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# Risky decisions and complex problem solving in Norwegian first responders

Anita L. Hansen[a,b], Jarle Eid[a], Kjersti B. Valdersnes[a], Gianluca Pescaroli[c,d] and Ilan Kelman[c,e]

[a]Department of Psychosocial Science, University of Bergen, Bergen, Norway; [b]Centre for Research and Education in Forensic Psychiatry, Haukeland University Hospital, Bergen, Norway; [c]Department for Risk and Disaster Reduction and Institute for Global Health, University College London, London, UK; [d]Centre for Risk Studies, University of Cambridge, Cambridge, UK; [e]University of Agder, Kristiansand, Norway

**ABSTRACT**

First responders such as firefighters are trained to manage dangerous situations. However, less is known about how danger and complexity affect their approach to challenging fire and rescue missions. Using qualitative interviews, the aim of the present study is to gain in-depth knowledge about demanding operational situations that are difficult to solve for experienced firefighters. Nine trained Norwegian firefighters were interviewed about complex problem solving in naturalistic settings. Analysis of the interviews identified three main categories: 1. *Unforeseen Events* elaborating on the impact of external/contextual factors as well as internal experiences along the unpredictable nature of their work, 2. *Processing and Communication of Information*, addressing the importance of cognitive capacity and common understanding of the situation and finally 3. *Decision Dilemmas* illustrating the kind of difficult, life-or-death decisions that firefighters must make. The results are discussed in light of the impact of dynamic risk factors, theories explaining decision making in realistic scenarios as well as human cognitive phenomena and capacity. Possible implications and future perspectives are discussed.

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**KEYWORDS** Firefighters; complex problem-solving; unforeseen events; working memory capacity; decision dilemmas

## 1. Introduction

Firefighters serve an essential role in providing safety and protection to their communities. They are highly trained and resilient, they share a strong professional commitment and pride (Lantz et al., 2023). Firefighters

**CONTACT** Anita L. Hansen anita.hansen@uib.no Department of Psychosocial Science, University of Bergen, Christiesgt. 12, 5015 Bergen, Norway.

are exposed to extreme danger and hazards such as toxic substances, injuries, and emotional stress (Fraess-Phillips et al., 2017; Orr et al., 2019). A core aspect of working as a firefighter is the emotionally charged nature of their work. When the alarm sounds, it could be a false alarm, a mere routine event, or a highly charged, complex, and dynamic situation where lives are at stake. The increased dependency on technology and infrastructure, changed the building environment and the operational context of emergency response. For example, a small fire starting in a peripherical building can escalate into a toxic cloud disrupting a transportation crossroad, and even localised incidents can trigger cascading effects and secondary crises, challenging dynamically how resources should be prioritised and creating new needs for cognitive capacity building (Miller & Pescaroli, 2018).

It is well known that acute stress causes activation of biological stress response systems and that strong emotional stress reactions can influence decision-making and problem solving (Pham, 2007). Firefighters must judge and make decisions when faced with unforeseen high-risk situations and extreme stress. However, few studies have explored what kind of situations experienced first responders consider most demanding.

Classical decision research assumes that humans are guided by stable preferences that serves to optimise the expected utility of the outcomes (Levine, Chan, & Satterfield, 2015). In a series of laboratory studies Kahneman and co-workers challenged the assumption of 'rational choice' inherent in the classical theories based on their observations that humans made decisions based on heuristics and biases (see Kahneman 2003 for an overview). Kahneman's research and the proposed dichotomy of thinking seen as intuitive, fast, and inaccurate versus analytical, slow, and accurate (Kahneman, 2003, 2011; Stanovich & West, 2000) underscored the significance of cognitive factors in decision processes. Still, a frequent objective and critic of both the classical studies and the studies of Kahneman (2003, 2011), has been that these studies primarily apply to a narrow and well-controlled context (Hoffrage & Marewski, 2015; Kruglanski & Gigerenzer, 2011). While laboratory studies of well-defined decision problems that allow solutions to be pre-defined and static in terms of right or wrong answers, this is rarely the case in naturalistic settings where decisions must be reached between domains of uncertain risk. Decision problems in naturalistic settings such as fire and rescue missions are often ambiguous and ill-defined or can be framed as complex decision dilemmas without pre-defined solutions to the problems (Findlater et al., 2019; Goel, 2010; Jonassen, 2000). Fire and rescue situations require complex coordination of resources and dynamic problem solving where the context may change rapidly and unexpectedly (Dörner & Funke 2017; Klein, Calderwood & Clinton-Cirocco, 2010). As demonstrated by Butler et al. (2023) and Cohen-Hatton et al. (2015) operational decision-making processes are complex, even for highly resilient firefighters

Decision research has in general been criticised for being too preoccupied with the individual (Wilkinson, 2010) and for not taking into account how social, cultural, professional, or interpersonal relations will influence decisions. In highly critical situations decisions are made in groups consisting of people from different fields and with different expertise (Wilkinson et al. 2022). Another frequent criticism has been the focus on calculation of probabilities. Typically, participants are presented with a narrative and asked to estimate the likelihood of a certain outcome. Kay and King (2020) have argued that when participants are asked to assess the outcome of such narratives, they will interpret the outcome considering a broader context. Research has shown that people use their memory, schema as well as values and beliefs when they judge and make decisions (Green et al., 2020; Zhao et al., 2022).

When it comes to safety critical decisions in high-risk situations an approach to study risky choice has been to frame narratives in terms of gains and losses and then asked which of two alternatives they favour, such as in the Asian disease experiment (Tversky & Kahneman, 1981). The results from this study revealed that when participants read the words 'lives saved' their choices were more risk averse, while their choices were more risk seeking when they read the words 'lives lost'. The use of pre-defined alternatives together with precise probability has also been criticised by Huber (2012, 2017). For instance, Huber (2012) argues that in realistic scenarios people are not interested in a precise probability. Instead, they are interested in whether an outcome is possible, or whether it will occur with certainty. According to Huber (2012) the decision maker will try to identify or imagine *many different alternatives,* including the possibly worst outcome from each alternative, and then choose the alternative with relatively best worse outcome. Further he emphasises that people always will strive to search for a risk-defusing operator (RDO), that is additional actions that can *eliminate* the risk from happening. Thus, in addition to considering existing alternatives a decision maker has at hand, the decision maker will act to *reduce the risk*. This is a more likely decision strategy for operators in high-risk occupations, such as the fire and rescue services.

