

# Investigating Mindfulness and Decision-Making Under Stress Using Immersive Virtual Reality Firefighting Scenarios

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## ABSTRACT

First responders, including firefighters, must maintain focused attention and make high-quality decisions under time pressure, with incomplete information, and rapidly evolving hazards. Their actions directly impact the safety and survival of civilians and fellow emergency responders. The aim of this study was to examine how trait mindfulness moderates the relationship between decision-making style (deliberative versus intuitive) and state mindfulness among firefighting incident commanders in immersive virtual reality emergency scenarios. Based on Klein's Recognition-Primed Decision model of naturalistic decision-making and the dual-process theory, as well as the concept of mindfulness, we hypothesize that higher trait mindfulness is associated with higher state mindfulness across scenarios, independent of decision-making style (H1). Additionally, trait mindfulness is expected to moderate the relationship between decision-making style and state mindfulness during these scenarios (H2). Sixty firefighters completed two immersive virtual reality scenarios while their decision-making style, trait mindfulness, and state mindfulness were assessed. Linear moderation analysis revealed a significant main effect of trait mindfulness on state mindfulness, as well as a significant interaction between decision-making style in the scenarios and trait mindfulness. The results suggest that higher trait mindfulness is associated with greater state mindfulness, especially among deliberative decision makers. Additionally, they suggest that mindfulness may function as a protective psychological resource in firefighters. The results also extend naturalistic decision-making theories by demonstrating how is associated with reduced susceptibility to distraction and greater present-moment awareness. Further research is needed to investigate causal mechanisms, generalize the findings to other groups of first responders, and develop interventions, such as real-time biofeedback systems.

**Keywords:** First responders, Decision-making, Mindfulness, Immersive virtual reality

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## INTRODUCTION

First responders, including firefighters, must maintain focused attention and make high-quality decisions in situations involving time pressure, incomplete information and rapidly evolving hazards. This is particularly important in high-stakes firefighting scenarios, since the decisions made by these professionals can directly affect the safety and survival of civilians and other emergency responders. Immersive virtual reality (iVR) has emerged as a powerful tool for investigating these processes under controlled yet ecologically valid conditions. iVR enables the simulation of high-pressure environments, allowing researchers to systematically examine the interaction between factors such as mindfulness and decision-making styles in dynamic, potentially stress-inducing situations (Wrzus, Frenkel and Schöne, 2024). Furthermore, iVR offers a cost-effective alternative to traditional live-exercise training, reducing logistical and financial burdens while maintaining high fidelity in scenario replication and is already being used in firefighter training programs (Berthiaume *et al.*, 2024; Oliveira *et al.*, 2024).

Studies indicate that individuals rarely engage in a methodical evaluation of numerous options when faced with high-pressure situations, instead relying on the rapid interpretation of situational cues and experience-based judgment (Cohen-Hatton, Butler and Honey, 2015). This form of decision-making is described by the naturalistic decision-making framework, especially by Klein's Recognition-Primed Decision (RPD) model (Klein, 1993, 2008). According to this model, experts identify patterns in complex situations and determine the most appropriate initial course of action through mental simulation rather than by analytically comparing alternatives. The RPD model emphasizes the importance of experience and pattern recognition in high-pressure situations. To identify these patterns, it is important to stay focused on the present moment and manage emotional reactions, both of which are aspects of mindfulness. Thus, mindfulness is a potential factor to consider when examining the decision-making processes of firefighters.

### Mindfulness

Most conceptualizations describe mindfulness as multidimensional, comprising at least two facets, as proposed by a consensus panel (Bishop *et al.*, 2004; Brown, Ryan and Creswell, 2007; Kabat-Zinn, 2013): (1) paying attentive awareness to the present moment and (2) adopting an open, curious, and accepting attitude. Mindfulness is also conceptualized as state- and trait-mindfulness (Van Dam *et al.*, 2018). Trait mindfulness refers to an individual's stable capacity for present-moment awareness and nonjudgmental attention across situations. State mindfulness, on the other hand, describes the momentary level of attentional presence and acceptance experienced in a specific context or time.

