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A preliminary study on the barriers and facilitators to improving the health, safety, and well-being of aging heavy vehicle drivers

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ABSTRACT

Introduction. Managers from road freight transportation organizations were interviewed on barriers and facilitators to implementation of occupational health, safety, and well-being interventions for aging heavy vehicle drivers. As aging drivers are more likely to be seriously injured or die in a work-related incident than younger drivers, it is important to recognize strengths and weaknesses throughout the system to identify intervention that addresses their specific needs. *Method:* A Systems Theoretic Accident Model and Processes (STAMP) control structure was constructed to chart the controllers, controls, and feedback channels in the system to identify gaps in health, safety, and well-being intervention in the system. The STAMP control structure also charted the barriers and facilitators within levels across the system. Eleven managers were recruited into the study representing a range of road freight transportation organizations throughout Australia. *Results:* Interview data revealed that barriers and facilitators existed at most levels of the system. Facilitators included advice from external agencies, support from upper management, modern technology, and regular social communication with drivers. Barriers were a lack of guidance on aging issues, operational conflicts with health and safety objectives, and the drivers' fear of disclosing health information associated with their driving role. In regards to formalized intervention in place to support aging heavy vehicle drivers, the system is reliant on fitness to drive medical assessments based on age and jurisdiction. *Conclusions:* As there was generally a lack of senior direction cited from the upper levels of the system on aging issues, there was much variation across the study on how aging risks are managed in the workplace for heavy vehicle drivers. *Practical Applications:* This study recommends that managers across the road freight transportation industry receive formalized aging-awareness health and safety training in how to manage work-related driving hazards for aging heavy vehicle drivers.

1. Introduction

The last few decades have seen an increase in the average age of Australian workers from 35 years to 41 years; currently the average age for heavy vehicle drivers in Australia is even older than this average workforce age (i.e., 48 years) (Australian Bureau of Statistics, 2019; Australian Government, 2022a, 2022b; Transport and Logistics Industry Reference Committee, 2019). Previous research in this area has defined an 'older worker' as 50 to 55 years and older (Peng & Chan, 2019). While there are many benefits associated with employing older heavy vehicle drivers (Newnam et al., 2020), employers are presented with the challenge of managing an ever-increasing aging workforce.

It has been found that there is considerable uncertainty amongst managers on how to manage older workers, and a gap exists between workplace policies and daily practice (Wainwright et al., 2019). Managers have reported their role is often challenged by an inability to recognize and anticipate the specific needs of their aging cohort of drivers (Newnam et al., 2020). This uncertainty is driven by the knowledge that aging workers are predisposed to injury due to age-related declines in physical, cognitive, and sensory capabilities (Bonnefond et al., 2006; Daigneault, Joly, & Frigon, 2002; Dayanidhi & Valero-Cuevas, 2014; Leveson, Allen, & Storey, 2002; Verdijk et al., 2007). Biomechanical intolerance, which includes the process of osteoporosis from aging, can lead to body fragility, and leave a worker more vulnerable to workplace injuries and transportation accidents (Forman et al., 2015; Mackay, 2007; Nedergaard, Henriksen, Karsdal, & Christiansen, 2013). Older workers are also more likely to suffer workplace injuries if they experience chronic

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health conditions (Peng, Rita, Chan, & Yim, 2020). A review of older workers by Farrow and Reynolds (2012) found that, when compared to younger age groups, workers over 60 years had fewer workplace accidents and injuries, but when these incidents did occur, they were more likely to be serious or fatal injuries. This research demonstrates that there are additional risks that require occupational intervention in the context of aging drivers.

It needs to be acknowledged, however, that chronological age, itself, does not predict driving performance. Rather ability to drive depends on both individual variations in functionality and physical capability, as well as the ability to adapt driving behavior via self-regulation (Laracy, 2006; Newnam, Blower, Molnar, Eby, & Koppel, 2018). It has been found that compensatory strategies, such as expertise and experience can also be protective in regards to maintaining safe driving (Crawford et al., 2016; Farrow & Reynolds, 2012) particularly for drivers aged over 60 years (Farrow & Reynolds, 2012). Furthermore, research has identified that heavy vehicle drivers demonstrate better driving skills than non-professional drivers including better lateral control, and safer driving attitudes (T. Chen, Sze, & Bai, 2019). In support, a study comparing older and middle-aged heavy vehicle drivers found that the older age cohort had a safer attitude to driving including higher seat belt usage and less consumption of alcohol (Newnam et al., 2020). This research suggests that despite the additional risks associated with biological aging, substantial experience within a heavy vehicle driving environment can improve safety behavior.

Beyond the benefits of driving experience, the workplace environment in road freight transportation also needs to be considered in the development of feasible and practicable prevention activities. Heavy vehicle driving can be a physically demanding role. For example, many drivers regularly undertake manual handling as part of loading and unloading their heavy vehicle cargo, resulting in frequent physical strain to perform these physically demanding tasks (Olson, Hahn, & Buckert, 2009). In addition, the driving task is not a role in which the driver simply sits comfortably. During driving and other work roles, heavy vehicle drivers adopt awkward body postures (including the neck, back, and upper limbs) that can result in musculoskeletal pain, and drivers often have poor blood circulation in their lower limbs (Sekkay et al., 2021). Additionally, long workdays over an extended period can also result in cardiac strain (Sekkay et al., 2021).

Beyond these ergonomic hazards, it has also been acknowledged that accessing healthy food and participating in regular physical exercise is a constant challenge for the road transportation workforce (Apostolopoulos et al., 2012; Boyce, 2016; Passey et al., 2014). As a result, drivers generally have a poor quality diet and cite many barriers to eating healthy food such as: a lack of dietary knowledge; difficulty accessing grocery stores while on the road; and insufficient time to cook and prepare nutritious food (Passey et al., 2014). A poor diet, long-term, can lead to chronic health conditions. For example, type 2 diabetes is commonly reported in heavy vehicle drivers (Guest et al., 2020; Thiese et al., 2021); this condition is largely preventable with a healthy diet and lifestyle (Hu, 2011). In addition, workplace health factors, such as these, have a cumulative effect over a career (Schulte, Grosch, Scholl, & Tamers, 2018). Well-being concerns such as stress, loneliness, and depression are also reported amongst heavy vehicle drivers (Crizzle et al., 2017). Thus, it is not surprising that health and well-being issues are a concern within this workforce, and are particularly relevant for aging drivers.

Within Australia, employers have an obligation under federal and state legislation, such as the Occupational Health and Safety Act 2004 (Vic) or equivalent, to provide, as far as practicable, a safe workplace with minimal risks to health and welfare (Victorian State Government, 2004). As a part of their managerial responsibility, employers must provide safe equipment and machinery, organize safe work systems, create facilities for welfare, and also arrange instruction, training or supervision where necessary (WorkSafe Victoria, 2020). Furthermore, the Chain of Responsibility principle within legislation was introduced within many jurisdictions of Australia to acknowledge that road safety is the responsibility of associated parties throughout the heavy vehicle transportation system beyond the drivers; parties deemed to be lawfully responsible for road safety include employers, contractors, operators, schedulers, consignors, consignees, packers, loaders, and unloaders (National Heavy Vehicle Regulator, 2022a). In particular, parties such as employers must take reasonable efforts to ensure that heavy vehicle drivers do not drive unsafely; this could include ensuring that work practices do not encourage drivers to speed, to drive while fatigued, or to exceed regulated hours (National Heavy Vehicle Regulator, 2022c). It should be noted that the Chain of Responsibility is focused on responsible parties at the lower and middle hierarchical levels of the road freight transportation system (National Heavy Vehicle Regulator, 2022a).

Despite obligations such as these, it has been found that 41% of employers had no actions in place to address the needs of their older worker cohort (Drake, Haslam, & Haslam, 2017). There are several explanations for this finding. First, implementing age-related risk management strategies can be viewed as discriminatory (Drake et al., 2017). Second, many employers do not view older workers as a vulnerable population with specific needs; thus, there is a reluctance to adopt health and safety strategies to assist older workers with specific requirements (Office of Industrial Relations Queensland Government, 2019). Third, there is limited guidance for employers in defining an 'aging' or 'older' worker. That is, managers have reported variability in their perception of an 'older worker' with an age range cited from 30 to 80 years (Office of Industrial Relations Queensland Government, 2019). Fourth, workers may not volunteer age-related concerns due to fear of adverse consequences, especially for those employees who did not trust their manager (Drake et al., 2017).

These reasons highlight the complexity of managing the health, safety, and well-being of aging heavy vehicle drivers. That is, the issues range from drivers not reporting health-related issues, to employer perceptions of an aging worker, to societal issues related to discrimination. This suggests that isolated intervention is unlikely to address the challenges associated with aging drivers. Indeed, a recent meta-review undertaken by Batson, Newnam, and Koppel (2022) concluded that most occupational health, safety, and well-being interventions are controlled by local management and directed toward changing aspects of the worker's physical condition, behavior or skillset (Batson et al., 2022). That is, limited intervention is managed at the higher levels of the system (Batson et al., 2022), which means there is limited capability for systemic change to improve the health, safety, and well-being of aging heavy vehicle drivers. One reason for this may be attributed to limited understanding of the challenges associated with targeting intervention for aging heavy vehicle drivers. Thus, the current study sought to investigate the barriers and facilitators associated with targeting intervention for aging heavy vehicle drivers from the perspective of middle level managers.

To achieve this objective, the Systems-Theoretic Accident Model and Processes (STAMP) control structure (Leveson, 2004) was used to help categorize the data collected from managers. In support, Leveson stated that middle management levels are the key to safety as they enforce safety behavior upon the lower level workers as instituted by controls at the upper levels (Leveson, 2011b). The knowledge and experience of these middle level managers are important as within the system hierarchy, they are the gatekeepers and interpreters between the legislation and

regulatory controls, and the drivers themselves. This viewpoint is supported in the heavy vehicle transportation industry (including road freight) with the creation of the Chain of Responsibility principle within legislation that clearly identifies the role of these controllers in the management of safety. Thus, examination of the knowledge and experience of the middle level managers within the road freight transportation system will reveal an important microsystem within the larger control structure of the road freight transportation macro-system. Furthermore, this study will provide critical information on the barriers and facilitators associated with intervention, which will assist with refining and creating intervention that is feasible and practicable for use by these middle levels of management.

The STAMP control structure used in this study was adapted from the template and research by Leveson (2004) and partly inspired by the work of Salmon, Read, and Stevens (2016) within the Australian road transportation environment. Thus, five levels of the road freight transportation system were created for the current study: Level 1: Parliament and Legislation; Level 2: Government Agencies and Regulation; Level 3: Strategic Management (Operational Delivery and Management); Level 4: Local Management (and Supervision); and Level 5: Operating Controller, Equipment, and Environment (Operating Process) (Leveson, 2011a; Salmon et al., 2016). Table 1 describes the road transportation hierarchical system and the key controllers responsible for safety constraints at each level of the STAMP control structure (Salmon et al., 2019; Salmon et al., 2016; Staton, Barnes, Morris, & Waterson, 2021). A human 'controller' is considered an actor in the safety system who fulfils the following criteria: (a) has a safety goal within the system; (b) whose actions affect a state of safety within the system; (c) has a mental model of how to control the safety process; and (d) is able to observe (or sense) the state of the system (Leveson, 2011b). A controller can also be an automated, programmed machine (or robotic system) that is operated by actuators and sensors, such as in an engineering process (Leveson, 2011b); however, this process is out of scope for the current study.

In summary, the aim of this study was to identify the barriers and facilitators that influence the implementation of effective health, safety, and well-being interventions for aging heavy vehicle drivers. It was anticipated that this identification process will enable feasible and practical intervention to be applied, where necessary, at the appropriate level of the road freight transportation system.

Table 1
Description of each STAMP level and key controllers in the road freight transportation system.

STAMP Level	Description of Level	Description of Controllers
Level 1: Government and Legislature	In the sociotechnical society, responsibility for safety is increasingly shifting to government control. Safety behaviour is controlled via laws to provide protection for the public (as demanded), and to ensure organizations operate responsibly.	Federal and State Parliament; Federal and State Ministers; Government legislation
Level 2: Regulators and Government Agencies	As individuals cannot control all the health and safety risks around them, government assume a role in controlling behaviour via regulation, and fund government agencies (or permit alternative bodies) to create policy and enforce standards.	Regulatory authorities; Government departments and agencies; Statutory bodies; Court system; Coroners; Industry associations These controllers create regulation to support legislation or aim to influence legislation.
Level 3: Strategic Management	This level includes the safety or organizational culture, or the direct or indirect leadership messages regarding the importance of health, safety, and well-being at work. Decisions (or allocation of resources) made by organizational stakeholders who influence the health and safety environment.	Upper management level of organizations; Operational divisions of stakeholders in the system
Level 4: Local Management	Direct supervisors or trainers (of the Level 5 workers) who have the ability to manipulate or influence safety behaviour on the roads. This level of control is also concerned with optimising the safety of the work environment, and enhancing the health and well-being of the Level 5 workers.	Direct organizational supervisors and local managers who exert direct control upon the process of driving, or are influential in the health, safety, and well-being of drivers
Level 5: Operating Controller, Equipment, and Environment	Workers who control the operating process of driving, and make day-to-day tactical decisions to produce the 'sociotechnical work' (i.e. the drivers who deliver the freight); Other road users who influence the ability to drive safely; Safety features of the trucks and machinery; Health and safety aspects of the natural and built road environment.	Tactical decision-makers who control the operation of driving and/or alter the vehicle and equipment systems; Vehicles and vehicle equipment; Road infrastructure; Driving environment

2. Method

2.1. Ethics approval

An ethics application was submitted to the Monash University Human Research Ethics Committee and granted approval on 2 November 2020 (Project ID: 267260).

2.2. Procedure

Managers from road freight transportation organizations were recruited with assistance from the National Road Safety Partnership Program (NRSPP), a collaborative network, which aims to improve road safety strategies in the workplace. The NRSPP is hosted by the Monash University Accident Research Centre (MUARC). The NRSPP used its network of industry partners to identify potential participants from road freight transportation organizations who were then invited via email to contact the research team if they were interested in being interviewed for the study. Interviews were then arranged by email and telephone.