Huber (2017) further assumes that people in non-routine situations will construct mental representations of possible outcomes or alternative actions. Mental simulation is therefore considered to be an important component in decision making (Klein, 1993). From research on experts (i.e. fire-fighters) dealing with complex problem solving and risky situations, Klein et al., (2010) developed a model called the recognition-primed decision (RPD-model). The model describes how experts, such as experienced firefighters, can react very fast based on salient cues or patterns in the situation, choose a course of action they consider as good or appropriate, and further evaluate this action by mental simulation using mental models that are developed through training or experience. Thus, the planned operation is assessed in relation to previous knowledge about effective solutions (Klein, 1993, pp. 138–147).

In other words - Klein is talking about the power of intuition (Klein, 2004) – in the form of knowing without knowing (Kahneman, 2011, pp. 237). This assumption is confirmed in a recent systematic literature review (Reale et al., 2023) demonstrating that when people make decisions in high-risk situations (dynamic decisional environments), they make use of recognition-primed decision strategies. Experts such as firefighters are selected and trained to handle extreme situations. They are highly resilient and are expected to solve complex problems based on their ability to judge and make appropriate decisions. However, an important question is: What if they are faced with situations where they have no previous experience, and recognition based on earlier experiences is not possible? A long-established conundrum in decision-making (e.g. Gardner, 1972) is that there are 'known knowns' (what we know we know), 'known unknowns' (what we know we do not know), and 'unknown unknowns' (what we do not know that we do not know). The increased complexity and uncertainty of contemporary society implies that crises and incidents are harder to predict, and situations with high uncertainty and many unknown factors are becoming business as usual in the operational reality of first responders. Training and exercises need to include tools such as scenario building aimed at supporting the flexibility of emergency response, but much is left to be understood in the intersection between organisational and individual resilience (Pescaroli et al.2023).

We do not know much about what trained firefighters find the most challenging situations and how they handle these situations. Reale et al. (2023) studied characterisation of skilled decision-making in difficult situations and argue that future research must focus on poor performance as well as common pitfalls. More knowledge about situations trained firefighters find difficult to solve will have important implications for further research and future education and training programs. The overall objective of the present study is therefore to gain in-depth knowledge about demanding operational situations that are difficult to solve, even for experienced firefighters.

## 2. Methods

### *2.1. Research design*

The present study applied a qualitative inductive design to explore common themes in demanding situations trained Norwegian firefighters have experienced in the fire and rescue services (Lindsay, 2019). This opportunity to study operational situations that were difficult to handle provides a unique insight into so called ill-structured situations, complex problem solving and dynamic decision-making including judgments, values, and professional experiences of fire and rescue workers (Ritchie et al., 2014).

To clarify researcher preconceptions a research protocol was developed and shared between the researchers. The protocol assumed that both individual factors (e.g. experience, preferences, values, and priorities) and contextual factors (e.g. teamwork, technology, weather, and location) would guide the way they approached and solved complex fire and rescue missions. Given the ever-changing nature and inherent dangers associated with fire and rescue missions, we expected the study to provide in-depth knowledge about demanding operational situations that are difficult to solve, even for experienced firefighters. In the analytical process these expectations were confronted and adjusted based on the qualitative data, until agreement was reached of a new understanding of the phenomenon (Malterud et al., 2021).

### 2.2. Participants

The Bergen Fire Brigade has about 188 first responders allocated at six fire stations across the city. The study sample consisted of nine very experienced male first responders in leadership positions. The first responders had on average 28 years of service and had been in their roles as fire commanders from 2 to 19 years. These nine fire commanders had different backgrounds and responsibilities in their current role, ranging from deputy fire chief and incident commanders to station commander. Some of them had the role of supreme fire officer on duty for a week at the time, some were incident commanders in charge of the team on duty (minimum 37 members of staff, 24-hour shifts during the week, and 48 hours during weekends), and others are station commanders.

### 2.3. Data collection

Individual semi-structured interviews were conducted in 2022 after all restrictions from the COVID-19 pandemic had been lifted. The interviews were conducted in the local Norwegian dialect in person at a fire station in Bergen by a trained researcher. The informants were interviewed while on duty. If a fire alarm occurred, the interview was postponed.

A semi structured interview guide was developed and shared between the researchers involved (Kallio et al., 2016). The interview guide addressed several aspects of operational issues in the fire and rescue services. In this study we were particularly interested in complex problem solving. Examples of questions:

- Could you give an example of a demanding operational situation where it was uncertain whether you would be able to solve it?
- Do you have an example of a situation where missions have become difficult to solve because of misunderstandings or problems with coordinating effort?

- Is there anything else other than the things we have been through that could make missions difficult to solve?

The interview progressed in accordance with the narrative of the informant. Follow-up questions were asked to clarify, elaborate, or when the informants expressed something of interest which fell outside of the interview guide. The interviews lasted between 35 and 60 minutes (50 min. on average) and were conducted by the same researcher. The sound recordings were stored in an encrypted server according to institutional policy and data management. To secure and protect the identity of the informants, each of them were given a code. Names and other personal identifiable or sensitive information were re-coded or removed from the transcribed files before files were subject to analysis by the research team.

### 2.4. Ethical considerations

The study protocol was approved by the Norwegian Centre of Research Data (NSD), which is the national centre and archive for research data in Norway (Ref code: NSD-977619). Prior to each interview the informants gave their verbal or written consent and were informed about their right to withdraw from the study without any following consequences. Established guidelines were observed to protect the anonymity of the participants and to ensure safe storage and use of the data material.

### 2.5. Data analysis

The transcribed material was analysed in accordance with the four steps in Systematic Text Condensation (STC), which is a strategy first described by Giorgi (1985), and later modified by Malterud (2012). STC is an inductive, iterative, and pragmatic method for analysing cross-sectional qualitative data (Malterud, 2012). Table 1 provides a summary overview of the common themes, sub-themes, and data examples associated with each sub-theme.