Recent research has shown that mindfulness strengthens brain regions essential for attention, self-regulation, and emotional control, such as the prefrontal cortex and anterior cingulate cortex, while reducing amygdala

activity associated with fear and stress responses (Calderone *et al.*, 2024). These neurobiological changes suggest that mindfulness may enhance the ability to maintain control over stress physiology and emotional reactions, thereby supporting more effective decision-making under pressure (Frenkel *et al.*, 2019); Karelaia and Reb, 2015; Prakash, Hussain and Schirda, 2015).

### **Decision-Making**

The dual-process theory of decision-making styles distinguishes between two cognitive systems. Intuitive, fast, automatic decisions and deliberative, slow, analytical decisions (Evans and Frankish, 2009). Intuitive decisions rely on implicit knowledge, heuristics, and affective responses, while deliberative decisions are based on explicit information and logical analysis. The interaction between these systems is crucial in high-stress environments, where rapid yet accurate judgments are required. The dual-process theory further suggests that the balance and interaction between these two systems can be influenced by contextual factors, such as time pressure and stress level, which are prevalent in emergency response situations. Given the dynamic and unpredictable nature of firefighting, the ability to flexibly shift between intuitive and deliberative processing—while maintaining emotional regulation—may be critical for optimal performance and adaptive decision-making in the field (Kahneman, 2024).

### **Mindfulness and Decision-Making**

Mindfulness has been proposed as a way to modulate the interplay between intuitive and deliberative decision styles (Sun *et al.*, 2015; Lachaud *et al.*, 2023). It does so by increasing present-moment awareness and cognitive flexibility. This can reduce impulsivity and enhance reflective decision-making (Frederick, 2005). Trait mindfulness can act as a protective factor, maintaining state mindfulness and protecting against stress-induced declines in attentional focus. Thus, individuals with higher trait mindfulness can sustain state mindfulness better during stressful events, especially when making complex or time-critical decisions. Empirical evidence supports this notion, showing that trait mindfulness moderates the relationship between decision-making processes and behavioral outcomes such as health-risk behaviors and stress responses (Black *et al.*, 2012). In the context of firefighting, this suggests that trait mindfulness could mitigate the negative impact of stress on state mindfulness. However, the specific interaction between decision-making style (deliberative vs. intuitive) and mindfulness in high-pressure scenarios is unclear. The present experiment aims to address this gap by examining how trait mindfulness moderates the relationship between decision-making style and state mindfulness in simulated firefighting command scenarios.

## Hypotheses

Based on these findings, we derived the following hypotheses:

- H1: Higher trait mindfulness will be associated with increased state mindfulness across scenarios, independent of decision-making style.
- H 2: Trait mindfulness will moderate the relationship between decision-making style in the scenarios and state mindfulness.

## METHOD

This study is part of the EMERDEC (Fundamentals of Decision-Making Processes in Primary Emergency Response) project. EMERDEC is an interdisciplinary research initiative that combines psychology, computer science, and emergency response research (Kern *et al.*, in press). This study was approved by the ethics committee of the University of Graz (No. 186–2024/25).

### Sample

A total of 63 active incident commanders from professional and volunteer fire departments participated in the study ( $M_{\text{age}} = 39.13$  years;  $SD = 9.27$ ; 62 males, 1 female). Three participants did not complete all relevant questionnaires due to individual (e.g., VR-Sickness) and technical reasons. The analysis was therefore conducted on a sample of 60 participants.

### Study Design and Procedure

The experiment took place in the VR laboratory of an Austrian fire training center. After receiving a general introduction and completing the initial questionnaires, the participants led two firefighting operations in the role of the incident commander in iVR. They were instructed to lead the operations as they would in reality, deciding how to proceed and articulating every order and message freely. At the incident commander's direction, the VR operator could trigger events (e.g., deploying the Self-contained breathing apparatus (SCBA) team for an interior attack). The scenarios were designed so that the firefighters were exposed to varying levels of cognitive load. The first scenario was designed to involve a low cognitive load, and the second a high cognitive load (Koenczoel *et al.*, in press). After each iVR scenario, the participants were given questionnaires. A multi-methodological approach was applied to measure subjective ratings, psychophysiological parameters, and video data. This paper focuses solely on the questionnaires given before and after each iVR scenario.

### Questionnaires

Decision-making style was assessed using the Unified Scale to Assess Individual Differences in Intuition and Deliberation (USID), the scale comprises 32 items that differentiate between intuitive (e.g., “*I rely on my instincts when solving problems*”) and deliberative (e.g., “*I analyze situations thoroughly*”).