2.3. Participants

Eleven managers, who are responsible for supervising (and/or managing) the workplace health, safety and/or well-being of heavy vehicle drivers, participated in the study. These managers represented a range of enterprises across Australia, from small family-owned businesses to large transportation companies. This sample size was considered sufficient to both represent this cohort, in

addition to be able to manage and present the material gathered from the interviews (Braun, Clarke, & Weate, 2016; Fugard & Potts, 2015; Sandelowski, 1995).

The work roles and responsibilities of the participants who were involved in a health, safety and/or being capacity are presented below. Each work role depicted below is not mutually exclusive, with several managers performing two or more roles. Roles were also presented in this format for purposes of anonymity. The work roles of the managers in the study included:

- STAMP Level 3: company director (n = 1); general manager (n = 1); national safety manager (n = 1); Chain of Responsibility manager (n = 1);
- STAMP Level 4: compliance manager (n = 3); risk manager (n = 1); quality manager (n = 1); governance manager (n = 1); sustainability manager (n = 2); fleet and maintenance manager (n = 1); operations manager (n = 1); health manager (n = 3); safety manager (n = 4); well-being manager (n = 1); transport manager (n = 1);
- STAMP Level 5: scheduler (n = 1).

For ease of reading and purposes of anonymity, all participants are labeled as 'manager' in the article. Quotes by managers are anonymously assigned to a participant number; i.e. P1–P11.

2.4. Materials – Interview schedule

Interviews featured open-ended questions in a semi-structured format, with prompt questions where necessary. The interview schedule included nine questions that were adapted from the study undertaken by Newnam et al. (2020). The previous study was focused on barriers and facilitators associated with managing the safety of aging heavy vehicle drivers in the trucking industry in the United States. The current study extends upon the work by Newnam et al. (2020) by exploring the barriers and facilitators in a country that has a Chain of Responsibility legislation whereby each party who works in the heavy vehicle industry in Australia is responsible and accountable for safety (National Heavy Vehicle Regulator, 2022c). For example, one interview question presented to participants asked them to nominate how any external parties, such as government or regulatory agencies, assisted them in managing their aging drivers. The interview questions are also underpinned by systems thinking principles in injury prevention (Leveson, 2004, 2011a). Overall, the interview questions were focused on:

1) the benefits and concerns of employing aging workers: '*What are some of the positive aspects or benefits of employing older heavy vehicle drivers?' and 'What are the challenges associated with (or facing) aging heavy vehicle drivers?*';
2) barriers and facilitators in managing aging drivers: '*What is a facilitator (or helps) your organization in supporting the safety, health, and well-being of heavy vehicle aging drivers?' and 'What are some of the barriers (i.e. things that stop you or make things challenging) associated with supporting the safety, health and well-being of aging heavy vehicle drivers?*';
3) interventions currently in place: *'What strategies are in place to support the safety, health and well-being of aging heavy vehicle drivers?*'; and finally,
4) support for managers: '*What do external parties (e.g., government or regulatory agencies) do to help you in managing the safety, health and well-being of aging heavy vehicle drivers?' and 'Where do you obtain your guidance material or get advice on occupational health, safety and well-being?*'.

All interviews were undertaken by one research team member, over the phone, with individual participants. All interviews were recorded and transcribed ad verbatim, with a human transcriptionist to reduce the rate of translation error. The average interview length was 23.8 minutes, with a range from 8.8 minutes to 38.3 minutes.

2.5. Data analysis

Interview data were imported into NVivo 12 Plus data analysis software for the purpose of thematic analysis. The data analysis methodology featured data immersion (reading and re-reading of interview transcripts), coding (examining and organizing interview data), creating categories (assigning data to broad groupings and hierarchical levels), and identifying themes (identify patterns as evidence) (Braun & Clarke, 2021; Braun et al., 2016). The coding approach was initially guided by the deductive method, grounded within STAMP theory (i.e., understanding the breadth of controls across the system levels). An inductive approach was then used to understand the barriers and facilitators associated with the controls across the system.

All transcripts were coded by two independent coders, and any discrepancies (5%) were resolved by consensus. Direct quotations were also extracted to portray the lived experiences of managers. Table 2 provides some example of statements regarding aging coded at each level of the STAMP control structure. Quotes were assigned to levels based upon the level of controller responsible for improvement to health, safety and/or well-being for aging drivers.

2.6. STAMP control structure

Following coding of interview transcripts, the controllers, control measures, and feedback channels, as mentioned by managers during their interviews, were mapped onto one of five levels of the STAMP control structure (as illustrated in Fig. 1). Data specific to aging drivers are highlighted in the control structure (i.e., bold italics).

If an individual, industry group, or organization was mentioned by one or more managers in their interview as influential, then that 'controller' was mapped onto the STAMP control structure at their level of responsibility in the system. Any workplace intervention, program, strategy, or technique used to assist with health, safety and/or well-being issues was listed as a 'control' at the designated level on the STAMP control structure. Feedback channels, as identified by managers, were also mapped onto the control structure; these could include, for example, medical information, assessment findings, or observations. To illustrate, one manager spoke of a satellite tracking device as a means of obtaining driving-related data; this was listed on the STAMP control structure as 'feedback.' Another example is that well-being resources (a form of 'control') were obtained from a not-for-profit mental health association (a 'controller' in the system).

Allocation of data to the levels of the STAMP control structure was partly guided by the generic template and research by Leveson (Leveson, 2004, 2011b), in addition to previous systems thinking research by Salmon et al. (2016). Additionally, hierarchy is allocated according to legal authority and decision-making authority in Australia; for example, the upper levels have legal effect, with legislation being law, and regulations being delegated laws (Commonwealth of Australia Parliamentary Education Office, 2022). Regulations are essentially the details of laws that have been decided upon by ministers or government departments,

Table 2
Examples of manager statements on aging issues (coded at each STAMP Level).

STAMP Level	Brief Description of Allocation to Level	Examples of Statements regarding Aging Issues at each Level
Level 1: Government and Legislature	Government has responsibility for providing protection via law-making. This involves preparing, enacting and amending laws. More awareness, and subsequent government intervention, via legislative amendment, is needed.	*"I think, from a government perspective, they just need to be aware that unfortunately we have an aging workforce, and whilst we, as a company are very fortunate because we have a lot of younger drivers as well, there are a lot of companies that don't."* [P4]
Level 2: Government Agencies and Regulators	Government legislation is converted to regulatory rules, and administered by government agencies and the court system. More targeted intervention for aging workers in high risk occupations is needed at the level of government agency decision-making.	*"I see a lot coming out from government organizations that's about supporting aging workers, but it's very much assuming - this is my view - very much assuming that these aging workers work in relatively safe and lower risk jobs to start with."* [P7]
Level 3: Strategic Management	Influence of leadership and organizational culture. More targeted intervention is needed within organizations to improve organizational culture, and strengthen a sense of well-being and belonging.	*"For me, I think, that's a thing that the older drivers love. And I think that's just been the culture all the time. And they just get in there and they have a banter and a laugh."* [P8]
Level 4: Local Management	Supervisors or trainers who maintain direct control over drivers. More targeted intervention is needed from organizational supervisors to support aging drivers in training activities.	*"And rather than say, 'Oh, you're too old for training', we try to turn that into a positive discussion about what they're going to achieve from the training."* [P7]
Level 5: Operating Controller, Equipment and Environment	Drivers, other road users, tactical-decision makers, equipment, and surrounding environment. There needs to be more acknowledgement of the skills and knowledge that aging drivers contribute to their work role, and to their organization, and their industry.	*"So, experience is very important because of the knowledge and skills of our customers, the roads they travel on, the types of [cargo] we cart. So, it's very valuable to us to have experienced operators."* [P6]

rather than legislators (Commonwealth of Australia Parliamentary Education Office, 2022).

The middle levels of the STAMP control structure are the interpreters of the law within the context of organizations and industry associations. The lowest level of the STAMP control structure features the workers who are the controllers with the lowest level of authority and decision-making power within the system. There are no control measures descending from Level 5 as this is the lowest level of the system; control measures at this level are usually tactical and operative. In addition to the controller, crucial work-related equipment and environment factors are also featured at Level 5 as this level represents the operating process model within the STAMP control structure (i.e., the process of driving).

Although not traditionally a component of the STAMP systems-thinking approach (Leveson, 2004), the barriers and facilitators to effective intervention were listed alongside the control structure in Fig. 1 to highlight their influence at each level of the road freight transportation system.

3. Results

3.1. Characteristics of aging heavy vehicle Drivers

To understand the issues involved in managing the health, safety, and well-being of aging heavy vehicle drivers, managers were asked to describe typical positive qualities and characteristic strengths of this cohort. All managers described multiple benefits of employing aging heavy vehicle drivers; these positive aspects were organized into themes for purposes of analysis. Table 3 presents the themes, articulated examples, and direct quotations. Positive characteristics were focused on personal traits such as a pro-social personality, in addition to work-related traits such as experience, knowledge, work ethic, and safety awareness.

3.2. Management strategies

Health, safety, and well-being intervention strategies, as revealed by managers, were mapped (as controls) onto the STAMP control structure (see Fig. 1) and assigned to one of five levels as described in Table 1. Managers identified many strategies within the road freight transportation industry that were used to manage the health, safety, and/or well-being of their entire cohort of heavy vehicle drivers; occupational strategies were identified at all five levels of the system. However, in regards to aging drivers, the current study identified only one bureaucratic intervention that was articulated as being specifically targeted to aging heavy vehicle drivers (i.e., regulated medical assessments, which are contingent on the heavy vehicle driver's age and the respective state or territory jurisdiction). Additionally, one manager reported that they had set up a Fatigue Management accreditation program within their workplace, and this scheme required that all heavy vehicle drivers participate in a yearly medical assessment from the age of 50 years and older (as opposed to every three years for younger drivers).

Beyond these types of interventions, participants generally reported that there were no programs specifically designed for aging drivers; for example, one manager stated "*I can't think of anything specifically for the aging population of our drivers*" [P5]. Additionally, in response to the question: "*And thinking of the support, that you get as an employer in managing aging heavy vehicle drivers, what do external parties, government or regulatory agencies, do to help you?*" one participant responded "*Nothing.*" [P9]. However, many of the managers adopted discretionary strategies to suit an individual driver in response to the challenges associated with managing their aging heavy vehicle drivers (see Table 4).

3.3. Management challenges

The interview data were analyzed to explore the challenges and management issues within the context of managing the health, safety, and well-being of aging heavy vehicle drivers (see Table 5). All identified challenges were categorized to STAMP Level 5 (see also Fig. 1), with the exception of the theme of generational differences which was focused on the work relationship between the aging heavy vehicle drivers (i.e., Level 5) and the upper managerial levels (i.e., Levels 3 and 4). Managers reported several aspects of the heavy vehicle drivers' skills, attitudes, and physicality that presented as managerial challenges.

3.4. Facilitators and barriers to implementation of effective intervention

Whereas the previous section was focused on the challenges associated with managing aging drivers, this section focuses on

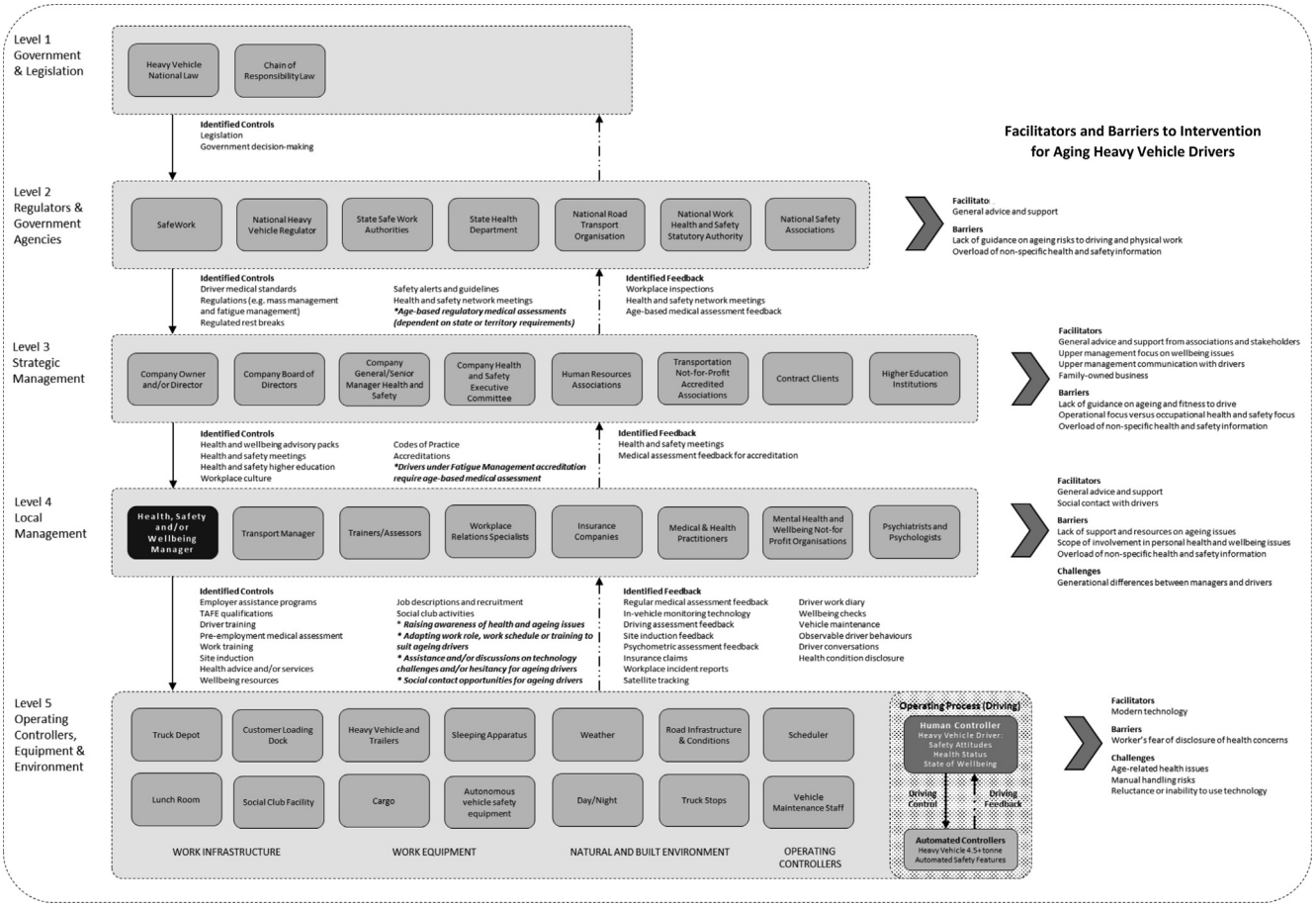

Fig. 1. STAMP Control Structure of Health, Safety, and Well-being Interventions for all Heavy Vehicle Drivers as Identified by Organizational Managers *(* Age-specific interventions as identified by managers are presented in **bold italics**).*

the facilitators and barriers to implementing effective workplace intervention. Analyzing the facilitators and barriers at each level of the STAMP control structure may be helpful for identifying where improvements in the system can be made, in addition to recognizing where the strengths in the system are. This analysis represents a key focus of the current study. Table 6 features the main themes related to workplace facilitators (with specific examples and direct quotations from managers). Facilitators were identified in STAMP Levels 2, 3, 4, and 5 (see also Fig. 1). Facilitators were articulated for most levels of the system, from guidance and resources from government agencies, to external stakeholders, in addition to support from within their own organization. In regards to the lower levels of the system, regular social interaction and integrated technology were cited by managers as helpful in optimizing the health, safety, and well-being of their drivers.