First, the transcribed material was read in entirety by all authors to obtain an overview of the data. Then, preliminary themes were identified and discussed by the researchers. Subsequently, the transcripts were thoroughly read to identify meaning units based on the preliminary themes. Further, the content of the meaning units was condensed and clustered into groups and sub-groups. This coding process was conducted by the first, second and third authors. This process resulted in three common themes. The first and second themes were further divided into two subthemes. At this stage, each code group was characterised by a condensate, a quote summarising and representing the phenomenon that the subgroup described (Malterud et al., 2021). Finally, the content of each code group was synthesised and summarised to present a re-conceptualized description of each code group. This analytical text was created to

**Table 1.** An overview of themes, sub-themes, and data examples of complex problem-solving situations.

| Themes | Sub-themes | Data examples |
|---|---|---|
| Unforeseen Factors | • External and contextual factors (e.g. weather, equipment, context)<br>• Internal experience-based unforeseen factors (e.g. fatigue, lack of plans, lack of experience and competence, discrepancy between expectations and actual situation) | Another example is lack of equipment, or the wrong equipment, arriving at a house fire and it turns out that our water pump on the car is not working, that's a crisis. (ID 5)<br>… there were probably poor preparations, as well as badly planned, they didn't foresee the consequences in time to realise they would need more help. It resulted in it escalating a whole lot and turning out as a much bigger fire than it needed to (ID 8)<br>Another type of [difficult] incident are incidents where the extent of the situation is so big that we can't make a plan on how to solve it. Planning is an important part of how we handle situations, but we are not capable of managing all of them. If a plane crashes, we aren't built for it, to put it like that. We aren't trained to handle these unpredictable incidents. (ID-2) |
| Processing and Communication of Information | • Cognitive capacity | … If I am giving one task to one person, for example to pass on the information I'm giving, he remembers maybe 70% of what I'm saying. And when he is going pass on that information to another group, they may get 70% of the information from the leaders. And if that information is going to pass yet another stage, the information gets less precise. It depends on how complex the situation is. (ID-4) |
| | • Common understanding | And if he has more than one station out, you kind of have one, every station has their leader at the scene, which he has to communicate with, and they have to have the same understanding of the situation, and have the same understanding of what's been decided, what's the plan, what are we supposed to do? So, if you don't have this communication, it doesn't work, you often have several stations that operate with different targets, without it being known to our effort manager. (ID-7) |
| • Decision Dilemmas | | You know the human life part, if you manage to save people if there are people inside the house, it gets more complicated. … The working method gets different because you have to, you take more risks, which makes it more complicated. There is a bigger responsibility on the people on the mission, because they are focused on their particular part, and overlook the complexity of the situation. (ID 3) |

elaborate and describe in more detail some of the nuances associated with each condensate. The analytical text was validated by comparing it with the codes and sub-groups and with the original transcribed interviews. From the analytical process, typical 'golden quotes' were identified to represent the results of the study. The analytical text and 'golden quotes' are presented in more detail in the result section. Table 2 gives an overview of the analytical process. In the analytical text, typical 'golden quotes' are used to represent the results of the study.

## 3. Results

The analysis identified three overarching themes labelled 1. Unforeseen Factors, which was further divided into two sub-themes: 1a) External and Contextual Factors and 1b) Internal Experience-Based Factors, 2. Processing and Communication of Information, divided into two other sub-themes: 2a) Cognitive Capacity and 2b) Common Understanding and 3. Decision Dilemmas (see Figure 1). In the following, each of these main themes will be further elaborated and illustrated by quotes from the interviews.

### 3.1. Unforeseen factors

The fire and rescue workers must be prepared to respond to several types of different situations, ranging from false alarms to severe situations. Thus,

**Table 2.** Overview of the analytical process in the study.

| | Step 2: Meaning units | | | Step 3: common themes |
|---|---|---|---|---|
| Step 1: Overall impression | Code[a] | Source[b] | References[c] | Overarching themes |
| The informants talked about how unpredictable events, processing and communication of information, and decision dilemmas were experienced as the most demanding situations. | • Unforeseen and unknown events | 8 | 25 | 1. Unforeseen events |
| | • Processing and communication of information | 8 | 16 | 2. Processing and communication of information |
| | • Decision dilemmas | 4 | 10 | 3. Decision dilemmas |
| | | | | Sub-themes<br>1a. External and contextual factors<br>1b. Internal experience-based factors<br>2a. Cognitive capacity<br>2b. Common understanding |

[a]Code: Identified meaning units.
[b]Source: Number of informants talking about the code ($N = 9$).
[c]References: Number of code related citations. The coding and counting of the quotes were done manually.

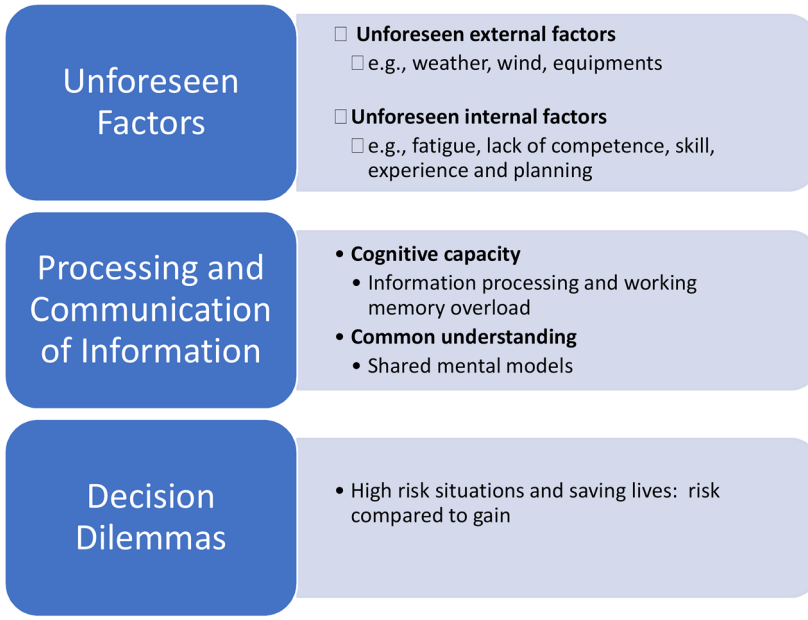


**Figure 1.** Overview of the overarching themes and sub-themes from the interviews.

the unforeseen nature of their work was frequently emphasised in the interviews. Quite often they could be called out to what turned out to be a false alarm or a minor incident. In other situations, the fire could have spread with residents trapped in the building. Based on the analysis of the interviews, external factors were experienced as demanding aspects of their operations. Moreover, these unforeseen aspects of their work could elicit inner experiences or responses, and sometimes emotional states such as fatigue, which added an extra burden to the situation. Such internal responses to external events were labelled as internal experience-based unforseen factors.

