered individual-level models rather than overstate team constructs. Check nonlinear stress effects, influential teams and heteroscedasticity. Conduct complete-case and principled multiple-imputation or full-information sensitivity analyses appropriate to missingness assumptions. Test incremental fit of additive versus interaction models, report effect estimates and confidence intervals, and control false-discovery risk for exploratory contrasts.

Prediction should use held-out teams or agencies, not random individual observations that leak crew characteristics across folds. A multilevel baseline model, an interaction model and an optional regularized/ensemble model may be compared only if the sample permits and the evaluation is prespecified. The comparison metric should include prediction error, calibration, interpretability and distribution shift; algorithms used in cyber-financial forecasting are not validated automatically for emergency-response psychology (Folorunso *et al.*, 2025; Akanni *et al.*, 2026) [1, 14].

The primary preregistered model should include main effects, hypothesized interaction terms and agency-level controls. Analytic sensitivity checks should contrast continuous stress indicators against incident categories, inspect nonlinear ambiguity effects and compare multilevel parameter estimates under alternative plausible random-effects specifications. Multiple imputation may be appropriate for missing predictors under a defensible missing-at-random assumption; outcome missingness following unusually severe incidents warrants explicit diagnostics.

Statistical reporting should emphasize standardized estimates, confidence intervals, intraclass correlations and conditional marginal effects rather than threshold significance alone. Any exploratory machine-learning benchmark should use group-blocked validation by crew or

agency and report calibration, subgroup error and predictor stability. Such benchmarks are supplementary prediction checks and do not validate a causal psychological mechanism.

$$RMSE = \sqrt{(1/N) \sum_{i=1}^N (ATP_i - \hat{ATP}_i)^2} \quad (8)$$

For standardized team-incident scores, RMSE is interpretable only relative to outcome variance and prespecified practical benchmarks. Report within-sample explanatory fit separately from genuinely out-of-sample performance.

4. Analytical Findings, Reproducible Scenario

Demonstration and Empirical Reporting Requirements

4.1. Evidence Synthesis and Evidentiary Status

This section evaluates the six prespecified hypotheses using two distinct kinds of information: (i) findings reported in the cited scientific literature and (ii) a deterministic numerical illustration of the model proposed in Section 3. No responder-level questionnaire, team-level observational record, incident log, or independent performance rating was made available. Accordingly, there are no newly estimated coefficients, sample distributions, inferential p values, confidence intervals, psychometric validation results or out-of-sample prediction metrics. The numerical demonstration is not an empirical result and cannot confirm H1–H6.

Psychological safety is associated with voice and learning behaviour in established organizational research (Edmondson, 1999; Frazier *et al.*, 2017; Newman *et al.*, 2017) [11, 18, 33]. Role ambiguity has demonstrated relationships with job performance in broader occupational populations (Jackson & Schuler, 1985; Tubre & Collins, 2000) [23, 41]. Research on team adaptation and actual firefighter operations provides a context-specific rationale for examining communication, coordination and adaptive performance (Burke *et al.*, 2006; Jouanne *et al.*, 2017) [5, 24]. These literatures justify a testable integrated model but do not estimate the psychological-safety × role-ambiguity or incident-stress × role-ambiguity effects in the proposed population.

Table 2. Evidence classification and present status of hypotheses H1–H6

Hypothesis	Prespecified empirical test	Current status
H1: PS → ATP	Positive adjusted PS coefficient ($\beta_1 > 0$)	Related published evidence; untested in target sample
H2: RA → ATP	Negative conditional RA slope	Related published evidence; untested in target sample
H3: PS buffers RA	PS × RA coefficient $\beta_4 > 0$	Unverified; illustrated only
H4: stress amplifies RA	RA × IS coefficient $\beta_5 < 0$	Unverified; illustrated only
H5: communication/coordination	Nonzero prespecified indirect effect with interval	Mechanism plausible; untested
H6: incremental prediction	Improved grouped held-out error and calibration	No data; cannot evaluate

4.2. Explicit Illustrative Model and Parameter Specification

To make the diagrams independently reproducible, define a scenario rather than fitting a statistical model. Let PS (psychological safety), RA (role ambiguity) and IS (incident stress) each range from 0 to 5. Define centered predictors $P = PS - 2.5$, $R = RA - 2.5$ and $S = IS - 2.5$. The assumed response equation is:

$$ATP^* = 3.30 + 0.25P - 0.24R - 0.13S + 0.07(PR) - 0.06(RS). \quad (7)$$

ATP* is a scenario index, not a validated scale score. Each coefficient in Equation (7) was deliberately assigned to illustrate the signs of H1–H4; none was obtained from field observations, a published effect-size estimate, calibration, or parameter fitting. The demonstration excludes disturbances, team random effects and causal mediation. Thus it cannot supply standard errors or confidence intervals. Its role is to make the conditional patterns and falsifiable implications of the planned model transparent.