*before making a choice*”) decision-making styles using a 6-point Likert scale (1 = strongly disagree, 6 = strongly agree) Betsch, 2004). The scale yields two subscales—intuition and deliberation—which can be combined into a composite index to quantify individual preferences. Prior to the experimental iVR scenarios, the self-report questionnaire was administered to assess the participants’ preferred decision-making style. After each scenario, participants evaluated their behavior using two items assessing deliberation and two items assessing intuition. Trait mindfulness was measured prior to scenarios using the Mindful Attention Awareness Scale (MAAS; Brown and Ryan, 2011) e.g. “*I find it difficult to stay focused on what’s happening in the present.*”, scored on a 6-point Likert scale (1 = almost always, 6 = almost never). State mindfulness was assessed after each scenario using the Multidimensional State Mindfulness Questionnaire (MSMQ; Sauer *et al.*, 2013; Blanke and Brose, 2025) e.g. “*I did things without paying attention.*” Three items were used, one from each of the three subscales, rated on a 5-point Likert scale (1 = not at all, 5 = very much).

## **Scenario Description**

### **Scenario 1**

The participants entered the iVR environment at the fire station, where they received their dispatch, a small outdoor fire. The incident commander and their team then drove to the scene. There were distractions along the way, such as cars passing quickly and right-of-way violations. Upon arriving at the fire, the commander conducted a reconnaissance and found two people sleeping next to a burning grill. They startled upon his arrival and approached the commander in a state of agitation. After the commander had calmed the individuals, brought them to safety, and extinguished the fire, the VR operator ended the iVR scenario.

### **Scenario 2**

The participants entered the iVR environment again at the fire station, where they received their dispatch order, a basement fire in a residential building. The incident commander and their team then drove to the scene, encountering distractions along the way. Upon arrival, a resident informed the commanders that someone was missing inside the building. After sending in the SCBA team, the commanders received a radio call from the team, reporting that they were advancing and searching for the missing person. There were then two different options.

In the first option, the SCBA team could rescue the missing person independently. The second option was that the commanders received a mayday call from the SCBA team, signaling an accident. They also lost contact, so the commander had to continue the operation as normal. A team from a newly arrived backup fire department finally rescued the SCBA team involved in the accident. A resident also informed the incident commander that the missing person was not involved in the incident. The VR operator awaited the incident commander’s final orders before ending the exercise.

## XVR-Environment

The study was conducted using XVR On Scene (version 10.1) and XVR Control Center by XVR Simulation (LearnPro Group, 2026). The scenarios were created and managed in the XVR Control Center. In addition to predefined events (e.g., at standard times or when entering a space in the VR environment), operators could trigger events manually (e.g., on a verbal command).

## Statistical Analysis

A linear moderation analysis using multiple regression was conducted to examine the moderating effect of trait mindfulness (MAAS) on the relationship between decision-making style (USID) and state mindfulness (MSMQ) across iVR scenarios. The model included the following predictors: scenario; preference for deliberative or intuitive decision-making style at baseline; preference for deliberative or intuitive decision-making style after the scenarios; trait mindfulness; age; and years of active service. The dependent variable was state mindfulness (mean after the scenarios). Additionally, interaction terms were tested to identify moderation effects. Statistical significance was set at  $p < .05$ . All analyses were performed in RStudio (Posit team, 2026).

## RESULTS

Descriptive statistics for all primary variables, including trait mindfulness, state mindfulness, and decision-making style (deliberative vs. intuitive), are presented in table 1. The linear moderation analysis revealed two significant effects. In line with H1, trait mindfulness showed a significant main effect on state mindfulness ( $F_{(1, 147)} = 6.01, p = .02$ ). Supporting H2, a significant interaction between decision-making style measured after the iVR scenarios and trait mindfulness was observed. The significant interaction indicated that higher levels of trait mindfulness were associated with higher state mindfulness, particularly among individuals with a preference for deliberative decision-making style after the iVR scenarios ( $F_{(1, 147)} = 8.18, p < .01$ ). No significant main effects were found for age ( $F_{(1, 147)} = 1.38; p = .24$ ), years of active service ( $F_{(1, 147)} = 2.06; p = .15$ ), scenario ( $F_{(1, 147)} = 0.003, p = .95$ ) and decision-making style ( $F_{(1, 147)} = 0.69, p = 0.40$ ). Similarly, no interaction was significant.