### *3.1.1. Unforeseen contextual factors*

Frequently reported challenges were the need to be prepared to tackle a wide variety of contextual factors ranging from strong winds to freezing cold, or heat. Forest fires pose different challenges compared to fires in urban areas where wooden structures and narrow streets (typical in Bergen) would cause additional problems for the crews making it difficult to use fire trucks and equipment:

> The weather is important, especially in areas we define as 'fire spread zones' in the city, such as areas with lots of woodwork. In these zones, with narrow

> streets, it can be hard to spot the fire from the outside. The wind is another external factor, the wind can make vacuum and pressure, and this is typical for fire spread zones, and it can often feel like the weather is working against us. This is a definitely a challenge. (ID-6)

Adding to the (external) challenges, is the worry about equipment malfunction or breakdown during missions. Technical malfunctions could present a threat to life and health of the firefighters and to the public. Attending to maintenance and proper care for trucks, tools and personal protective equipment is therefore a high priority:

> Yes, well, it happens sometimes that there is a fault in our gear. But we have our daily routines, so we check all our gear in the morning, everyone who comes to work are checking all our smoke diving gear, cars and all its contents. (ID-2)

Operations always presented a risk that could escalate and become even more critical. Confined spaces like a tunnel fire, where visibility is reduced, and escape routes are obstructed presented a significant challenge too. One of the incident commanders emphasised the risks associated with tunnel fires:

> [In tunnels] with lanes in both directions, situations may occur, for example missing personnel or cars that have collided. [The fire and rescue workers] went into the smoke, and suddenly they heard car sounds, without knowing where they came from. Suddenly a car on its way out of the tunnel drove by extremely quickly, and this creates a high risk. (ID-2)

### *3.1.2. Unforeseen internal factors*

A prolonged trajectory of complex fire and rescue situations would pose additional challenges. In some cases, such as forest fires, it could take several days to extinguish and control the situation. In these situations, basic human needs such as rest and sleep become important factors to control to avoid fatigue and maintain a resilient response. In one situation a fire in a storage facility lasted several days:

> I think [the silo fire] is the craziest experience I've ever had because there were so many unknown factors … we took material from the factory and did some tests while the fire was going … because we couldn't use water to put out the fire, and I needed an answer to why we couldn't use water. Yes, we did research while the fire was going. So, there were a lot of parallels going on at the same time, it was an exhausting session, I was really tired, it went on too long. (ID-1)

In response to the many challenging aspects of fire and rescue, the experienced incident commanders emphasised the value of experience and training. In addition to basic training, familiarisation with tools and personal protective equipment was essential. Taking part in missions provided an opportunity to learn by example and practice fire drills and routines. Since

each day at the fire and rescue service could be quite different from the other and difficult to predict, training mostly focuses on generic skills that can be applied to different situations. This general approach to training and development provides invaluable when responding to specific incidents. When the alarm sounds, the incident commander will immediately start to plan and prepare based on the initial available information about the situation. While the dispatcher at the alarm central will continue to feed information forward to the incident commander, s/he will begin to develop a plan and inform the crew as they transit to the location of the incident. Still, it is not until they arrive at the scene that they can fully assess the situation at hand. It was frequently reported that it was challenging when they realised that they didn't have the required competence, experience, and their plan did not work or their plan was not good enough. In such cases they had to make new plans during the mission. These challenges can be exemplified by the following quotes, respectively:

> Well, lack of seat competence can form the basis for missions to be challenging to solve… (ID-5)

> I had such an incident … yes, about 2 ½ years ago … 2 years ago, at xx, with a fire in a silo. And I don't have a lot of experience with fires in silos. The starting point was that I didn't know a lot about this…(ID-1)

> We had to think of how to handle the situation, make a tactical plan and understanding the goal of what we were doing, … and then we had to consider the risks, and think of worst-case scenarios. (ID-6)

Overall, a mismatch between what they *expected,* and *the actual scene* was seen as quite common by our informants. Like one of them also emphasised:

> Yes, [a challenge] could be if you arrive, and the picture you've made in your head, is not the same as the reality, you always make a picture in your head on your way to a fire- or injury-site. And if it then doesn't match with the one in your head, you will most likely use some time to readjust your thoughts, to how you should tackle the situation, and how you decide to use your resources. (ID-8)

### *3.2. Processing and communication of information*

Several of the firefighters emphasised that the ability to process and understand information could be difficult during operations and in particular to bring information forward. Moreover, it was frequently reported that a common understanding of the situation was important. However as different services and agencies are working together and they all have their own agenda, this could sometimes be a challenge. Thus, maintaining cognitive capacity and securing a common understanding of the situation emerged as two important sub-themes:

### 3.2.1. Cognitive capacity

Although it would have been ideal to have a good understanding of the situation with specific and correct information about the situation before arriving at the scene, this is seldom the case. The incident scenario may appear different than first expected – and in the initial stage of a response there are many things going on simultaneously. Uncertainty and incorrect information add to the complexity there are lots of different elements to process and sort in order to solve the problems at hand and respond to the situation:

Thus, as one of our interviewees reported:

> The first message can contain a lot of information, which you then have to narrow down to what you actually have use for. What part of the information is useful for the mission? What part of the information is not useful? For example: big industrial building, what is the building's…? What dangers are there? What is the wind like? I may get all this information before even getting out the garage. I think it is more difficult the bigger the situation. Unclarity. … When all the information comes pouring in, what do you pick up? What is useful, and what is not? And then you are supposed to drive a car at the same time, get to the place of the situation, it is quite a demanding task, and sometimes you have to prioritize; should I drive the car, or should I concentrate about all the information, because sometimes it is too much to handle. (ID-1)

Moreover, it was also reported that it could be a challenge to effectively respond and communicate or pass on important information:

> Yes, disturbing noises on the radio, definitely, there's a lot of information going through, you often don't catch everything…. It has probably solved a lot, but there is a challenge if you're not good at giving status updates frequently, share all the information you've received from your department, and then pass it on to the task manager or the mission leaders. It's important, and I can tell we need to get a lot better at this. (ID-6)

> If I am giving one task to one person, for example to pass on the information I'm giving, he remembers maybe 70% of what I'm saying. And when he is going pass on that information to another group, they may get 70% of the information from the leaders. And if that information is going to pass yet another stage, the information gets diluted It depends on how complex the situation is…' (ID-4).