3.5. Barriers to occupational health safety and well-being interventions

Managers were asked about the barriers associated with the implementation of health, safety, and well-being intervention for aging heavy vehicle drivers (see Table 7). The identified barriers arose from both internal and external workplace factors. Barriers were identified in STAMP Levels 2, 3, 4, and 5 (see also Fig. 1). A major barrier was a lack of guidance from the upper levels in regards to aging risks and countermeasures conducive to creating a safe, healthy, and well workforce for their older drivers. At the other end of the scale, a drivers' reluctance to disclose health-related information pertinent to the work role was also a managerial obstacle to intervention.

3.6. STAMP control structure

The STAMP control structure is illustrated in Fig. 1. Overall, the majority of identified controls and feedback were mapped at the lower levels of the road freight transportation system. Controllers were charted in the grey boxes, in Fig. 1, at their level of responsibility within the system. For example, the managers were listed at Level 4 on the control structure. Work training was listed as a type of 'control' as its purpose is to enhance safety; alternatively, health advice was another type of 'control' as its purpose was to improve physical health. Examples of 'feedback' channels were: satellite-tracking in work vehicles (safety feedback); the driver work diary (health and safety feedback); or psychometric assessment results (well-being feedback).

It should be noted that only six forms of intervention featured in Fig. 1 were specific to aging heavy vehicle drivers (highlighted in bold italics), with only two of these being formalized interventions (i.e., safety controls directed from the upper levels of the system). The two formalized interventions were regulated and industry accredited driving medical assessments that were dependent on age and state of jurisdiction (chartered at Levels 2 and 3 respectively). However, there were several individualized strategies for aging drivers that were improvised and implemented by managers (charted at Level 4) on an as-needed basis, such as health and safety advice, and technological assistance (see Table 7 for further detail).

Table 3
Positive characteristics of aging heavy vehicle drivers.

	Identified Examples	Example Quote
Knowledge and Experience	Experience; knowledge of industry and operations; careful handling of cargo; task efficiency; better driving skill; clever; thinkers; good ideas to improve work role; long term thinkers	*"Definitely [the older drivers'] experience and knowledge around the vehicle. Their knowledge around site access or how to get vehicles into sites is a key one for the older types of drivers, yeah." [P1]* *"... they got the skill. So, when we look at drivers, of course, I think the most critical thing is their driving skill. Because their ability for defence driving that's the critical one. Their driving behaviour. Probably because they got experience, and they have done mistakes before, you know, when they were younger." [P10]*
Work Ethic	Good work ethic; happy to be employed; don't complain; reliable; not late; steady; no bad habits; can-do attitude; more stable; respect for equipment and vehicles	*"... [the older drivers] generally want to work, because they're happy to have a job." [P9]* *"... look age is no barrier. A lot of experience, and are good people, and they want to work." [P9]*
Safety Awareness	Knowledge of safety hazards; less likely to be injured; less safety incidents; protect themselves; manage fatigue	*"But the thing is that [the older drivers] are very smart ... [w]hereby some of the younger ones, around 20 to 30 years old, they are the ones who most likely got injured." [P10]*
Pro-Social Personality	Easy going; grateful; more social; settled; mentorship of younger drivers; training of others	*"So, they're really easy going, no-fuss sort of people. I really can't recall an over 60 giving me a lot of grief, put it that way." [P7]* *"That they have knowledge of the industry, and they can pass that knowledge on. So, we do like to get our older drivers together with our younger drivers to mentor them - which is a positive thing." [P5]*

4. Discussion

The aim of this study was to understand the barriers and facilitators associated with the health, safety, and well-being management of aging heavy vehicle drivers in the Australian road freight transportation system. This study extends previous research that has examined the key barriers and facilitators associated with managing aging heavy vehicle drivers in the context of the U.S. road freight transportation industry (Newnam et al., 2020). A defining difference between safety management of heavy vehicle drivers in the United States is that Australia has the Chain of Responsibility principle within legislation for safety breaches for safety breaches; thus, it is important to understand the roles and responsibilities of the controllers within this system to ensure the effective translation of policy into practice. This study also builds upon the findings of a recent meta review (Batson et al., 2022) that found that most occupational intervention (as identified in the research literature) is controlled at the local management level (e.g., direct supervisors, health and safety advisors, well-being instructors) of the system. This group of controllers, thus, represent an important 'gateway' to understanding the factors that support and constrain intervention for aging heavy vehicle drivers. That is, this group plays an important role in interpreting and translating policies and procedures created by senior management and conveying safety messages to drivers, including the priority and value given to intervention.

In contributing toward system awareness of safety constraints, the current study identified several managerial strategies used to enforce this safety behavior for the aging heavy vehicle drivers. This study identified several improvised, individualized strategies dedicated to managing the health, safety, and well-being of aging heavy vehicle drivers, including: encouragement; social communication, technology assistance, and enforcement of health and safety messages. Consistent with previous research, managers also implemented strategies such as: health surveillance; role and capability assessment; flexible working hours; age-limited conditions on work; supervisor observation; and personal development courses (Drake et al., 2017). For example, several managers used the means of behavioral observations with some of their aging drivers, especially in regards to health concerns. In another example, a manager recalled having to stay back at work to assist his older driver, who worked night-shift, to guide him in booking a Covid vaccine appointment. Thus, despite a lack of specific direction on aging issues from the upper levels of the road freight transportation system, there were individualized strategies put in place by managers to assist their aging heavy vehicle drivers.

This study also identified several lower levels facilitators to intervention within the system including regular social communication with drivers, and assistive technology. Managers also noted that aging heavy vehicle drivers were most receptive to health, safety, and well-being intervention when these approaches incorporated the following channels of communication: daily in-person chats (including open-door policies); social events that incorporated training sessions; and lunch facilities that promoted social interaction. This finding suggests that intervention for aging drivers going forward should ideally feature these forms of social communication.

In regards to technology, managers identified that their fleet of modern vehicles were often equipped with features that enhanced driver safety, in addition to functions that reduced physical work strain. However, despite these assistive devices, the managers believed there was hesitancy in the adoption of new technology by their aging heavy vehicle drivers. Other research does support the finding that aging drivers often avoid using novel technology (Sendall et al., 2021), even going so far as to change their place of employment (Newnam et al., 2020). However, other research has found that many older adults are increasingly engaging in the technological age. In the United States, internet use is currently at 96% for adults aged 50–64 years, and 75% for adults aged over 65 years (Statista, 2022). Thus, given opportunity and encouragement, it has been demonstrated that the aging population can adapt. However, this study has identified the need for managers to be equipped with the skills to teach aging heavy vehicle drivers in the use of new technology.

Facilitators to intervention were not identified at the top level of legislation and government, possibility indicating a lack of familiarity or understanding of this level of control, given that safety legislation (i.e. Occupational Health and Safety Act 2004 (Vic) and Chain of Responsibility legislation) does exist for health and safety within Australia (Australian Government, 2011; National Heavy Vehicle Regulator, 2022b, 2022c; Victorian State Government, 2004). Notwithstanding this finding, managers reported several upper level facilitators, albeit at regulatory and senior organizational levels, which assisted them in managing their heavy vehicle driver workforce such as: support from within their organization; in addition to advice and resources from

Table 4
Strategies used for Aging Heavy Vehicle Drivers as identified by managers.

Strategies	Example Quote
Raising awareness and enforcing message of healthy eating and lifestyle	*"I think it's an ongoing – like any sort of campaign, it's just repeating it over and over and just trying to embed that. It is – it can be more difficult with the older ones that have been around a long time, and are, sort of, set in their ways, and those types of things. But I think, on the flip side of that, is as people become older, generally become more aware of their health. And want to, sort of, take care of themselves a bit more." [P2]*
Raising awareness and education of mental health	*"Their mental well-being is something that I'm very mindful of too, because they don't recognise mental health. Umm, so it's a concern that, you know, when they come and you just get to know them, and slowly chip away where they're at." [P11]*
Adapting work role or work schedule to suit individual aging worker	*"Adapting. I mean, you know, you talk to my general manager, and he shares the same view as me, and that is, if they've worked for us for so long, the least we can do is keep them safe, so that they can retire and be happy." [P7]*
Assistance or discussions regarding technology	*"And sometimes we do have challenges [with aging drivers]- we're trying to introduce new [technology] - like we've just gone to a mobile phone device. So, introducing people to their phone. And getting them to understand how to put in hours." [P5]*
Social contact	*"And I know there's a number of our older guys that - and you see them wander past and you say 'G'Day' to them, and they'll have a yarn to you - those sort of things." [P7]*
Encouraging training of aging drivers	*"And rather than say, 'Oh, you're too old for training', we try to turn that into a positive discussion about what they're going to achieve from the training." [P7]*
Adapting training for aging drivers	*"... yeah, we need to provide some support for them. But I'll say, we can't do things, like, you know, enrol them for a Microsoft Word course or what - that kind of training would not work. So, it really needs someone to sit beside them and go through that kind of stuff with them." [P10]*
Monitoring and observation of aging drivers	*"Now, our older drivers - we've got one that we've, sort of, observing and managing a little bit at the moment. He's slowing down a little bit. So, we're a little bit concerned about him." [P6]*

external agencies who specialize in health, safety, and/or well-being issues. These findings are supported by previous research that has reported that senior levels of support, such as resources from government agencies and industry stakeholders, are readily available for workplace managers (Sendall et al., 2021). However, despite the plethora of information available on health, safety, and well-being issues, research often indicates that heavy vehicle drivers have poor knowledge on healthy lifestyle behaviors such as healthy eating (Passey et al., 2014). Thus, even though managers have an availability of resources offered from the upper levels of the system, there is difficulty filtering this information to the drivers at the lowest level of the system.

Despite a range of strengths in the system, it was found that there was limited specific guidance or direction from regulators, government bodies, and upper levels of organizational management on how to manage aging issues. This finding was consistent with research undertaken in the United States whereby managers expressed concern over a lack of senior direction in managing the safety risks of their older drivers (Newnam et al., 2020). Thus, despite the existence of the Chain of Responsibility principle with legislation in Australia, there is limited guidance for the managerial levels of the road freight transportation system to follow in implementing this guiding principle, especially in regards to the risks associated with aging heavy vehicle drivers. The outcome of this is that managers are often left with the responsibility of navigating issues that arise when conflicts occurred between occupational health and safety priorities, and other operational goals in the organization such as productivity and meeting customer expectations.

The lack of guidance in aging issues is often further compounded by a lack of feedback from aging workers in regards to disclosure of health and medical conditions; this issue was identified both in the current study, as well as in previous research (Drake et al., 2017; Newnam et al., 2020). Furthermore, the non-disclosure of health and medical concerns noted in the current study is consistent with research that older heavy vehicle drivers tend to self-manage their own health issues (Newnam et al., 2018). It could also be suggested that there is a heterogeneity in the translation of resources available to managers, which may also explain the individualized strategies put in place. These findings also indicate that there is a lack of cohesion throughout the middle and lower levels of the road freight transportation system in how health, safety, and well-being issues are handled in the workplace, especially in regards to managing aging drivers.

4.1. Practical implications

Findings from the study suggest that guidance is needed to assist middle level managers in their safety management of aging heavy vehicle drivers. Despite the implementation of individualized strategies for aging workers identified in the current study, additional guidance on implementing and interpreting laws, regulations, policies, and resources from upper level controllers in the system is critical to optimize their effectiveness. To explain, as noted in the current study, managers articulated an abundance of health, safety, and well-being resources; however, there was a lack of specialized guidance material or training cited on aging issues. Having a consistent approach to training road freight transportation managers on aging issues would benefit heavy vehicle drivers across the industry. As previous research has noted that much intervention takes place from Level 4, (i.e. supervision and training of workers), in the workplace system (Batson et al., 2022), then formally recognized education, directed from Levels 2 or 3, could be delivered to managers to provide them with confidence in dealing with the aging issues that they are already handling in an extemporized manner. Based on this results of this study, a course in raising awareness of the risks associated with aging (Porter et al., 2008), in the context of driving, could be created for middle managers. This type of aging-awareness training has previously been implemented in the mining industry, and featured aspects of: typical age-related changes; hazardous work tasks for aging workers; modifications available to suit aging workers; and healthy lifestyle guidance for aging workers (Porter et al., 2008). Research has reported that although line managers are almost exclusively not formally educated in aging-awareness, they have expressed interest in receiving this form of training (Drake et al., 2017). Ideally, aging-awareness training could feature all aspects of the aging process, with an emphasis on support strategies; additionally, age discrimination awareness could be also included as it has been reported that many managers are concerned with being discriminatory (Drake et al., 2017; Newnam et al., 2020; Wainwright et al., 2019).