Table 3: Fully disclosed illustrative coefficients used only for Figures 2–3

Scenario term	Assumed value	Interpretive role
Intercept	3.30	Reference index when PS = RA = IS = 2.5
PS main effect	+0.25	Illustrates H1
RA main effect	−0.24	Illustrates H2 at centered moderators
IS main effect	−0.13	Context effect; not separately labelled a hypothesis
PS × RA	+0.07	Illustrates H3 buffering
RA × IS	−0.06	Illustrates H4 stress amplification

Holding stress fixed, the illustrative conditional role-ambiguity slope is $\partial \text{ATP}^* / \partial \text{RA} = -0.24 + 0.07(\text{PS} - 2.5) - 0.06(\text{IS} - 2.5)$. At IS = 2.5, it equals −0.345 for PS = 1, −0.240 for PS = 2.5 and −0.135 for PS = 4. Holding PS = 2.5, that

slope equals −0.150 at IS = 1 and −0.330 at IS = 4. The values are arithmetic implications of selected assumptions, not estimates of actual firefighter responses.

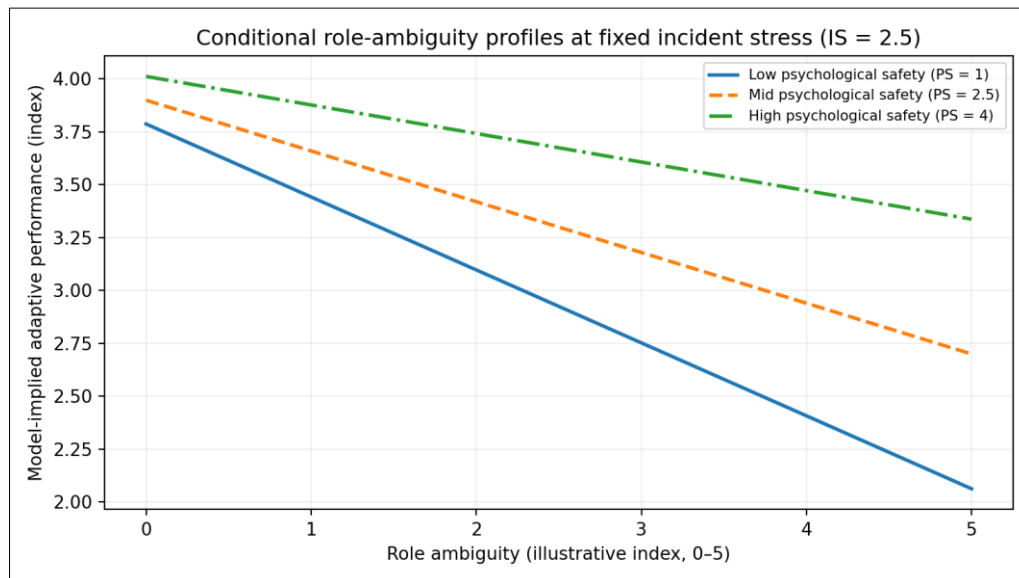
**Fig 2:** Deterministic illustration of role-ambiguity slopes at three psychological-safety levels (no observed data).

Figure 2 displays a decline in the assumed performance index as role ambiguity increases; higher PS produces a shallower decline because the imposed PS × RA coefficient is positive.

Lines show point calculations only and contain no uncertainty bands because no stochastic data-generating model or measured dataset was used.