### 3.2.2. Common Understanding

Information management was seen as a crucial aspect of incident command in all stages of fire and rescue operations. Processing, sorting, and identifying significant information contributed to establish, adapt, and maintain much needed situational awareness. The incident commanders became the focal information point in disseminating and updating information back to the fire central and in coordinating their resources. Recent

advances in information communication technology such as the use of drones and remote sensors have improved internal communication and coordination substantially:

> I think communication is important, but it can be hard to create a picture together, like a common understanding in the crew when we are going out on a mission, right? Some of them may remain at the main fire station, and are working with the next steps in The seven step-model, sending out more people, gear, food, and clothing to the mission, right? It isn't always easy for them to understand our point of view. We have developed in a positive direction when it comes to this, with for example drones and streaming, cameras, and such, to make it easier for the crew at the station to understand and see the situation from our point of view. (ID-4)

In addition to this internal coordination, more complex situations also required extended coordination with other emergency services and agencies. In complex situations, the secure communication network for emergency services is an essential tool:

> Every [service] have their own agenda, and that is challenging. The fire department has their agenda, with extinguishing fires, and save lives, the health department have their agenda, with saving lives, and the police department are investigating, and have control over the site of the incident. They manage the site of the incident. They must have control over what the situation is, who have done what in addition to following the investigation, everyone focuses on their own 'task'. This cooperation has been improved after we got our Tetra-system, which contains common communication-channels. (ID-4)

### *3.3. Decision dilemmas*

On site, it is important to be aware of inherent risk and operational decisions that could pose a threat to personnel or victims who may be trapped in the incident. Several of the fire commanders emphasised that since the main objective of the fire department is to *save lives*, some of the most challenging experiences involved situations where crew were at risk of dying because the situation was so dangerous. Some of our interviewees had many different examples of such difficult decision dilemmas and how challenging it was to judge in some situations. As one of our interviewees emphasised:

> We never give up, but some situations, a classic example is when you approach a house fire with a 'no go', you have the option of sending smoke divers into the fire, and they can do their work, search through the house etc., to a certain point. [You need to] balance between the risk to your own crews compared to the gain. A house fire that has developed too far in the wrong direction creates a danger of the building, or building materials, collapsing, and a high risk to your own crew. In situations like this it often comes to a point where we are deciding to call it off. (ID-2)

Other important examples of decision dilemmas were from a tunnel fire:

> Where you have a long driving distance, and big fires with lots of energy, where they often spread to other cars and with missing personnel inside, that is extremely challenging, because your own crew is at risk. (ID2)

> High temperature in the concrete roof of the tunnel creates a risk of falling rocks, suddenly the probability of on one of your own team-members being hit by a falling rock is another risk. In other words, there is a high risk in sending in resources in these types of fires. (ID 2)

Also, another interviewee had several examples of how difficult it could be to face decision dilemmas. One example was related to a situation where people were taken by a landslide:

> The landslide was also continuing, and we had to call of the rescuing right there at the time, and I wouldn't say that it was the same as giving up because we called it off in fear of losing our own people. It was a very demanding decision. We had the choice to continue anyway, but that would've been at our own risk. (ID 6)

Yet another example was related to a burning house with two people inside and whether he should risk the lives of two smoke divers to rescue these two people:

> Should I as leader, send two smoke divers inside a burning house, when I know there are two people inside? This is related to an actual incident at XX, should I send them in, or not? As a leader you're supposed to be 100% sure that it's safe for your boys to go inside, but if I feel an ounce of uncertainty, you're still supposed to attempt a rescue, how far are you supposed to go, and do I have enough experience as leader to make this decision? (ID-6)

It could also happen that they had to take risks due to wrong assumptions. Yet another interviewee emphasised:

> Yes, … if we have a situation where we haven't been able to quality assure those who are going to solve the mission, for example smoke divers – who are going through a quality check once a year. If this checking is missed, if we don't get to assure that the person involved are fitted for the mission, and it takes a long time before it turns out he is not fitted for the task, a fault in the system … That never happens, the quality check may miss by a couple of weeks, but not more. If that would've been the reality, you risk sending out smoke divers or firemen who are not able to handle the mission, based on the assumptions given earlier. (ID5)

Although the incident commanders are highly experienced and trained, they are constantly confronted with the risk of danger and potential of mission failure. The incident commanders emphasised the importance of planning and preparations to ensure a calm, professional approach to

missions. Finally, the emotional relief when missions were successfully completed was recognised:

> We had to break the window, also the one in the door, and then I managed to reach out, and he handed me the key to the door which had locks on both sides, I managed to open the door and rescued him, it was a good feeling. (ID-2)

Other data examples related to the different categories are presented in Table 1.

## 4. Discussion

By using qualitative interviews, the aim of the present study was to gain in-depth knowledge about demanding operational situations that are difficult to solve for experienced firefighters. The study has identified and described several examples of different ill-defined problems experienced firefighters find difficult to handle. The current results indicate that situations could be difficult due to Unforeseen Contextual and Internal Factors. Other difficult situations were Processing and Communication of Information, which could be divided into Cognitive Capacity and Common Understanding. Finally, we identified Decision Dilemmas as highly demanding situations.

### *4.1. Unforeseen factors*

Overall, the present study demonstrated that there was an agreement among the interviewees that the most difficult problems were those that could be classified as unfamiliar and unforeseen. These events are perceived as impossible to foresee. In many ways the present results confirm that the most challenging situations are situations with many unknown factors, as also emphasised by Kay and King (2020). This was reported by almost all our interviewees, and it was exemplified by external and contextual factors such as the weather including the wind, technical problems, and other unforeseen factors. In all these cases unexpected events caused escalations of dramatic and dangerous situations. These factors can be regarded as *dynamic risk factors* – they are changing, and they are perceived as unforeseen, being deemed to be impossible to describe and predict in terms of probabilities – because the possible outcomes of these factors are not well-defined (cf. Kay and King, 2020 p. 43), or pre-structured (Huber, 2011). In naturalistic situations, risky decision-making is by definition subject to uncertain outcomes (Huber, 2011). New training strategies need to integrate the understanding of which crisis drivers that could be common in scenario triggered by different threats or hazards, to facilitate pathways of decision making in something that has not been experienced before (Pescaroli et al., 2023).

Along with these external and contextual factors the present study also identified internal experience-based factors such as fatigue, acknowledgment of lack of competence and experiences, as well as a lack of good planning. The results showed that it was frequently reported that it was extremely challenging when there was a mismatch between expectations (mental pictures) and reality (the actual scene). Kahneman and Klein disagreed about many issues, but they agreed that *skilled* intuition is based on experience (Kahneman & Klein, 2009). It takes a long time to develop these skills, but when these skills are developed it is possible to solve complex problems based on recognition (i.e. intuition). However, the present study showed that in some cases it was not possible to solve problems based on *recognition,* due to this mismatch between expectations and actual scene. As the interviews demonstrated, some situations required readjustment, new planning, and search for new solutions to a problem.

These results correspond with Huber's (2011) model of risky decision making. Huber is talking about mental representations of risky alternatives and uncertain outcomes and argues that to solve risky decision problems people are searching actively for alternatives and additional information. These different alternatives and their outcomes are represented as a mental causal model. Such mental simulation of causality in the form of imagining alternatives to reality (counterfactuals) has been proposed to play an important part in assessing the causal role of a prior event (Wells & Gavanski, 1989). A mental causal model contains alternatives, outcomes and a casual relation that produces the outcome when an action is performed. Importantly, when there is time pressure and if one or different alternatives have different uncertain outcomes, this may lead to capacity overload on cognitive processes and mechanisms such as working memory (Huber, 2011).