Table 5
Challenges associated with management of aging heavy vehicle drivers.

	Identified Examples	Example Quote
Generational differences (between managers in Levels 3 and 4, and the drivers in Level 5)	Resistance to change safety views; reluctance to change health habits; reluctance to ask for assistance when needed; dislike of new technology; more hesitant generally; not keen to work longer hours; multiple personal commitments to manage	*"But, the older workers really love those Kenworth vehicles which are the older trucks that don't have any of the safety stuff on there, or they don't - you know - and that can be a challenge too, because you're trying to get them to pop into a nice new Volvo, and they're used to dealing with a Kenworth." [P3]*
Level 5 Age-related health issues	Unhealthy eating; less physical activity; increased weight; sleep apnoea; more prone to injury if they can't move quick enough; more fatigue; more medical conditions and health issues (e.g. heart conditions, diabetes, musculoskeletal, alcohol); slips, trips and falls; slower reflexes; issues with medical reviews; mobility problems; they don't recognise mental health; less active; decades of unhealthy living; lack of nutritional knowledge	*"... send them in for their check-up - you know, one bloke, they took his licence off him until they get the blood pressure right." [P9]* *"... so, we have also had a couple of issues with the older drivers. We had a serious incident where we think maybe their reflexes weren't as [quick as] someone younger - which resulted in the incident. Umm, obviously sometimes with the fitness to drive medicals, we find with the older drivers, sometimes that they've got to go - they've got other medical conditions. So, they need to go and get some further advice from other doctors and things like that, before they pass. So, they've got other conditions." [P5]*
Level 5 Manual handling challenges	Body stresses; loading and unloading challenges; difficulty climbing into trucks; longer recovery time for injury and for physical work generally	*"... it could be getting in and out of the vehicle, their mobility may be reduced as they get older." [P1]* *"I like them to go to a physio, so that whatever the injury they've caused - has been caused, umm, the physio can explain why it's happened and how to avoid that to happen again." [P11]*
Level 5 Reluctance or inability to use technology	Reluctance or hesitancy to use information technology or drive modern trucks with autonomous features; may turn-off driving safety feature or ignore safety technology; they don't own (or are reluctant to use) smartphones, emails, apps, zoom, or teams (e.g. to access mental health resources); difficulty with online induction tests; difficulty with logging hours electronically; difficulty with cabin technology; take longer to understand technology	*"So, I think a few challenges that they face, because they don't have emails, they don't use smartphones and all that. So, I think, you know, with the current trend, you know, the company has mental health apps that they can use on the mobile. And then with the working from home things, you know, we use Teams, we use Zoom, to talk to our colleagues and co-workers, so that, you know, for the well-being purpose. But I think is, with the older driver, they don't have all this technology." [P10]*

Table 6
Facilitators to managing occupational health safety and well-being interventions.

	Identified Examples (Including Quotes)
Advice and support from external agencies	Level 2 Advice and support from national safety associations Level 3 Advice and support from professional association membership; industry groups; insurance services; health and safety advisors; networking opportunities with other transportation organizations *"... when we get together, networking with other transport companies is really good. Because you learn a lot from them as well." [P11]* *"We seek a lot of information from our insurers." [P4]* Level 4 Advice and support from not-for-profit health, safety, and/or well-being support organizations *"... also onboard with the 'Healthy Heads, Trucks and Sheds' program at the moment." [P1]*
Support from upper management	Level 3 Upper management focus on well-being; upper management communication with drivers *"... [the manager] did a company-wide presentation the other day and said that mental health is going to be her number one priority going forward. She has started to see that that's a problem." [P8]*
Accumulated knowledge within the organization	Level 3 and 4 Sharing of knowledge from skilled managers and support staff across the organization Level 5 Maintaining experienced drivers *"I think hanging on to that experience. You know, you maintain that experience and that wealth of knowledge that those people have." [P2]*
Communication/Social contact	Level 3Family-business operation Level 4 and 5Regular base contact with drivers; daily chats with drivers; manager open-door policy; social events with training sessions Level 5Lunch facilities for social interaction; mobile phone technology for regular communication *"... each of the facilities has a lunch room for the drivers, and the comradery in the lunch room is just fantastic for their health and well-being." [P8]*
Modern technology	Level 5 Modern vehicles with safety technology; data-tracking devices; vehicles and equipment with automated functions to eliminate body strain *"I think the biggest plus for us, and we can tell once again through our tracking devices, how a driver likes to operate." [P6]*

4.2. Limitations

Several limitations of this study need to be acknowledged. First, several participants were recruited into the study following referral from a road safety organization and a well-being resource group; therefore, the sample may not have been representative of the population as the study participants may have had a greater awareness of health, safety, and well-being issues, and may have already implemented these types of strategies as a result. Additionally, participants self-selected into the study, and therefore, may have a greater interest in health, safety and well-being issues than other road freight transportation managers. Future research

Table 7
Barriers to managing occupational health safety and well-being interventions.

Themes	Identified Examples (including Quotes)
Lack of guidance, knowledge and scope of involvement in personal health and well-being issues	Level 2 Lack of guidance from government on aging issues for high risk jobs; lack of guidance from government agencies on medical issues in regards to aging and heavy vehicle driving Level 3 Lack of policy or senior managerial guidance on medical issues in regards to aging and heavy vehicle driving Level 4 Scope of involvement in medical and well-being issues; issue of age discrimination; lack of applicable information in regards to specific health and well-being issues. *"But, I guess, from a company point of view, it's always difficult because how involved in someone's personal life, you ought to be." [P4]*
Wide diversity in guidance material although not specific to aging and driving issues	Overload of information from competitive and privately-run providers in Levels 2, 3, and 4; Wide range of resources obtained from many providers in Levels 2, 3, and 4 including: regulators, government departments, health and safety associations, mental health associations, internet, insurance agencies, and trucking associations human resource associations, and education providers. *"So, yeah, lots of tools out there. Probably, you know, there could be even too much, do you know what I mean? It's such a saturated market. There's a lot of providers these days who will try and offer you everything under the sun that'll fix your problems. But I think, umm, you know, there isn't any one perfect product. You have to be balanced and work with regulators, work with providers, and most importantly, work with your employees and listen to what they need." [P3]*
Operational focus versus Occupational health and safety (OHS) focus	Level 3 Upper management attention and focus on operational priorities; customer expectations and priorities on productivity; fatigue management challenges. *"... within our business, we've got directors, but we've also got senior managers. And some of those senior managers and their team managers - umm, getting them up to speed, is been a bit of a challenge for us. Umm, and not because they don't want to. It's probably more because - well, maybe they don't want to. But it's also more because they've got operational constructs to achieve, and that's where their focus is." [P7]*
Worker's fear of medical issue or mental health disclosure, especially in regards to losing job	Level 5 Non-disclosure of medical or health information pertinent to driving role; mental health stigma; history of not asking for help. *"... last year we had one who's never had an accident before, umm, had sleep apnoea, he didn't advise us, and he fell asleep at the wheel. Umm, now he survived luckily. But it's things like that. And we said, 'You just had to tell us. We'd change your shift, mate'. Because he was doing night shift, which doesn't work well with sleep apnoea. He's now doing day shifts, and hasn't had a problem." [P8]*

could overcome this issue by exploring alternative recruitment methods. Second, this study had a small sample size (n = 11). However, the size was considered adequate to represent the 'shared experience' (Crouch & McKenzie, 2006) of middle managers, and it evoked a richness of responses to justify representation of the group (Braun et al., 2016).

Furthermore, a wide range of job roles within health, safety, and well-being in the industry was presented in the participant group. Regardless, future research could address this issue by validating the findings of this study with a larger sample or using alternative data collection methods (e.g., survey). Study recruitment was also conducted during the COVID-19 pandemic, and being based in an environment with an extensive government lockdown (i.e., in Melbourne, Australia; Smith, 2020) contact with people within organizations was additionally challenging. A third limitation of the study is that scarce detail was provided on study participants, however, this decision was made to preserve the anonymity of participants. A final limitation of the study is that only participants from one level of the system were interviewed. Thus, the control structure represents a view point or experience on only one group of controllers in the system; and thus, the findings of this study could be considered a microsystem within the wider road freight transportation system. Future research could validate the findings of this study by including safety knowledge and perceptions from the perspective of drivers, regulators, government representatives, and other stakeholders nominated in the Chain of Responsibility principle within legislation.

Despite the limitations of the study, many of the identified findings and recommendations may also be applicable to drivers of all ages, given that eventually almost every driver will become an 'aging driver.' Additionally, training managers in health and safety awareness, will most likely benefit their entire workforce.

5. Conclusion

As research has reported that aging workers are often fearful of reporting capability changes due to fear of negative consequences (Drake et al., 2017), it could be suggested that aging heavy vehicle drivers are thus often unaware of the value that they bring to an organization. Despite some aging concerns conveyed, the current study found that managers appreciate their aging drivers for their experience, work ethic, safety awareness, and pro-social personality. The valuable characteristics of aging heavy vehicle drivers suggests that engaging them in workplace health, safety, and well-being intervention is achievable, if any issues, such as with technology or ailing health, can be overcome. Despite the Chain of Responsibility principle within legislation in several jurisdictions in Australia, there is little guidance for middle level managers in the system to implement health, safety, and well-being intervention for aging heavy vehicle drivers. It can be suggested that to compensate for the lack of official guidance and direction from the upper levels of the system regarding aging issues, managers have created individualized strategies to manage day-to-day and ongoing concerns with their aging drivers. As these strategies are not consistently implemented throughout the road freight transportation industry, formalized aging-awareness training with a focus on health, safety and well-being risks is recommended for all managers of aging heavy vehicle drivers. This training would thus fill a gap of health, safety, and well-being constraints within the road freight transportation system.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Determinants of the duration of sick leave due to occupational injuries: Evidence from Spanish manufacturing

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ABSTRACT

Introduction: Despite the significant economic impact of occupational injuries on companies and society, studies focused on analyzing the determinants of workdays lost due to sick leave remain scarce and incomplete. This paper contributes to this issue by (a) analyzing the drivers of sick leave duration, distinguishing factors that explain the health recovery time from those that could lead workers to a voluntary extension of the absence period, and (b) formulating and empirically testing the effect of gender, citizenship, temporary work, job tenure, amount of disability benefit, and size of the injured worker's firm on the number of days the employee is off work after the injury. *Method:* Hypotheses are tested on a comprehensive dataset that includes all nonfatal occupational injuries causing sick leave that occurred in the manufacturing sector in Spain during 2015–2019, with more than 400,000 injuries. We conduct ordinary least squares and count data regression models in which the number of days off work is regressed on employees and work characteristics while accounting for a set of variables to control the injury's nature and severity. *Results:* The results show that after considering the intrinsic characteristics of the injury and the severity of the worker's injuries, women, native workers, workers with more seniority, workers with higher salaries, and those working in larger companies have longer periods of sick leave. The results suggest that moral hazard considerations significantly impact the time to return to work after an occupational injury. *Practical applications:* Based on the findings, several insights for company managers and public decision-makers are discussed. Specifically, interventions aimed at improving the organization of work and the working conditions of workers in manufacturing industries are highlighted, as well as the need to improve control and supervision mechanisms during the recovery process of injured workers.

1. Introduction

According to the European Statistics on Accidents at Work (ESAW, 2019), in 2018, there were approximately 3.3 million nonfatal injuries in the EU-28 that resulted in at least four calendar days of absence from work. In the United States, according to the National Safety Council (NSC, 2019), work-related injuries totaled 4.65 million in 2019, resulting in 105 million production days lost, and it estimated total work injury costs of $171 billion.

The costs of an injury are directly associated with the duration of the worker's sick leave: the longer the incapacity period, the higher the economic costs to the company and society. The total number of working days lost due to injury-related sick leave is the result of two types of absence: involuntary and voluntary, each having different origins. The involuntary absence is determined by the worker's natural medical recovery time, that is, the time that the injured worker needs to complete healing after the injury. It is, therefore, an unavoidable absence once the worker has been injured. However, the duration of sick leave may be prolonged by the voluntary absence behavior of the injured worker, which refers to the decision of delaying the return to work motivated by reasons under the worker's control. Determining the actual level of recovery of an injured worker's health, and whether he or she fits to perform safely the tasks required by the job, is often difficult and costly to verify accurately by an outside observer, even a physician. Such imperfect and asymmetric information creates a situation of moral hazard, which facilitates the worker's ability to extend the time off work beyond the natural recovery time. Fortin and Lanoie (2000) refer to this as a duration moral hazard. Thus, the

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observed duration of sick leave is determined not only by medical and health factors that motivate a 'legitimate' absence as a result of work-related ill health but also by factors that motivate an 'illegitimate' absence from work.

This paper focuses on both types of driving factors. Specifically, it analyzes the duration of sick leave due to work injuries while helping to uncover several elements that may be behind an undue extension of the injured worker's recovery time. Thus, we formulate a number of hypotheses on the association of sick leave days with certain variables related to the employee's personal and working conditions that may influence his or her willingness to return to work. These hypotheses, along with factors related to injury severity and other control variables, are tested in a comprehensive empirical analysis based on a sample of more than 400,000 nonfatal work injuries that occurred in the manufacturing industries in Spain during 2015–2019. This is a distinctive feature of our work, as previous studies tend to present partial statistical analyzes with small samples, often based on self-reported surveys in specific industries, or focused on the individual impact of a specific type of injury or variable on sick leave duration, without adequately including other relevant variables. From the theoretical discussion and empirical findings, we draw implications for managers and policymakers to mitigate the scope of both voluntary and involuntary absences due to work-related injuries.