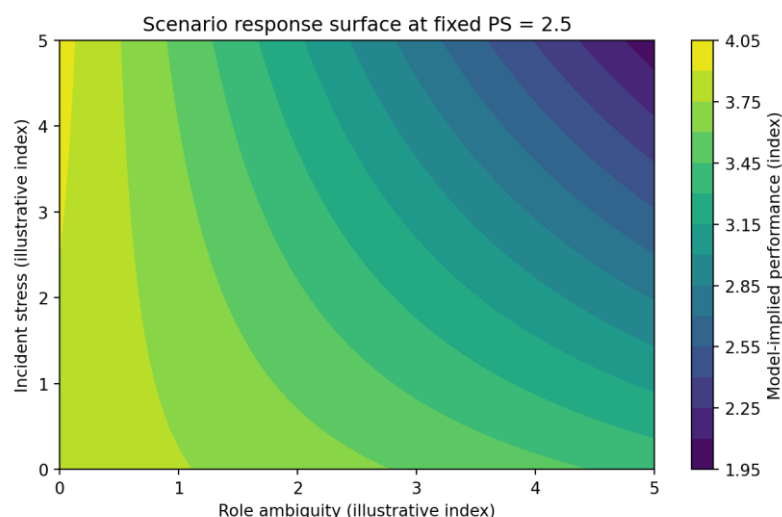
**Fig 3.** Deterministic role-ambiguity–incident-stress surface under fixed psychological safety (no observed data).

Figure 3 holds psychological safety at 2.5 and varies role ambiguity and incident stress. Lower values in the high-ambiguity/high-stress region arise mechanically from the specified negative RA, IS and RA × IS coefficients. The

heatmap represents neither observed density nor an estimated regression surface; its colours must not be interpreted as measured risk probabilities.

4.3. Numerical Consistency, Rival Explanations and Falsification

An arithmetic cross-check of Equation (7) avoids the appearance of arbitrary figure generation: when PS = 2.5 and IS = 2.5, ATP* equals 3.90 at RA = 0 and 2.70 at RA = 5. When PS = 2.5, RA = 2.5 and IS changes from 0 to 5, ATP*

changes from 3.625 to 2.975. These values follow directly from the declared coefficients. Interactions in an eventual fitted model must instead be assessed over empirical common-support regions and accompanied by cluster-appropriate uncertainty intervals.

Table 4. Reproducible scenario spot checks (illustrations, not observations)

PS	RA	IS	Equation (7): ATP*
2.5	0	2.5	3.900
2.5	5	2.5	2.700
2.5	2.5	0	3.625
2.5	2.5	5	2.975
1	2.5	2.5	2.925
4	2.5	2.5	3.675

The empirical hypothesis tests must permit disagreement with the stipulated illustration. For H3, an interaction at or below zero, or a confidence interval excluding operationally meaningful buffering, would challenge the expected protective pattern. For H4, a near-zero or positive RA × IS coefficient would contradict stress amplification. Extreme incident conditions could plausibly diminish the utility of team voice if authority allocation is insufficiently clear. Main effects in the presence of interactions must be interpreted at the centering values, not as unconditional effects. An association between PS and ATP may also reflect training quality, experienced leadership, team familiarity or staff selection rather than a distinct climate mechanism.

4.4. Empirical Results Required to Evaluate Mediation and Prediction

The communication-and-coordination mechanism in H5 must be examined using measured, appropriately time-ordered variables. A prespecified sequential indirect path PS → COM → COO → ATP can be summarized by a1d2b2, as developed in Section 3; estimation would require a confidence interval derived using a suitable multilevel procedure. A nonzero product alone does not establish a causal mediator without defensible assumptions on confounding and temporal ordering. Similarly, H6 demands held-out crew- or agency-level validation; random individual-level splits would allow shared team characteristics to leak across training and validation data.

Table 5. Minimum empirical outputs required before claiming confirmation of H1–H6

Assessment domain	Required reporting	Decision implication
Sample and clustering	Personnel, teams, incident counts, attrition, missingness, ICCs	Confirm sufficient independent groups
Measurement model	Item distributions, loadings, omega/composite reliability, agreement, invariance	Support construct and team-level interpretation
Main effects (H1–H2)	Coefficients, units, 95% CIs, covariates, random effects	Estimate magnitude and uncertainty
Moderation (H3–H4)	Interaction coefficients, simple slopes, 95% confidence bands, overlap	Evaluate buffering or amplification
Mediation (H5)	Path estimates, indirect-effect interval, temporal assumptions	Assess proposed mechanism without overstating causality
Prediction (H6)	Group-held-out RMSE/MAE, calibration, baseline contrasts, subgroup error	Test transportability and incremental value

For an empirical submission, the final analysis should report model diagnostics and prespecified sensitivity analyses: alternative stress formulations, nonlinearities, influential crews, missing-data assumptions, separation of observed and perceived stress, and agency-level heterogeneity. Conditional effects should be plotted only across ranges adequately represented by sampled teams. Since no dataset exists in the present submission, none of the inferential, reliability or predictive fields in Table 5 can legitimately be populated.