The results here on mental pictures compared to reality also match existing knowledge on the creation of mental images (e.g. a *mental casual model)* requiring involvement of the visual spatial sketchpad (VSSP) part of the working memory (Baddeley et al., 2015). The VSSP has limited capacity (i.e. 3–4 objects; Baddeley, 2003), and according to Logie (1995) it can be divided into two components, the visual cache and the inner scribe. The visual cache ensures storage of information (e.g. mental pictures) in short term memory, while the inner scribe makes it possible to spatially process information. This means that the visual cache makes it possible to keep a picture of the different alternatives and possible outcomes and their consequences in mind, simultaneously the inner scribe makes it possible to take in and manipulate new information from the environment.

Research has shown that the ability to create a novel picture in mind can easily be disrupted by concurrent tasks (Pearson et al., 1999). Thus, it is extremely sensitive to stress and if many different things are going on at the same time, it may result in overload on the working memory capacity. Working memory is one of the most important executive

functions underlying planning and problem solving (Cowan, 2014), but also decision-making (Furley & Memmert, 2012). Overload on the working memory capacity may therefore have severe negative implications for planning, problem solving and decision making.

### 4.2. Processing and communication of information

Moreover, the current results revealed that mismatch between expectations and actual scene could be caused by misunderstanding due to poor processing and communication of information. In some cases, there were so many things going on simultaneously that it was very difficult to process information. A classic example was that it was very difficult to focus on driving a car (usually at high speed), in an otherwise noisy environment, and simultaneously process verbal information about what was going on. Driving a car and simultaneously processing verbal information puts high demands on attentional processes and working memory.

Research has shown that stress such as background noise disturbs concentration and performance on tasks that depend on working memory (Alimohammadi et al., 2019). Speech-based information is handled by the phonological loop of the working memory (Baddeley, 2003; Baddeley et al., 2015). It consists of the phonological store, which makes it possible to keep verbal information in the short-term memory for a few seconds, and the articulatory control process, which makes it possible to maintain and manipulate information in the store. Also, the phonological loop has limited capacity, and since it is very important for perception of verbal information (Baddeley et al., 2015), it has consequently, implications for further communication of important information (cf. '*If I am giving one task to one person, for example to pass on the information I'm giving, he remembers maybe 70% of what I'm saying. And when he is going pass on that information to another group, they may get 70% of the information from the leaders. And if that information is going to pass yet another stage, the information gets diluted. It depends on how complex the situation is…ID-4',* see Table 1). Due to the limited capacity of the phonological loop, it may therefore be very difficult to process all the information in an otherwise stressful and noisy situation.

It was also reported that poor communications could cause a lack of common understanding and awareness of the situation among the crew, and the different services involved such as the police, health staff and the firefighters. Successful solution of complex problems requires collaboration among people with different expertise and backgrounds. Professionals at different levels and with different decision-making authorities must work together (Dörner & Funke, 2017; Wilkinson et al. 2020). Thus, overall communication was an important factor and problems related to the communications could be very challenging. This sub-theme confirms the importance of shared mental models (Espevik et al., 2006), and the

need to assure information sharing as a premise to tackle complex crisis (Pescaroli et al., 2023).

### 4.3. Decision dilemmas

Finally, the interviews revealed that decisions concerning 'saving lives' were extremely difficult, because the risk could be so high for the crew. So, if there were one or two people inside a building, should two smoke divers be sent into the building and risk their lives as well? In situations like this the risk compared to the gain had to be considered, which is of course a difficult decision dilemma. It was reported that sometimes they had to decide '…*to call it off*…' (cf. ID-2, Result section page 13). However, it was also clear from the interviews that they really don't give up. As one of them reported '… *you are still supposed to attempt a rescue*…' (cf. ID-6, Result section page 14), and the interview gave examples of highly risky situations where smoke divers went inside and managed to rescue people. Whether mission leaders get risk averse or risk seeking in situations like this is impossible to say based on the current study (cf. Tversky & Kahneman, 1981). However, Pham (2007) has argued that when people are exposed to words such as 'saving people' or 'saving lives', these words activate a particular value-laden schema, and saving people's lives are important regardless of how many.

There was an agreement among those interviewees who had been forced to make decisions about the risk to their own crew compared to the gain, that these decisions were the most difficult decision-situations. In contrast to classical research about decisions related to saving lives (e.g. Tversky & Kahneman, 1981), there might not be any right and wrong answers to such complex problems, as in real life people can die, and in real life decision makers become responsible for their decisions (Kay & King, 2020). What kinds of risk-defusing actions the decision-maker finds acceptable, in the heat of the moment, can be influenced by many different interacting factors (Huber 2011).

## 5. Limitations with the study and suggestions for further research

The present study is a descriptive qualitative study with a limited, but still very experienced (≥28 year) sample of fire commanders. Further, the interpretations of the results are made by the authors of the paper, thus there is a risk for biases. However, few studies have examined how firefighters maintain their operational capacity when faced with unforeseen high-risk decisions in their line of duty (Heino & Kalalahti, 2021; Klein et al., 2010), and the present study offers unique examples of complex problem solving in naturalistic settings. Thus, the study generates some important ideas and guidelines for further research.

Almost all the interviewees in this study reported that unforeseen events were among the most difficult tasks to handle. However, another potential limitation with the current study is that the firefighters were not asked about how these events were appraised. According to Lazarus and Folkman (1984) the appraisal of a critical, stressful, or threatening situation is important to understand the emotional, cognitive, and behavioural consequences of an event. Thus, an issue to be examined in more detail in future studies could be to investigate how firefighters react to unexpected events, where routine is lacking, and mental simulation of the situation is not possible?

Professionals may perceive, appraise/interpret, and react to critical situations in different ways. Firefighters are selected and well trained to handle highly critical situations, and it is well known that they solve complex problems fast due to their expertise and intuition (Klein, 1993; Klein et al., 2010). Less is known about the cognitive-affective processes and emotion regulation strategies during complex problem-solving. More in-depth knowledge about firefighters' handling of critical situations is needed. This includes more knowledge about their thoughts and beliefs about emotional responses to unforeseen events, their choice of emotional regulation strategies, and the effects of these strategies on psychophysiological arousal and working memory. On a macro cognitive level, the present study calls for renewed attention to effective strategies to support firefighters in managing uncertainty, anticipating complexities, mentally simulating likely roadblocks and leverage points. Developing strategies to increase working memory capacity and higher order cognition in the form of planning, problem-solving and decision making could be a viable way forward (Cowan, 2014; Furley & Memmert, 2012). Thus, future research should combine in-depth interviews about cognitive-affective processes, with experimental methods assessing objective outcome variables such as psychophysiology and basic cognitive mechanisms in support of practical interventions, simulation and training.