2. Hypotheses development

2.1. Gender

The manufacturing sector is a male-dominated context. The traditional gender imbalance that prevails in manufacturing industries, with women being a minority, contributes to internalizing gender stereotypes and propagating discriminatory norms that negatively affect women at work (e.g., Kanter, 1977; King, Hebl, George, & Matusik, 2010). Likewise, many empirical studies have found that in predominately male organizations sexual harassment occurs relatively more often than in more gender-balanced workplaces (e.g., Gutek, Cohen, & Konrad, 1990; Willness, Steel, & Lee, 2007). Further, it is a fact that women are more involved in household and family care activities than men (e.g. Eurostat, 2019). Thus, working women face a double burden (i.e., a higher workload because they spend significantly more time than men on household chores and caring work, such as childrearing or caring for sick family members). Such pressure may act as an incentive to extend the period of paid sick leave, as women are often unable to shirk their responsibility for domestic and family duties. Furthermore, women are affected not only by stressors common to both sexes but also by stressors unique to women, such as their lower social position and active role in private life (Casini, Godin, Clays, Mahieu, & Kittel, 2013). As a result, women usually face higher levels of work stress and lower well-being and morale (García-Herrero, Mariscal-Saldaña, García-Rodríguez, & Ritzel, 2012), which increases the probability of wanting to be out of the workplace for more days. Previous studies show that women tend to present higher levels of labor absenteeism than men (e.g., Johnson & Ondrich, 1990; Mumford & Bridges, 2001; Fontaneda, Camino, González, & Ritzel, 2019).

In summary, the traditional gender roles and gender discrimination that persist in both the private and professional spheres may influence the duration of women's sick leave, which leads us to postulate the following hypothesis:

H1. The duration of work-related injury absence is longer for women than for men.

2.2. Sickness benefit

In the event of a work injury, the injured worker is entitled to receive a disability benefit (subsidy) during the time she/he is on sick leave. Thus, the employee receives a daily allowance, which is calculated according to the worker's earnings. However, there is a monetary cost or penalty for being on sick leave, as the benefit is usually lower than the worker's base salary and sometimes workers do not receive income during the first few days of their sick leave. The penalty is relative. For a worker with a low wage perceiving a disability allowance that only covers part of it, each day that he or she is on sick leave is clearly costlier than for a worker with a high salary who receives the full amount for the entire period of sick leave. In this regard, the level of the sickness benefit can be a source of moral hazard: a worker decides to prolong the period of sick leave when the increase in welfare associated with leisure offsets the reduction in income. Previous evidence suggests that increased sickness benefits can increase absence rates and the duration of absences (e.g., Johansson & Palme, 1996; Henrekson & Persson, 2004). This leads us to postulate the following hypothesis:

H2. The value of the sickness benefit for temporary disability is positively associated with sick leave duration.

2.3. Temporary workers

Data from the European Working Conditions Survey consistently shows that compared with permanent workers, employees with temporary contracts are more exposed to worse working conditions and suffer more health problems (e.g., Eurofound, 2021). Picchio and Ours (2017) argue that temporary workers are more likely to be assigned dangerous tasks because they usually have less bargaining power. Additionally, a short duration of the contract may reduce incentives to invest in specific human capital and build worker expertise, As Núñez and Prieto (2019) show, firms tend to invest more in the occupational safety and health of the workforce with a higher stock of human capital. These authors find a direct relationship between firms' investment in internal human capital creation (training) and their investment in occupational safety and health. Koene and van Riemsdijk (2005) suggest that low levels of investment in training and skills mean that temporary workers are less likely to identify with the firm where they work. In this context, the lower degree of employer commitment to temporary employees may lead them to reciprocate with a lower level of commitment than full-time employees. As Arocena, Villanueva, Arévalo, and Vázquez (2010) note, reciprocal behavior is at the core of several psychological and sociological theories regarding equity, relative deprivation, and social exchange.

From a different perspective, if the injured worker's contract terminates while on sick leave, he or she will continue receiving the temporary disability benefit until the end of the incapacity period. The temporary worker could seek to extend the period of absence to continue obtaining the financial subsidy. It is likely that due to the fear of losing labor income, some workers seek to prolong their sick leave in order to receive compensation for some extra days. This incentive may even be greater because the unemployment benefit is traditionally smaller and often more complicated to obtain than the subsidy for incapacity. For instance, in Spain, the worker must have made social contributions for at least 12 months in the previous six years to be entitled to unemployment insurance benefits. Further, as worker's disability compensation is usually more generous than unemployment benefits, an insurance substitution moral hazard could exist (Fortin & Lanoie,

1992, 2000). The above discussion leads us to postulate the following hypothesis:

H3. Employees with temporary contracts have a longer duration of absence due to work injuries than employees with permanent contracts.

2.4. Job tenure

Tenure refers to the length of time that an individual has served in the same job. Tenure can confer greater status, rank, or precedence to an employee who has served for a shorter period. In addition, tenure often means that more senior employees earn more money than other employees doing the same or very similar work. Furthermore, severance pay generally increases with tenure, so it is more expensive for a company to dismiss an employee who has been with the company for a long time than an employee who has been with the company for a short time. Tenure can help to keep the job when the company is forced to cut staff. In other words, tenure reduces workers' vulnerability. Thus, the lower the tenure, the greater the pressure to return to work and avoid undue sick leave duration. Therefore, we posit that:

H4. The seniority of the worker is positively associated with the duration of sick leave.

2.5. Immigrant workers

It is well known that immigrant workers are more exposed to adverse and unstable working conditions than native employees. As Porthé et al. (2010, p. 417) argue, immigrants' employment is "characterized by high job instability, a lack of power for negotiating employment conditions, and defenselessness against labor demands." Furthermore, immigrants typically face greater difficulties in entering the labor market in the host country, while they are relatively helpless as regards the threat of unemployment, and are critically dependent on their jobs and incomes (Khan & Rehnberg, 2009; Sterud et al., 2018), In short, immigrant workers are in situations of greater social and economic vulnerability than native workers, so they are more fearful of the possibility of losing their jobs as they face greater difficulties in finding a new one. Consequently, it seems reasonable to expect that an immigrant worker will feel more pressure to avoid the time it takes to return to work after an injury at work being perceived as excessive, and thus minimize the risk of having his or her job threatened. We summarize the arguments above into the following hypothesis:

H5. Immigrant workers exhibit a shorter duration of sick leave than native workers.

2.6. Firm size

In general, the intensity of monitoring and control is inversely related to the size of the organization. In small companies with shorter and more direct hierarchical structures, absenteeism from work does not go unnoticed. In smaller organizations, interpersonal relationships are usually closer, which translates into a higher level of involvement and commitment to both the sustainability of the company and the repercussions of absenteeism for workmates. By contrast, larger companies have higher rates of job rotation and employee turnovers and have more resources to replace employees on sick leave quickly, and workers at such companies have less of a direct perception of the consequences of their absenteeism. As the company grows, relationships become more impersonal, and organizational control is weaker, so employees may feel more tempted to take advantage by trying to prolong sick leave duration. In this vein, several previous studies show that the size of the organization is positively correlated with absence rates (e.g., Barmby & Stephen, 2000; Dionne & Dostie, 2007). Thus, our final hypothesis is as follows:

H6. Employees of larger firms have longer periods of sick leave than those of smaller firms.

3. Empirical analysis

3.1. Data and variables

Our dataset contains data for all nonfatal injuries that occurred in the manufacturing sector in Spain during 2015–2019 and resulted in absence of more than one day from work. The 417,680 occupational injuries recorded in the period under review caused more than 13 million lost work days, resulting in a total expenditure on disability benefits of 618 million euros (calculated as the sum of the allowances received by the injured workers while they were on sick leave). It should be noted here that sick leave due to work-related disease is not considered. Injuries on the way to/from work, and those suffered by self-employed workers are also not included in our dataset.

Another important concept is the notion of incapacity, which is defined as a situation in which a worker is unable to work, temporarily or permanently, as a consequence of a common illness or an injury at work. In this case, the worker receives health care from the social security system, and the maximum duration of the incapacity period is 365 days. This period can be extended by 180 days when there are reasons to presume that the worker's situation can be cured medically during that time. The decision on when the worker is fully recovered to carry out the usual tasks of his or her job depends on the assessment of a medical professional and must be strictly based on medical criteria. Temporary and permanent incapacity for work is protected by an economic benefit within Spain's social security system. The financial benefit consists of a daily allowance calculated based on the regulatory base (mainly the wage earned in the previous months) and the origin of the disability. For injuries at work, a minimum of 75% of the regulatory base is recognized from the first day after the work injury. This allowance is paid either by a mutual insurance company or the National Social Security Institute. Supplementation of the allowance at the company's expense either by collective agreement or agreement between the company and the workers is a widespread practice (López-Tarruella, 2006).

The data used in this study come from the official records of occupational injuries provided by the Statistics of Work Accidents (Estadística de Accidentes de Trabajo, EAT), published by the Ministry of Labor and Social Security of Spain. The EAT data are drawn from the occupational injury reports, which is the official document by which the employer notifies the occurrence of an occupational injury, how it occurred, the place, and the consequences of the injury. Specifically, the files record data on the firm where the injury occurred, personal and professional characteristics of the injured employees, and the type and medical diagnosis of the injuries. It should be noted that our sample contains anonymized data for injuries occurring over five years. This is pooled data, not panel data since the observations in each year do not necessarily refer to the same employee (in fact, it is most likely that the workers injured each year are different).

As shown in Table 1, the average and median length of sick leave are 30.7 and 13 days respectively. Women account for 13.8% of the injured workers, while foreign workers and workers

Table 1
Description of study variables regarding the duration of work-related sick leave in the manufacturing industry in Spain.

Variable	Description	Mean (Median)
Duration	Number of days off	30.7 (13)
Subsidy	Sick leave benefit (euros)	47.2 (43.5)
Size	Number of employees	280 (50)
Age	Age of the worker in years	41.2 (41)
Female	1 = Women, 0 = Men	0.138
Foreign	1 = Foreign, 0 = Spaniard	0.084
Temporary	1 = Temporary contract, 0 = Permanent contract	0.278
Tenure	1 = employee more than 3 years in the same job 0 = employee less than 3 years in the same job	0.521
Serious	1 = the medical qualification of the injury was serious 0 = the medical qualification of the injury was minor	0.006
Hospital	1 = injured worker required hospitalization 0 = injured worker required ambulatory care	0.067
Multiple	1 = more than one injured in the same injury, 0 = only one injured	0.005
Night	1 = the injury occurred during the night shift, 0 = otherwise	0.109
Weekend	1 = the injury occurred over the weekend, 0 = otherwise	0.048
Type	Dislocations sprains and strains	0.424
	Superficial wounds and injuries	0.388
	Bone fracturesTraumatic amputations	0.075
	(loss of body parts)	0.062
	Burns scalds and frostbite	0.020
	Multiple injuries	0.005
	Psychic trauma, traumatic shock	0.003
	Drowning and suffocation	0.001
	Effects of extreme temperatures light and radiation	0.001
		0.001
	Effects of noise vibration and pressure	0.001
	Poisonings and infections	0.001
	Heart attacks strokes and other non-traumatic pathologies	0.019
	Other	
Occupation	Craftsmen and skilled workers	0.477
	Plant and machinery operators and assemblers	0.242
	Elementary occupations	0.235
	Technicians; support professionals	0.019
	Catering, personal, protection and sales service workers	0.013
		0.008
	Accounting, administrative, and other office employees	0.005
		0.002
	Scientific and intellectual technicians and professionals	
	Directors and manager	
Sector	Food, beverages and tobacco (NACE 10,11,12)	0.234
	Textile, leather and footwear	0.035
	(NACE 13,14,15)Wood and cork	0.037
	(NACE 16)Paper and graphic arts	0.042
	(NACE 17,18)Coke and refined petroleum products	0.001
	(NACE 19)Chemical products	0.031
	(NACE 20)Pharmaceutical products	0.010
	(NACE 21)Rubber and plastic	0.050
	(NACE 22)Other non-metallic products	0.056
	(NACE 23)Basic metals and metallic products	0.250
	(NACE 24, 25)Electronic and electrical equipment	0.084
	and machinery	0.088
	(NACE 26–28)Transport equipment	0.036
	(NACE 29,30)Furniture and others	0.046
	(NACE 31,32)	
	Repair and installation of machinery and equipment (NACE 33)	
Region	Dichotomous variables for 17 Spanish autonomous communities	

with temporary contracts account for 8.4% and 27.8%, respectively. Finally, the average benefit received by injured workers is 47.2 euros per day.

We use several proxies to control for the factors that influence the recovery time of an injured worker discussed above. First, the medical assessment of the seriousness of the injury, which is defined according to the doctor's criteria at the time of certifying the sick leave (SERIOUS). Second, the type of care required by the injured worker (inpatient or outpatient care) is a good control variable for injury severity. Logically, inpatient care (HOSPITAL) is indicative of an injury with more far-reaching health consequences, requiring a longer recovery time than an injury requiring outpatient medical care. Third, the age of the employee is included to proxy the worker's health status and recovery capacity. As argued above, we expect a positive association between the variable AGE and our dependent variable (i.e., the consequences of an injury are more severe for mature workers than for younger workers, which usually translates into more days off work). Fourth, we have included the variable MULTIPLE, which indicates whether the injury caused more than one injured worker. In general, when several people are injured in the same incident, it is because it is a major incident (e.g., a violent explosion) that causes more serious injuries.

Likewise, injury dichotomous variables control for differences in the extent and consequences associated with different types of injuries, which are listed in Table 1 in the way they are reported in the EAT. More than 80% of the injuries fall into two broad categories (dislocations, sprains, and strains; and superficial wounds and injuries), which are the typical injuries that occur in manufacturing activities. The occupation and industry dichotomous variables control for specific features associated with the worker's activity. As expected, Table 1 reveals that most injuries occur in blue-collar jobs. Regional dichotomous variables are included to account for additional unobserved characteristics that may influence the recovery time, such as differences in the effectiveness of medical assistance protocols and inspection activity among regional health authorities.