4.5. Operational Interpretation and Limits of Transfer

Taken together, the cited scholarship supports a practical

distinction between an interpersonal climate that encourages timely hazard communication and a command structure that allocates decision rights. A crew may feel safe to challenge an unsafe order yet remain uncertain about which team controls a task. Conversely, a clear command hierarchy can coexist with low willingness to report mistakes. These dimensions should be measured separately. The scenario calculations illustrate why a buffering interaction is worth testing, not why it should be expected to prevail in every fire ground or multiagency rescue context.

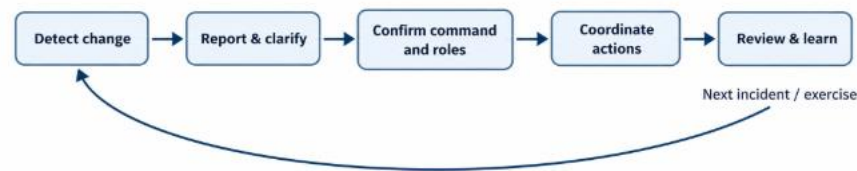


Fig 4: Proposed operational adaptation sequence for scenario design and after-action learning.

Figure 4 translates the conceptual framework into a candidate training sequence: detect changes, raise and clarify concerns, confirm authority and roles, coordinate action, then learn from the response. The loop is a proposed protocol for evaluation rather than an intervention shown by this report to improve safety or operational outcomes.

Actionable research priorities are a standardized incident-role briefing, a concise route for raising time-critical objections, closed-loop communication checks and observer-scored performance during staged handoff and escalation exercises. These interventions require controlled evaluation before effectiveness claims. Cybersecurity alerting and financing studies cited elsewhere in this paper remain contextual design and implementation analogies; they do not provide evidence for H1–H6. The present Section 4 is therefore appropriately characterized as analytical illustration and empirical reporting specification, not a conventional statistical Results section.

5. Conclusions, Recommendations and Limitations

5.1. Conclusions Supported by the Current Evidence

Existing scholarship makes psychological safety, role ambiguity and adaptive team performance a theoretically coherent set of variables for operational emergency-response research. Evidence on teamwork and firefighter operations supports their practical relevance, but the proposed joint moderation and mediation relationships remain untested. This report therefore supplies a publication-oriented theoretical framework and reproducible empirical protocol rather than a claim of original confirmed findings. Confirmation requires prospective collection and analysis of independent operational and team-level data.

5.2. Operational Recommendations

Fire and emergency-response organizations should evaluate concise incident-role briefings, confirmation of operational authority, closed-loop communications and structured opportunities for speaking up about hazards. Scenarios should include deliberately ambiguous handoffs, rapidly deteriorating conditions and cross-agency transitions; observers should assess both adaptation quality and compliance with safety-critical controls. Supervisors should reinforce hazard escalation without penalizing good-faith concerns. These recommendations are theory-informed practices to be evaluated, not intervention effects demonstrated by the present study.

5.3. Institutional and Research Implications

A future longitudinal multicentre investigation should distinguish routine events from rare catastrophic incidents and assess how leadership, staffing, shift fatigue, training and experience modify the core paths. Teams should be observed repeatedly and coded by blinded independent raters wherever feasible. A prespecified analysis plan, anonymized codebook, registered hypotheses and appropriately controlled

access to non-identifying datasets would improve transparency. Predictive risk-alert systems should undergo domain-specific calibration and safety review before operational deployment.

5.4. Limitations and Transparency Statement

The principal limitation is the absence of a primary dataset; thus the report contains no empirical parameter estimates, inferential tests or validated predictive claims. The literature spans heterogeneous workplaces, and transfer to firefighters requires contextual verification. Some user-specified finance and cyber-risk publications have limited direct relevance and are used explicitly as analogies rather than psychological evidence. Bibliographic entries should be cross-checked against final publisher records before journal submission. No ethics approval, participant consent or data access is represented as having occurred. A conventional empirical research article would require replacement of Section 4 with authentic results and an appropriately qualified revised abstract.

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