## 6. Concluding remarks

Briefly summarised the present study offers in-depth knowledge about demanding operational situations that are difficult to solve, even for experienced firefighters. Unforeseen contextual and internal factors, information processing and communication errors, and decision dilemmas were frequently reported as highly demanding factors. Thus, the current study has some important implications for practical interventions in education and training. However, managing uncertainty will always be difficult, but the current study provides guidance for future research in firefighters. More in-depth knowledge about firefighters' handling of critical situations is needed. This includes more knowledge about internal cognitive-affective processes and emotional regulation strategies, as well as objective data on psychophysiological arousal, and working memory, as all these mechanisms influence operational decisions.

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## Notes on contributors

*Anita L. Hansen* (https://www4.uib.no/en/find-employees/Anita.Lill.Hansen) is Professor in Cognitive Psychology at the University of Bergen. Her research interests focus on cognitive and biological mechanisms involved in self- and emotion regulation.

*Jarle Eid* (https://www4.uib.no/finn-ansatte/Jarle.Eid) is Professor of Work and Organizational Psychology at the University of Bergen, Norway. His research interests focus on leadership, operational psychology, team training and development in safety critical organizations.

*Kjersti Bergheim Valdersnes* has a PhD in Work and Organizational Psychology from the University of Bergen, Norway. Her research focus is operational psychology, and safety climate in high risk organizations.

*Gianluca Pescaroli* is Associate Professor in the Department of Risk and Disaster Reduction at University College London, England. He is also a Senior Risk Advisor at the Centre for Risk Studies, University of Cambridge. Gianluca's research focuses on building and improving resilience to systemic risks, including high-impact, low-probability events, with a particular interest in cascading effects and continuity planning.

*Ilan Kelman* https://www.ilankelman.org is Professor of Disasters and Health at University College London, England and a Professor II at the University of Agder, Kristiansand, Norway. His overall research interest is linking disasters and health, integrating climate change into both.

## References

Alimohammadi, I., Kanrash, F. K., Abolghasemi, J., Shahbazi, A., Afrazandeh, H., & Rahmani, K. (2019). Combined effect of noise and smoking on the cognitive performance of automotive industry workers. *Basic and Clinical Neuroscience*, *10*(5), 515–526. https://doi.org/10.32598/bcn.10.5.513

Baddeley, A. (2003). Working memory: Looking back and forward. *Nature Reviews. Neuroscience*, *4*(10), 829–839. https://doi.org/10.1038/nrn1201201

Baddeley, A., Eysenck, M. W., & Anderson, M. C. (2015). *Memory*. Psychology Press: Tayler and Francis Group London.

Butler, P. C., Bowers, A., Smith, A. P., Cohen-Hatton, S. R., & Honey, R. C. (2023). Decision making within and outside standard operating procedures: paradoxical use of operational discretion in firefighters. *Human Factors*, *65*(7), 1422–1434. https://doi.org/10.1177/0018720821104186

Cohen-Hatton, S. R., Butler, P. C., & Honey, R. C. (2015). An investigation of operational decision making in situ: incident command in the U.K. fire and rescue service. *Human Factors*, *57*(5), 793–804. https://doi.org/10.1177/0018720815578266

Cowan, N. (2014). Working memory underpins cognitive development, learning, and education. *Educational Psychology Review*, *26*(2), 197–223. https://doi.org/10.1007/s10648-013-9246-y

Dörner, D., & Funke, J. (2017). Complex problem solving: What It Is and What It Is Not. *Frontiers in Psychology*, *8*, 1153. https://doi.org/10.3389/fpsyg.2017.01153

Espevik, R. E., Johnsen, B. H., Eid, J., & Thayer, J. (2006). Shared mental models and operational effectiveness: Effects on performance and team processes in submarine attack teams. *Military Psychology*, *18*(sup1), S23–S36. https://doi.org/10.1207/s15327876mp1801s_3

Findlater, K. M., Satterfield, T., & Kandlikar, M. (2019). Farmers' risk-based decision making under pervasive uncertainty: Cognitive thresholds and hazy hedging. *Risk Analysis: An Official Publication of the Society for Risk Analysis*, *39*(8), 1755–1770. https://doi.org/10.1111/risa.13290

Fraess-Phillips, A., Wagner, S., & Harris, R. L. (2017). Firefighters and traumatic stress: A review. *International Journal of Emergency Services*, *6*(1), 67–80. https://doi.org/10.1108/IJES-10-2016-0020

Furley, P. A., & Memmert, D. (2012). Working memory capacity as controlled attention in tactical decision making. *Journal of Sport & Exercise Psychology*, *34*(3), 322–344. https://doi.org/10.1123/jsep.34.3.322

Gardner, N. K. (1972). The appraisal and control of complex development projects. *Research Policy*, *1*(2), 122–155. https://doi.org/10.1016/0048-7333(72)90015-7

Giorgi, A. (1985). Sketch of a Psychological Phenomenological Method. In A. Giorgi (Eds.), *Phenomenology and psychological research* (pp. 8–22). Duquesne University Press.

Goel, V. (2010). Neural basis of thinking: Laboratory problems versus real-world problems. *Wiley Interdisciplinary Reviews. Cognitive Science*, *1*(4), 613–621. https://doi.org/10.1002/wcs.71

Green, R., Gray, R. M., Bryant, J., Rance, J., & Maclean, S. (2020). Police decision-making with young offenders: Examining barriers to the use of diversion options. *Australian & New Zealand of Criminology*, *53*(1), 137–154. https://doi.org/10.1177/0004865819879736

Heino, O., & Kalalahti, J. (2021). Securing Operational capability for exceptional circumstances: How do professional first responders respond to the unexpected? *Sustainability*, *13*(11), 6418. https://doi.org/10.3390/su13116418

Hoffrage, U., & Marewski, J. N. (2015). Unveiling the Lady in black: Modelling and aiding intuition. *Journal of Applied Research in Memory and Cognition*, *4*(3), 145–163. https://doi.org/10.1016/j.jarmac.2015.08.001

Huber, O. (2011). Risky decision making with mental causal models. In W. Brun, G. Keren, G. Kirkeboen, & H. Montgomery (Eds.), *Perspectives on thinking, judging and decision making* (pp. 179–189). Universitetsforlaget. https://www.researchgate.net/publication/236888588_

Huber, O. (2012). Risky decisions: Active risk management. *Current Directions in Psychological Science*, *21*(1), 26–30. https://doi.org/10.1177/0963721411422055

Huber, O. (2017). Evaluation-dependent representation in risk defusing. *Frontiers in Psychology*, *8*, 836. https://doi.org/10.3389/fpsyg.2017.00836

Jonassen, D. H. (2000). Toward a design theory of problem-solving. *Educational Technology Research and Development*, *48*(4), 63–85. https://doi.org/10.1007/BF02300500

Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *The American Psychologist*, *58*(9), 697–720. https://doi.org/10.1037/0003-066X.58.9.697

Kahneman, D. (2011). *Thinking, fast and slow*. Penguin Books.