Finally, we note that weekend and night shifts are common in many manufacturing firms. There is ample evidence that night work and lack of sleep, as well as altered circadian rhythms, constitute a potentially dangerous combination of factors. Nightshift workers are often tired and sleepy due to their shift work schedule. Excessive fatigue reduces concentration, which increases the likelihood of making mistakes and the occurrence of more serious injuries. The night shift is considered to be more prone to unsafe work behaviors (Larson, 1998) and shift work can be stressful and detrimental to workers' health conditions (Rosa & Colligan, 1997). Furthermore, the time the injury happens can also determine how quickly and accurately first aid is administered. For instance, in many companies and jobs, there is a shortage of staff working during night shifts and weekends. Thus, prevention and medical assistance services may not be fully operational, delaying and reducing the effectiveness of the first response to the injury. Therefore, the variables NIGHT and WEEKEND are included to account for their potential impact on the recovery time.

3.2. Methods

The focus of our analysis is to test H1–H6 stated above. For this purpose, our econometric analysis is based on the estimation of the following equation:

$$\begin{aligned} y_i = {} & \beta_0 + \beta_1 FEMALE_i + \beta_2 SUBSIDY_i + \beta_3 TEMPORARY_i \\ & + \beta_4 TENURE_i + \beta_5 FOREIGN_i + \beta_6 SIZE_i + \gamma_1 AGE_i \\ & + \gamma_2 SERIOUS_i + \gamma_3 HOSPITAL_i + \gamma_4 MULTIPLE_i \\ & + \gamma_5 WEEKEND_i + \gamma_6 NIGHT_i + \mu TYPE_i + \varphi OCCUPATION_i \\ & + \theta SECTOR_i + \rho REGION_i + \delta t + \varepsilon_i \end{aligned} \quad (1)$$

where the dependent variable y_i is the number of days absent from work for individual i; the next six variables refer to the key variables of interest for testing H1–H6 the rest of variables account for the characteristics of the context and severity of the injury; t is a time trend with $t = 1,..,5$ corresponding to the years from 2015 through 2019; and the Greek letters are the parameters to be estimated.

First, we have estimated Eq. (1) with an ordinary least square regression (OLS). In a second model, the dependent variable is considered a count variable, as it is measured as a non-negative integer and represents the number of times (days) that the person is on sick leave due to an injury at work. A negative binomial distribution is widely used to describe data that are too heterogeneous to be fit by a Poisson distribution, as the former has an extra parameter to adapt the variance independently of the mean (e.g., Arocena, Núñez, & Villanueva, 2008). However, there are many cases in which the number of individuals falling into the zero class cannot be determined; in these cases, it is necessary to truncate the model (Sampford, 1955). The resulting restriction of the domain gives rise to a conditional distribution. Given the characteristics of our data, the truncated negative binomial (TNB) distribution is the appropriate approach to estimate [1], as it allows for overdispersion, combines event counts with the Poisson distribution and unexplained variation with the Gamma distribution, and considers that the zero value cannot occur.

Table 2
Coefficients estimated through the OLS regression and the Truncated Negative Binomial (TNB) model for the duration of sick leave after an injury at work.

Variable	OLS	TNB
Female	2.634 (0.221)***	0.091 (0.006)***
Subsidy	0.059 (0.005)***	0.002 (0.0001)***
Temporary	0.397 (0.020)	0.002 (0.005)
Tenure	1.095 (0.185)***	0.040 (0.005)***
Foreign	−1.413 (0.261)***	−0.047 (0.007)***
Size	0.001 (0.0001)***	0.0004 (0)***
Age	0.434 (0.007)***	0.016 (0.0002)***
Serious	114.259 (0.926)***	1.244 (0.023)***
Hospital	16.644 (0.288)***	0.447 (0.007)***
Multiple	3.801 (1.042)***	0.114 (0.027)***
Weekend	1.575 (0.334)***	0.065 (0.009)***
Night	0.394 (0.229)*	0.016 (0.006)***
Time	0.329 (0.050)***	0.010 (0.001)***
Constant	7.971 (1.581)***	2.496 (0.041)***
Injury variables	yes	Yes
Occupation variables	yes	Yes
Industry variables	yes	Yes
Regional variables	yes	Yes
alpha	-	1.348 (0.004)***
F(62, 417613)/ LR chi2	1010.03	60516.48
Prob > F/chi2	0	0
Number of observations	417,680	417,680

Notes:
Robust standard errors are in parentheses.
*, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

4. Results

Table 2 reports the parameter estimates of the OLS and TNB models. First, in the TNB model, we note that the dispersion parameter alpha (which reflects the fact that the conditional variance exceeds the conditional mean) is significantly greater than zero, strongly indicating that the data are over-dispersed and are better estimated using the negative binomial model than the Poisson model (where alpha is constrained to be zero). A glance at the estimated coefficients in Table 2 reveals that both models provide similar conclusions. We note that all occupation, injury type, sector, and regional dichotomous variables listed in Table 1 are included in the estimates, although their coefficients are not shown in Table 2.

Let us focus first on the key variables of hypotheses H1–H6. The positive and highly significant coefficient for FEMALE provides evidence that women have a longer duration of absence after an injury at work than men. Likewise, the statistically significant positive sign for SUBSIDY indicates that higher levels of subsidy imply a longer duration of sick leave. We, therefore, accept H1 and H2. On the contrary, the estimated coefficient for TEMPORARY is not statistically significant, so H3 is not supported. As hypothesized in H4, the positive and statistically significant coefficient of TENURE indicates that injured workers with longer tenure are absent from work more days than less senior workers. On the contrary, the negative sign for the variable FOREIGN shows that the period of incapacity is shorter for immigrant workers than for national employees, and therefore provides support for H5. The positive and highly significant coefficient for SIZE supports H6, suggesting that extending sick leave is easier in large organizations.

All proxies for the injury severity behave as expected, showing a positive association with the duration of sick leave. Table 2 shows two further results of interest. First, occupational injuries occurring during the weekend and night shifts generate significantly longer sick leave. Second, the positive and statistically significant coefficient of the time trend variable shows that the duration of sick leave has increased over the period analyzed.

The findings are particularly significant for manufacturing industries, where, compared to the service sector, on average workers earn higher wages, have greater seniority in their jobs, firms have a larger average size and there is a higher percentage of large firms. Likewise, as Di Pasquale, Miranda, and Neumann (2020) note, there is a marked upward trend in the percentage of older workers employed in manufacturing and production environments. In Spain, according to the Economically Active Population Survey, the percentage of manufacturing workers over the age of 50 increased from 25.2% to 28.7% between 2015 and 2019, and the percentage of plant and machine operators and assemblers over the age of 50 increased from 27.8% to 33.4%. In addition, 6.1% of employees work more than half of their working days in night shifts (5.2% in the case of employees over 55 years old), while around 20% of employees work at least one Sunday shift per month (17.6% in the case of those over 55 years old).

Before discussing the managerial implications of these results, we perform a marginal analysis to provide an estimate of the magnitude of the effect on the dependent variable of each of the variables that were found to be statistically significant. To do so, we calculate the difference in expected counts between one category of the variable and the other, holding the rest of the variables at their median value.

The results indicate that female workers spend on average 2.37 days more sick leave than male workers when the other variables are kept at their median levels. Along the same line, the duration of sick leave for foreign workers is 1.24 days shorter than that of national workers, while that of employees with more tenure is 1.06 days longer than that of less senior workers. On the other hand, workers injured during the night and weekend shifts are respectively 0.41 and 1.7 days longer on sick leave than those injured outside these time shifts.

As firm SIZE and SUBSIDY are continuous variables, a different margin command is used. Specifically, the margin command gives the expected counts for the values of two previously defined categories of the variable while holding the rest of the variables at their median values. Thus, we first define two categories for firm size: small and medium firms, or SMEs (less than 250 employees), and large firms (with 250 or more employees). The average duration of the incapacity period in large firms is one day longer than in

SMEs. For the marginal analysis of SUBSIDY, the two defined categories of the variable are Low subsidy (below the first quartile) and High subsidy (above the third quartile). The mean duration of sick leave for employees receiving the high subsidy is five days longer than that for employees receiving the low subsidy. As shown in Table 1, the median value of sick leave duration is 13 days, so the marginal analysis reveals that the magnitude of the effect of most of the variables is substantial.

5. Discussion and conclusions

5.1. Practical applications: Managerial and policy implications

The diverse explanatory sources of the duration of sick leave suggest different interventions at different levels, from company management to public administration, highlighting the need to adopt a holistic approach for effective management aimed at reducing lost work time and its associated private and public costs.

The first type of intervention concerns factors related to the attendance motivation of workers who are most prone to duration moral hazard in the manufacturing sector. We find positive associations between the duration of sick leave and female workers. Improving the working conditions of these groups may facilitate their return to work after an appropriate medical recovery time. Various policies and actions to be considered may be related to personal, family, and work reconciliation so that any worker can maintain a full professional career while exercising their right to care for their family, undergo training, or enjoy their leisure and free time. Concrete examples are the implementation of flexible working hours, working from home, and continuous working hours for childcare, among others. Moreover, there is an opportunity for the companies to develop strategies that help employees gradually get back to their normal duties. A phased return to work may facilitate an effective transition of being back to the job and create a supportive environment in the workplace. In this sense, the role and responsibility of physicians might be also reviewed. For instance, to analyze whether physicians need more training on assessing gradual return to work while avoiding sending a worker back (too) early.

The second type of general intervention is related to the improvement of control and supervision mechanisms in the recovery process of injured workers. Our analysis shows that the threat of moral hazard is more intense for native-born workers, with longer job tenure and higher wages (and higher disability benefits), and who are employed in larger firms.

Third, several work-related circumstances that are largely manageable affect the severity of injuries and, therefore, the length of the medical recovery time. Better occupational health and safety prevention and protection help reduce the risk of serious injuries. Likewise, enhancing the quality and speed of primary care after the injury improves diagnosis and promotes quicker medical recovery. In this sense, our results suggest that firm management should consider strengthening safety and medical assistance when organizing work on more dangerous shifts (e.g., night shifts, weekends) and assigning and designing jobs for more vulnerable workers (e.g., older workers). In line with Katiraee, Calzavara, Finco, Battini, and Battaïa (2021), the results highlight the need to integrate age differences among workers into the design and management of production systems in manufacturing companies.

Similarly, public policy interventions aimed at improving social and labor conditions, increasing labor inspection capacity, and creating an appropriate regulatory context to require companies to adopt a robust occupational risk prevention system should be considered. Such policies should not be seen as an expense but as an investment that generates benefits that are reflected in the improved health of workers, increased productivity of companies, and savings of resources for the public insurance system.

5.2. Limitations and future research

Our empirical analysis is not without limitations. Fundamentally, some variables that influence the regular recovery time after an injury at work are not contemplated in our empirical analysis. For example, differences in the care received, information on whether the injured worker has any comorbidity, or a greater detail of the specific tasks and operations that the worker has to perform. Unfortunately, these variables are not available in the information provided. Likewise, the dataset does not contain firm identifiers, which does not allow us to incorporate firm-specific fixed effects. Addressing these issues would increase the accuracy of the estimates.

Finally, the findings indicate that the duration of sick leave has increased over the period analyzed, which were years of economic growth in Spain. Given that the regulation of sick leave did not change during the period considered, this result suggests a positive association between the duration of sick leave and the economic cycle, which might point to the propensity to abuse sick leave when the economic context becomes more favorable. On the other hand, as our work focuses on the analysis of absenteeism related to occupational injuries, we consider equally relevant the analysis of the magnitude and the determinants of presenteeism related to occupational injuries, which would lead the worker to return to work after an insufficient medical recovery time. These are issues that call for further and more in-depth research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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EMERG-ing data: Multi-city surveillance of workplace violence against EMS responders

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ABSTRACT

Problem: Between 1980 and 2021, emergency medical services (EMS) calls experienced a 421% increase, while calls for fires declined by 55%. The more exposure, the more the opportunity for workplace violence (WPV). Due to the non– existence of a reporting system that captures physical and verbal violence, it has been difficult to quantify the degree of WPV experienced by the U.S. fire and rescue service. *Methods*: To describe WPV in three large metropolitan fire departments, an existing data system was modified. The EMERG platform was selected because it is one of the most confidential data systems available to collect exposures. *Results*: In a one-year pilot of EMERG, 126 events were reported. Verbal violence was present in 81% of all reports, with physical violence only at 19%. Patients were the most frequently reported assailant (73%).The most frequently reported injury was emotional stress (70%). Six percent of all injuries reported moderate-to-major physical injury severity, and 30% reported moderate-to-major mental injury severity. *Discussion*: Verbal violence as a contributor to first responder stress is often underestimated. This pilot shows that it can and should be captured. That mental injury severity was consistently rated higher than physical injury severity across all injuries is not surprising given the prevalence of verbal violence reported and because physical violence has emotional sequela. *Summary*: Data from the EMERG reporting system give us evidence, on a larger scale than has ever existed for the fire and rescue service, that verbal and physical violence, and the resultant emotional stress and mental injury severity, is an issue that needs further attention and resources. *Practical Applications*: In order to ensure robust surveillance, it remains likely that triangulation of multiple data sources will still be required to approximate the true burden.

1. Problem

Systematic literature reviews (1978–2016) of violence against first responders using peer-reviewed and industrial literatures found that between 57% and 93% of Emergency Medical Services (EMS) responders reported having experienced an act of workplace violence (WPV) at least once in their careers (Taylor et al., 2017; Murray et al., 2020). EMS responders are workers with paid or volunteer EMS duties, including firefighters, Emergency Medical Technicians (EMT), and paramedics. Paramedics are EMS responders with additional education and advanced clinical skills.

According to Koritsas (2009), WPV has verbal and physical forms. Verbal violence is defined as using offensive language, yelling, or screaming with the intent of offending or frightening. Physical violence is defined as physically attacking or attempting to attack. It includes behaviors such as punching, slapping, kicking, or using a weapon or other object with the intent of causing bodily

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harm. It also includes property damage or theft (e.g., theft of the ambulance, medication bag), sexual harassment, and sexual assault (Koritsas et al., 2009). The World Health Organization (WHO) expands on this definition to encompass the physical and psychosocial impacts of WPV on employees, stating that violence can be an "explicit or implicit challenge to their safety, well-being, or health" (World Health Organization, 2002).