**Table 1:** Characteristics of participants.

Characteristic	
Gender	
Female, n	1
Male, n	62
Age in years, M; SD	39.13; 9.27
Years of active service, M; SD	21.92; 8.79
MAAS, M; SD	2.20; 0.49
MSMQ	
VR1, M; SD	3.31; 1.11
VR2, M; SD	3.32; 1.02

(Continued)

**Table 2:** Continued.

Characteristic	
USID Index	
Baseline	-1.07; 0.49
VR1, M; SD	-0.39; 0.77
VR2, M; SD	-0.51; 0.92

*Note.* MAAS = Mindful Attention Awareness Scale;  
MSMQ = Multidimensional State Mindfulness  
Questionnaire; USID = Unified Scale to Assess  
Individual Differences in Intuition and Deliberation.

## DISCUSSION

The current study indicates that higher levels of trait mindfulness are associated with higher state mindfulness, particularly among individuals with a more deliberative decision-making style in the scenarios. These effects were independent of which iVR scenario was played, the age of the fire commanders, and how long they had been on the service.

These findings support and extend existing research by identifying mindfulness as a protective cognitive resource (Karelaia and Reb, 2015; Calderone *et al.*, 2024). They contribute to the RPD model of naturalistic decision-making (Klein, 2008), which emphasizes pattern recognition and mental simulation in experienced responders. While the RPD model emphasizes the efficiency of intuitive judgements in dynamic situations, our results suggest that trait mindfulness can enhance these processes by reducing distractions and improving awareness of the present moment. Integrating mindfulness into decision-making theories could provide new insights into how cognitive and emotional regulation can be trained to optimize performance in high-stakes, time-sensitive scenarios. For the training of fire department commanders, this could mean that it might be advisable to include modules for increasing trait mindfulness.

For people with a preference for deliberative decision-making, the level of trait mindfulness appears to positive influence the level of state mindfulness in the scenarios. This significant interaction may reflect the behavioral mechanisms by which mindfulness mitigates the vulnerability of analytical decision-makers to decision inertia (Power and Alison, 2019). Studies indicate that mindfulness training leads to a reduction in unnecessary deliberation (Shortland *et al.*, 2021). From a practical perspective, the results suggest that individuals who prefer deliberate decision-making style and are more prone to a decline in state mindfulness under stress could benefit from mindfulness-based interventions. For example, real-time biofeedback devices could be developed to monitor physiological stress markers (e.g. heart rate variability or electrodermal activity) and provide cues as soon as stress levels reach a critical threshold, reminding individuals to refocus their attention. These devices could be particularly useful for incident commanders who need to maintain their focus while simultaneously adapting to rapidly changing emergency situations.

Several limitations and strengths should be acknowledged. A key strength of this study is the integration of iVR scenarios, which combine ecological validity with experimental control and provide actionable insights for resilience training. The findings enhance applicability by replicating firefighting conditions and directly informing the development of targeted interventions, such as mindfulness-based training and real-time biofeedback tools, to improve adaptive decision-making in operational settings. However, the cross-sectional design prevents causal inferences about the relationship between mindfulness and decision-making style. Additionally, reliance on self-reported decision-making styles after scenarios introduces potential retrospective bias. Future studies would benefit from incorporating objective measures, such as behavioral coding of verbal commands or physiological data collection.

To advance this research, future studies should use longitudinal approaches to determine if increases in trait mindfulness improve state mindfulness and decision-making under stress. Incorporating physiological measures (e.g., heart rate variability and cortisol levels) alongside objective performance metrics (e.g., response times and resource allocation efficiency) would provide more comprehensive insights into the mechanisms underlying these effects. Randomized controlled trials of mindfulness training interventions could elucidate whether deliberate practice enhances state mindfulness and critical outcomes, such as decision quality and error rates, in operational settings.

## **CONCLUSION**

In summary, this study indicates that trait mindfulness can prevent a decline in state mindfulness during potentially high-stress situations, particularly among decision-makers with a preference for deliberative decision style in iVR scenarios. While these findings suggest promising avenues for mindfulness-based interventions, future research must address causal mechanisms, objective performance outcomes, and generalizability to diverse populations of firefighters. Integrating neurobiological, behavioral, and technological approaches can advance the development of targeted resilience training for first responders.

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