Kahneman, D., & Klein, G. A. (2009). Conditions for Intuitive Expertise: A failure to disagree. *American Psychologist*, *64*(6), 515–526. https://doi.org/10.1037/a0016755

Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing*, *72*(12), 2954–2965. https://doi.org/10.1111/jan.13031

Kay, J., & King, M. (2020). *Radical uncertainty. Decision-making for an unknowable future*. The Bridge Street Press.

Klein, G. (2004). *The power of intuition: How to use your gut feelings to make better decisions at work*. Crown Currency.

Klein, G. A. (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. A. Klein, J. Orasanu, R. Calderwood, & C. E. Zsambok (Eds.), *Decision making in action: Models and methods* (pp. 138–147). Ablex Publishing.

Klein, G., Calderwood, R., & Clinton-Cirocco, A. (2010). Rapid decision making on the fire ground: The original study plus a postscript. *Journal of Cognitive Engineering and Decision Making*, *4*(3), 186–209. https://doi.org/10.1518/155534310X12844000801203

Kruglanski, A. W., & Gigerenzer, G. (2011). Intuitive and Deliberate Judgments Are Based on Common Principles. *Psychological Review*, *118*(1), 97–109. https://doi.org/10.1037/a0020762

Lantz, E., Nilsson, B., Elmqvist, C., Fridlund, B., & Svensson, A. (2023). Serving the community while balancing multiple responsibilities–experiences of working as a paid part-time firefighter. *International Journal of Emergency Services*, *12*(1), 17–28. https://www.emerald.com/insight/2047-0894.htm https://doi.org/10.1108/IJES-03-2022-0018

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal and coping*. Springer Publishing Company.

Levine, J., Chan, K. M. A., & Satterfield, T. (2015). From rational actor to efficient complexity manager: Exorcising the ghost of Homo economicus with a unified synthesis of cognition research. *Ecological Economics*, *114*, 22–32. https://doi.org/10.1016/j.ecolecon.2015.03.010

Lindsay, S. (2019). Five approaches to qualitative comparison groups in health research: A scoping review. *Qualitative Health Research*, *29*(3), 455–468. https://doi.org/10.1177/1049732318807208

Logie, R. H. (1995). *Visuo-spatial working memory*. Lawrence Erlbaum.

Malterud, K. (2012). Systematic text condensation: A strategy for qualitative analysis. *Scandinavian Journal of Public Health*, *40*(8), 795–805. https://doi.org/10.1177/1403494812465030

Malterud, K., Siersma, V., & Guassora, A. D. (2021). Information power: Sample content and size in qualitative studies. In P. M. Camic (Ed.), *Qualitative research*

*in psychology: Expanding perspectives in methodology and design* (2nd ed., pp. 67–81). American Psychological Association. https://doi.org/10.1037/0000252-004

Miller, J. L., & Pescaroli, G. (2018). Psychosocial capacity building in response to cascading disasters: A culturally informed approach. *International Journal of Disaster Risk Reduction*, *30*, 164–171. https://doi.org/10.1016/j.ijdrr.2018.04.018

Orr, R., Simas, V., Canetti, E., & Schram, B. (2019). A profile of injuries sustained by firefighters: A critical review. *International Journal of Environmental Research and Public Health*, *16*(20), 3931. https://doi.org/10.3390/ijerph16203931

Pearson, D. G., Logie, R. H., & Gilhooly, K. J. (1999). Verbal representations and spatial manipulation during mental synthesis. *European Journal of Cognitive Psychology*, *11*(3), 295–314. https://doi.org/10.1080/713752317

Pescaroli, G., Guida, K., Reynolds, J., Pulwarty, R. S., Linkov, I., & Alexander, D. E. (2023). Managing systemic risk in emergency management, organizational resilience and climate change adaptation. *Disaster Prevention and Management: An International Journal*, *32*(1), 234–251. https://reliefweb.int/report/world/managing-systemic-risk-emergency-management-organizational-resilience-and-climate-change-adaptation-science-policy-roadmap https://doi.org/10.1108/DPM-08-2022-0179

Pham, M. T. (2007). Emotion and rationality: A critical review and interpretation of empirical evidence. *Review of General Psychology*, *11*(2), 155–178. https://doi.org/10.1037/1089-2680.11.2.155

Reale, C., Salwei, M., Militello, L. G., Weinger, M. B., Burden, A., Sushereba, C., Torsher, L. C., … Banerjee, A., et al. (2023). Decision-making during high risk events: A systematic literature review. *Journal of Cognitive Engineering and Decision-Making*, *17*(2), 188–212. https://doi.org/10.1177/15553434221147415

Ritchie, J., Lewis, J., McNaughton Nicolls, C., & Ormstrom, R. (2014). *Qualitative research practice*. Sage.

Stanovich, K. E., & West, R. F. (2000). Advancing the rationality debate. *Behavioral and Brain Sciences*, *23*(5), 701–717. https://doi.org/10.1017/S0140525X00623439

Tversky, A., & Kahneman, D. (1981). The framing of the decision and the psychology of Choice. *Science (New York, N.Y.)*, *211*(4481), 453–458. https://doi.org/10.1126/science.7455683

Wells, G. L., & Gavanski, I. (1989). Mental simulation of causality. *Journal of Personality and Social Psychology*, *56*(2), 161–169. https://doi.org/10.1037/0022-3514.56.2.161

Wilkinson, B., Cohen-Hatton, S. R., & Honey, R. C. (2022). Variation in exploration and exploitation in group decision making: Evidence from immersive simulations of major incident emergencies. *Journal of Contingencies and Crisis Management*, *30*(1), 82–91. https://doi.org/10.1111/1468-5973.12355

Wilkinson, I. (2010). *Risk, vulnerability, and everyday life*. The new sociology, Routledge.

Zhao, W. J., Richie, R., & Bhatia, S. (2022). Process and content in decisions from memory. *Psychological Review*, *129*(1), 73–106. https://doi.org/10.1037/rev0000318