The National Fire Fighter Near-Miss Reporting System identified the most common mechanism of injury on EMS runs to be assault (Taylor et al., 2015). Acts of violence experienced by EMS responders have been described as "hit on the arm during a struggle," "punched in the eye," "jumped up and punched right in the face," and "head butted" (Taylor et al., 2016). While physical assaults are the most reported, systematic reviews of EMS responder WPV revealed that verbal violence is the most prevalent type of violence experienced, and patients being the most prevalent assailant (Taylor et al., 2017; Murray et al., 2020). Verbal violence is the most common form of violence experienced, but it is often not captured in formal reports because workplace incidents without a resultant physical injury are not covered by workers' compensation. Patient-specific predictors of violence include drug or alcohol intoxication, mental illness, and underlying health conditions (e.g., seizure, hypoglycemia; Taylor et al., 2015).

In 2021, the National Fire Protection Agency (NFPA) reported an estimated 72% of all emergency calls to fire departments were for medical services. In that year, there were 26 million EMS calls to fire departments, a 10% increase from 2020 (National Fire Protection Agency, 2022). The 911 system in the United States is strained by high call volume of non-emergent and low-acuity calls, which make up a large percentage of the workload for EMS responders. As a result of this tenuous system, EMS responders have reported high occupational stress (Cannuscio et al., 2016). Acute and chronic stress, including secondary traumatic stress (also known as compassion fatigue), can result in numerous health symptoms, including severe mental illness (van der Ploeg et al., 2003; Renkiewicz et al., 2022). Occupational stress also plays a contributing role in the high rate of suicidal ideation and suicidal attempts among EMS responders (Stanley et al., 2015; Stanley et al., 2016; Renkiewicz et al., 2022). Exposure to WPV, compounded by pre-existing and cumulative occupational stressors, can have a devastating impact on the physical and psychological health of EMS responders.

Past research has examined reports of violence by EMS responders with the goal of identifying trends in violent encounters. These involve short, post-call questionnaires (Grange & Corbett, 2009) or the examination of the Longitudinal EMT Attributes and Demographics Study II (LEADS II), which collected retrospective exposures to violence (Gormley et al., 2016). However, national violence reporting systems specific to EMS responders are not known to be part of fire and rescue infrastructure. We sought to investigate reporting of violence by modifying an existing confidential reporting system (EMERG) and piloting it with EMS responders in three large metropolitan fire departments. The goals were to: (1) capture reporting of both physical *and* verbal violence, and (2) analyze reported data to understand the incidence of WPV experienced by fire-based EMS responders.

2. Method

2.1. Partners

Three fire departments and their union locals participated in the study: International Association of Fire Fighters (IAFF) Local 58 and Dallas Fire-Rescue Department; IAFF Local 22 and the Philadelphia Fire Department; IAFF Local 145, San Diego Association of Prehospital Professionals (SDAPP), Teamsters 911, American Medical Response (AMR), and San Diego Fire-Rescue Department. This collaboration was part of a larger workplace violence study, the Stress and Violence to fire-based EMS Responders (SAVER) project (Taylor et al., 2019; Taylor et al., 2022; Murray et al., 2020). The EMERG aim of the SAVER study was union-led and department-supported, meaning unions took the leadership role in recruitment and retention because our previous research found that department members were more comfortable reporting injuries to their unions than to their departments (Taylor et al., 2016).

For the confidential violence reporting system, we partnered with the Center for Leadership, Innovation and Research in Emergency Medical Services (CLIR) (now part of the Center for Patient Safety, https://www.centerforpatientsafety.org/pso). CLIR was involved in several initiatives to improve safety culture, including an incident reporting system called Emergency Medical Error Reduction Group (EMERG). CLIR created EMERG to improve patient and provider safety by encouraging incident reporting, analysis, and sharing of best practices to improve the safety, quality, and consistent delivery of all emergency medical services. The EMERG reporting system was selected for use in the present study because it was a certified Patient Safety Organization (PSO), therefore all data submitted are protected under the Patient Safety and Quality Improvement Act of 2005, codified at 42C.F.R. Part 3, as "Patient Safety Work Product" and are privileged and confidential. This means reports from firefighters and EMS responders are anonymous and protected from discovery and punitive use.

2.2. EMERG Modifications

The existing EMERG reporting system was not specific to EMS responders, nor specific to violent event reporting. Modifications were made to the EMERG system that responded to the needs of the fire and rescue service broadly, and the participating study sites specifically. A diverse group of members from each study site, including leadership, union, paramedics, and dispatch representatives present at the SAVER Model Policy Collaborative (Taylor et al., 2022) contributed to the modification and refinement of the EMERG violence report. Emphasis was made to keep the report as similar as possible across departments to allow for detailed analysis, with small variations to accommodate differences in titles and roles between the departments, as well as other regional/local elements. Each study site was provided a secure, private, department-specific password enabled webpage containing the EMERG report. The only required field on the report was the narrative question "Tell us what happened." The report also collected voluntary information about the incident, assailant, victim, and injury type, cause, and severity. Please see the Appendix for the data collection instrument. The EMERG pilot began in December 2019 and ended in November 2020. This study was approved by the Drexel University Institutional Review Board.

2.3. EMERG data Management

The research team were made analytical contractors to EMERG. Upon completion of the Alliance for Quality Improvement and Patient Safety's Confidentiality Training (AQIPS; https://www.aqips.org/), they were permitted to extract each department's data for research purposes. Data from each department were tabulated individually and entered into a combined master dataset. De-identified summary reports were created and shared with the study sites at the end of each quarter. For Quarters 1–3, the number of reports per department were too small to guarantee anonymity, so an aggregate report was shared with the study sites. For Quarter 4, department-specific cumulative reports were developed. Prior to any dissemination of the quarterly reports, drafts

were reviewed by CLIR's legal counsel to ensure all necessary protections of the patient safety status were abided. All reports were inspected and approved for internal dissemination to the departments by CLIR's legal counsel. Departments were then provided the summary reports and discussions were held with the research team via video conference.

2.4. EMERG data analysis

EMERG reports were analyzed in Excel. Variables included the date and time of the incident, place of assault, method of violence, demographics, and injury type. Certain variables were manually coded. For example, the variable "method of violence" was comprised of multiple response categories (e.g., choked, grabbed, and slurs and hate speech) that would then be grouped together by three separate categories: physical violence, verbal violence, and both verbal and physical violence. Missing data were not imputed. Descriptive summary statistics and data visualizations were included in each quarterly and final report. When data were available, violence reports were cross-referenced with fire department's workers' compensation claims for violence-related injuries to evaluate the degree of reporting.

2.5. Health communications campaign and implementation

A comprehensive health communication campaign was developed for each study site. First, a communication needs assessment was completed by the primary labor union and department contacts to ensure that the materials, communication channels, and strategies would resonate with their membership. Next, messaging materials were designed to create awareness of the EMERG system and its protections, empower EMS responders to report all violence exposures, and communicate joint department and union support for reporting all episodes of verbal and physical violence from patients, families, and bystanders to EMERG – regardless of whether an injury occurred. Emphasis was placed on educating how verbal violence may lead to direct psychological outcomes and behavioral health impacts. At the start of each quarter, study sites issued a joint memo from the department's safety officer and/or EMS commissioner along with the union president to their membership to signify the importance of reporting to EMERG. Lastly, each department identified communication "champions" responsible for creating a culture of reporting and delivering encouragement reminders to members to report their exposures to verbal and physical violence. The champions also served as an internal feedback loop so that comments from the field and insights as to how EMERG and the message campaign was being received could be communicated to the research team. Membership feedback was an important element of EMERG reporting and contributed to the development and preparation of materials for the communication campaign, as updated communication toolkits were provided each quarter.

The communication toolkits were tailored to each department, developed in advance with input from the study site champions. In Quarter 1 (December 2019), departments were given a "launch box," containing instructional flyers, promotional flyers, and magnets. Materials were distributed and placed in high-traffic areas in stations, ambulances, and hospital EMS rooms. All materials were customized with QR codes and log-in information. The toolkit also featured a FAQ document for department champions and EMS field supervisors, who served a crucial role in empowering members to report their violent encounters. Departments were also provided a digital toolkit, featuring copies of all flyers, a social media campaign "Saturday Safety Tips," and videos from department and union leaders, department members, the research team, CLIR, and other industry partners. The digital toolkit became the primary method for disseminating communication materials in March 2020 at the start of the COVID-19 pandemic. Approximately five media elements were developed per department each quarter, totaling over 60 flyers across the entire EMERG campaign.

3. Results

3.1. Quantitative data

The EMERG reporting system received 126 violent event reports from three departments in one year. Assailants and responders were predominantly male, with assailants being slightly older on average (TABLE 1).

Since only the free text response was required, the total number of responses in each figure varies from the total reports received. The "Method of violence" category was filled in for 124 out of 126 reports (98%). Physical violence was present in 41% (n = 51) of reports, with "verbal only" (40%, n = 49) more common than "physical only" (19%, n = 24) [data not shown].

Eighty-two (82) injuries were found in 68 reports [Fig. 1a]. Emotional stress was the most common injury reported (n = 52). Six percent of all injuries reported moderate-to-major physical injury severity, and 30% reported moderate-to-major mental injury severity (Fig. 1b).

The case inclusion criteria for "physical injury only" required that the person sustained a physical injury alone or in combination with emotional stress. Of the 40 physical injuries reported, 10 had emotional stress also selected as a form of injury (25%). Looking at physical injuries only, 13% were determined to have physical injury severity from moderate-to-major, whereas 28% of physical injuries were reported as having moderate-to-major mental injury severity (Fig. 1c).

The case inclusion criteria for "emotional stress injury only" was if the respondent only reported one injury, that cause was emotional stress, and no other physical injuries were noted (n = 42). Looking at the mental injury severity ratings of emotional stress injuries only, 57% were rated as minor, 29% as moderate, and 5% as major (Fig. 1d). Across all injury types, emotional stress injury was rated as having higher severity than physical injury.

Patients were the most common assailant (73%, n = 90), and agitation and intoxication were reported as the top two underlying

Table 1
EMERG Report Demographics (n = 126).

AGE: average (range)		
Assailants	**Responders**	
45 (18–91)	34 (20–58)	Years
45	9	Unknown/missing
GENDER: n (%)		
Assailants	**Responders**	
91 (72.2)	93 (73.8)	Male
32 (25.4)	33 (26.2)	Female
2	0	Unknown/missing
JOB EXPERIENCE: average (range)		
Assailants	**Responders**	
N/A	10 (1–30)	Years
RACE: %		
Assailants	**Responders**	
2%	0%	Alaskan Native
3%	1%	Asian
43%	5%	Black/African American
1%	0%	Native American
16%	8%	Latino
4%	1%	Middle Eastern
1%	0%	Native Hawaiian
37%	78%	White
1%	1%	Choose not to say

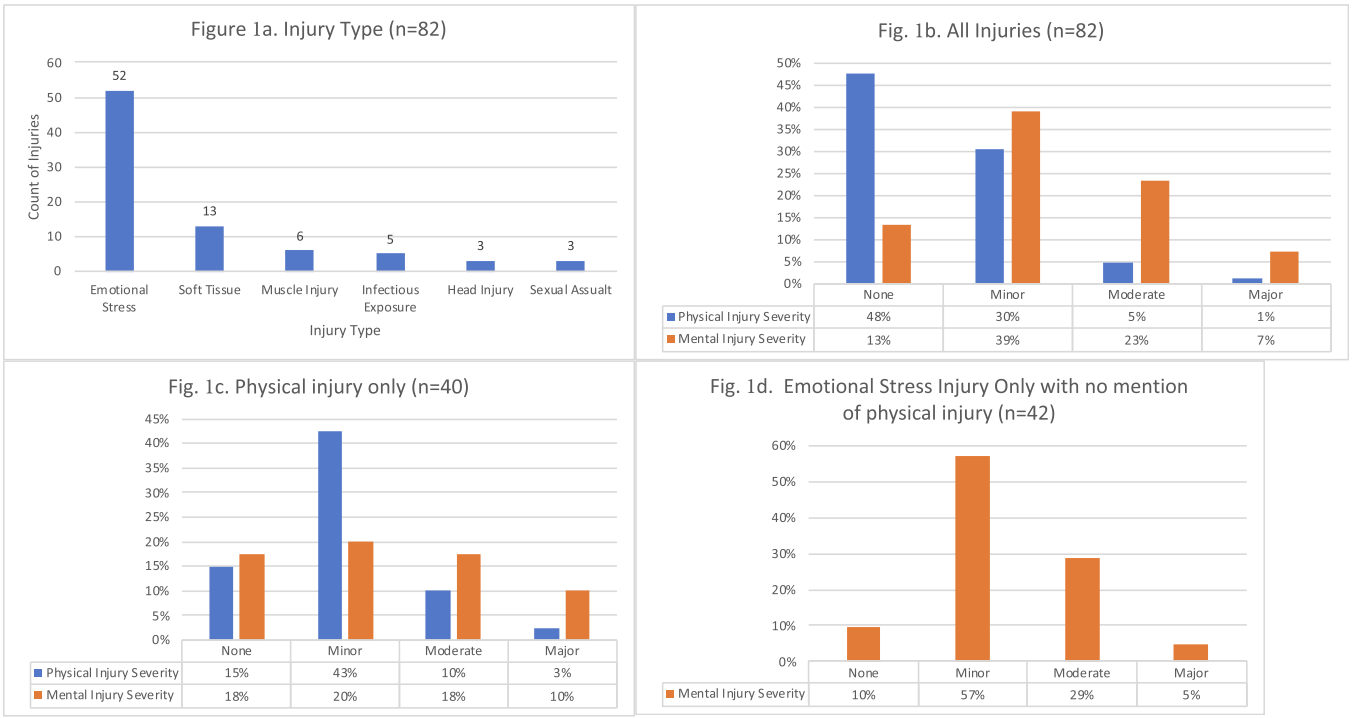

Fig. 1. Injury Type.

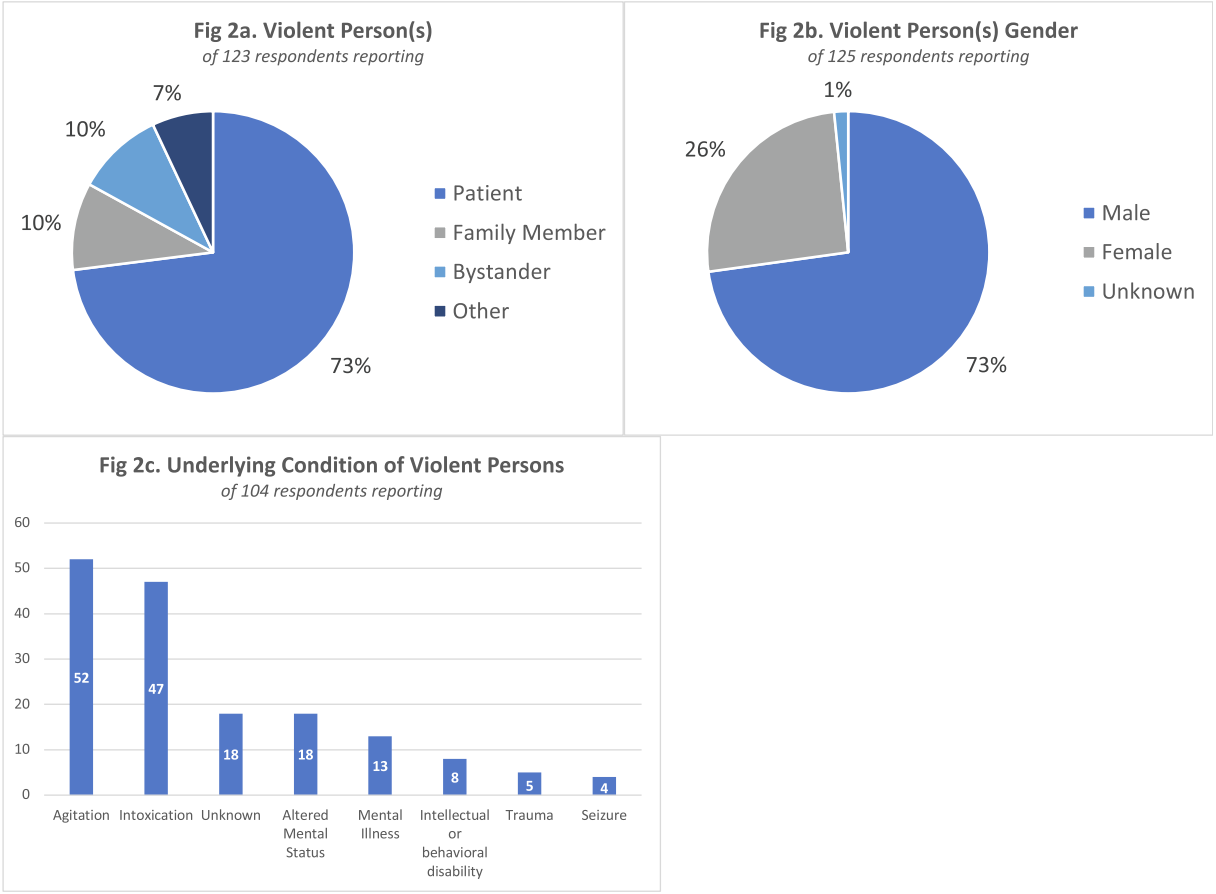

Fig. 2. Violent person type, gender, and underlying condition.

conditions related to violence against responders. Assailants were reported as male in 73% (n = 91) of responses (Fig. 2).

We asked the responders about notification of fire department leadership and law enforcement involvement regarding the violent event. Fifty-two (52) percent of participants did not report the violent event to their department (n = 64). Law enforcement was on scene 44% of the time (n = 54), and assailants were arrested in 16% of reports (n = 19) (TABLE 2).

3.2. Narrative data

Examples of free-text responses to the prompt, "Tell us what happened" describing the event are organized by type of violence (e.g., physical, verbal, both) in Table 3. This was a required field with no limits on word length and respondents were very detailed in their descriptions as the following example and Table 3 illuminate. Complete reports are available in the online Appendix (n = 126).

We were in transport to the hospital with an individual who was in custody for ingesting 40 g of heroin (per the patient and officer). We picked the patient up at the jail. The officer stated he was going to be following the ambulance to the hospital because he was a single officer in his car and no one else was available to ride in the ambulance. Prior to transport while still at scene with police, the patient was placed in soft restraints due to behavior and concern of EMS safety. The patient was moved to the ambulance where transport continued to hospital. Once the ambulance began traveling, the patient told me to remove the restraints. The restraints remained and were not adjusted. Patient was able to, at one point, unbuckle his shoulder straps. Once patient was able to unbuckle the straps, he leaned forward and began trying to bite the restraint knot on the gurney. Patient was stopped from this act. The patient was able to remove his legs from under the seatbelt buckle. Patient swung his legs over to the bench seat and was able to kick a pair of trauma shears loose from the bench seat seatbelt harness. This act, once noticed of what his intentions were, was also immediately stopped. Paramedic went to jump seat in the ambulance to stand by and monitor the patient. The patient was able to kick the IV tray and have items from the IV tray go loose. At this time, partner pulled the ambulance over and requested police. Partner came to assist me in the ambulance, and we noted the patient was able to gain control of a pair of scissors in the ambulance. A fight to seize the scissors from the patient began. The patient was in a sitting position on the side of the gurney with his legs off the side to his left. By now, the right arm restraint had broken and the patient had movement of his right arm freely, the strap on his left arm had pulled so hard that he had more movement to his left arm as well, unsure if the restraint on his left arm held up and kept him restrained. Once noted the patient had scissors in his hand, this was called out loudly in the back of the ambulance for the safety of my partner and I. A "cover now" was aired on the radio for immediate assistance from the police. Over four minutes went by before the first officer showed up at scene. Dispatch on the fire dispatch medical had to confirm our location, they also sent a "cover now" and officers to the wrong location as my partner and I attempted to restrain a patient with a deadly weapon. Patient held the scissors in an aggressive manner. I was able to grab one end of the scissors and repeatedly told the patient to release his hand but he did not. Patient was told several times to relax and cooperate and did not. This gives me the impression he had a high intent of harming either himself or EMS crew. Patient was placed in a carotid restraint by me in the ambulance and was controlled from there forward. Patient dropped the pair of scissors in the ambulance. Patient was controlled until police arrival at scene. Once the police arrived, they took custody of the patient. Medic continued transport of the patient to hospital where he was evaluated. Entirety of the call is all recorded on our monitor.*

*"Cover now" is a code used by the responder for immediate assistance due to imminent danger

We asked respondents, "In your opinion, what caused this violent event?" (Table 4) Thirty-seven (37) percent felt that the event was caused by the assailants's drug or alcohol use. EMS responders specifically noted "ETOH" (ethyl alcohol), PCP (phencyclidine) and K2 (a synthetic cannabinoid) as substances used most often among violent patients. Twenty-three (23) percent reported that the violent event was caused by the assailant's general agitation or dissatisfaction with EMS response, especially regarding slow response times or perceived low quality of care.

4. Discussion

The one-year pilot of the modified EMERG reporting system received 126 violent event reports from three metropolitan fire departments. Verbal violence was more commonly reported than physical and was present in 81% of all reports. As we have seen in our prior review of the scientific and gray literatures, verbal violence was the more common form of workplace violence experienced by this group of fire and rescue service members (Murray et al., 2020). Patients were the most common assailants, and their top two conditions were agitation and intoxication.

Of all injuries reported, emotional stress was the most common. This seems logical given the prevalence of verbal violence reported and because firefighters have previously reported that physical violence has emotional sequela (Taylor et al., 2016). Additionally, 25% of physical injuries also had mention of a concurrent emotional stress injury. Mental injury severity was consistently rated higher than physical injury severity across all injuries.

We include all narratives reported in an **online supplement** so that the scientific community and public may more deeply appreciate the lived experiences of those who respond to 911 calls. It is distressing to read these narratives and realize what EMS responders deal with every day. Multiplying each story with the increasing number of calls that EMS is running, it is very easy to visualize how this must be exacting an emotional toll. Violence should not be an accepted or expected part of the job, but it has been for decades. This study, along with the supporting scientific and grey literatures, supports the need for systems-level approaches to violence prevention in the fire and rescue service, with a focus on and primary prevention.

Table 2
Departmental Notification and Police Involvement.

	Did you report this incident to your department?		Was law enforcement notified of the incident?		Was law enforcement present on scene?		Was the assailant(s) arrested?	
	n	%	n	%	n	%	n	%
No	64	52%	51	41%	68	55%	88	75%
Yes	52	42%	67	54%	54	44%	19	16%
Unknown	7	6%	6	5%	1	1%	10	9%
Total	**123**	**98**	**124**	**98**	**123**	**98**	**117**	**93**

Table 3
Examples from EMERG Narrative Data by Violence Type.

Physical	Verbal	Both
"As we arrived, the patient reached down into the lifeguard's medical bag and pulled out a pair of scissors and began cutting himself, then standing up waving the scissors in a threatening manner towards the crews. Patient was agitated, erratic, not making sense or following instructions."	"After the run the patient was walking away the boyfriend walked up to the window of the rescue asking what the patient told EMS. EMS asked the patient to back up because he was not wearing a mask. The patient then states I am going to shoot you. EMS drove away from boyfriend."	"During transfer from wheelchair to gurney of a combative psych patient I was punched in the left jaw by the patient. He threatened to assault all personnel on scene and while I was trying to remove items from his lap so they wouldn't get dropped or broken during the transfer he swung on me and connected."
anywhere from 10 to 12 minutes."	outfit and letting his hair down so he wouldn't be recognized). I had to be escorted to my car because he tried following me to my car after work."	
chair, she grabbed my left forearm and scratched me, digging her fingernails in, breaking the skin and causing an inch-long laceration which bled. Patient continued to squeeze my arm and dig the fingernails in, causing further bruising. I was unable to remove her hand from my arm as I was lifting her."	the women until police arrived to assist. No physical assault occurred. This incident was the 5th in a string of verbal and physical violence related incidents I had in a one-month period."	security very loudly and aggressively."

Table 4
Provider Opinion of Underlying Cause.

Cause	n	%
Drugs/alcohol	47	37.30%
Blank	20	15.87%
Agitation/Dissatisfaction with EMS	29	23.02%
Unknown	13	10.32%
Mental health diagnosis	7	5.56%
Underlying medical condition	6	4.76%
Law enforcement presence	4	3.17%
Total	126	

There are limitations to consider with this study. First, nonresponse bias may be present, as those who reported to the system may have been more motivated to do so than colleagues who did not. Second, there were no restrictions implemented in EMERG to limit how many times an individual responder reported an event nor were there restrictions on how many responders could report the same event. Upon inspection of the narratives, we did not find any duplicate reports by the same person for one event, but we did observe multiple reports by different people of the same event. We estimate that this was less than 10% of all reports.

Third, most data elements were collected through predetermined checkboxes. Brief definitions were provided for each category. While there is always the possibility that respondents may not have understood the categories or definitions, this was proactively addressed by having each fire department contribute to the final data elements. EMS responders are used to filling out first report of injury forms with similar categories, in addition to being skilled healthcare providers, so we feel confident that they know the difference between emotional stress and head injury. For the same reason, we also feel confident that they can objectively approximate categories such as injury severity, despite the self-reported nature of the EMERG report and individual subjectivity of certain response categories. Additionally, the data captured the opinions and descriptions of the EMS responders, so there could be misclassification error in data on patient characteristics. Data were not linked to Patient Care Reports, which would have allowed for more detailed descriptions of the patient, their medical history, and medical treatment provided.

Lastly, as this was a feasibility pilot, the findings presented here are only representative of the three large-metropolitan department participants and are not generalizable to the United States fire and rescue service. Data that we collected for the last 10 years through our relationship with one of the three departments show an annual average of 5–10 workers' compensation claims for violent injury. With EMERG, even though it was a new system, we saw quadruple the number of reports in six months than we saw in one-year previously. In this department, the number of violent events reported to workers' compensation in 2019 was 24, while the number to EMERG was 47. Since we did not capture unique identifiers in EMERG, we are unable to discern why there was a difference in reporting. It may be that EMERG captured more events because it included both verbal and physical violence, whereas workers' compensation systems only capture injury from physical violence resulting in lost time.

Due to the non-existence of a widely available reporting system that captures physical *and* verbal violence, it has been difficult for researchers to quantify the degree of WPV experienced by the U.S. fire and rescue service. While there are limitations to this study, the findings are remarkable because we have collected the industry's largest sample of real-time verbal violence reports to date. This is significant because resources, both funding and otherwise, to investigate this issue are challenging to secure. Indeed, EMERG and the larger SAVER grant that the present study is seated within, is the very first FEMA-funded grant to address the EMS-side of the fire service. These data give us evidence, on a larger scale than has ever existed for the fire and rescue service, that verbal and physical violence, and the resultant emotional stress and mental injury severity, is an issue that needs further attention and resources.

The strengths of this study include the modification of an existing reporting system by the fire and rescue service for the purpose of workplace violence data collection. The strong understanding of EMS responders who participated in the pilot about the importance of reporting verbal violence showed that it can and should be captured. The communication campaign that emphasized the importance of reporting both physical and verbal violence likely strengthened EMS responder understanding of verbal violence and the need to report such events. We were glad to see this reporting outcome since violent events without physical injury are not captured anywhere. While we wait for the development of more inclusive violence data reporting systems, there are actions that unions, fire departments, and EMS agencies can take immediately to protect their members. The fire and rescue service developed SAVER Model Policies (Taylor et al., 2022) and Systems-level Checklist (Taylor et al., 2019), which are ready for implementation. These interventions are fire-service specific, but organizations that routinely encounter workplace violence (such as health care and education) could easily adapt them to their unique contexts. Any agencies wishing to receive help with policy adoption and subsequent evaluation are encouraged to contact the authors.

5. Summary

In one year of EMERG operation, we received 126 reports from three fire departments. Verbal violence was the most frequently reported type of violence (81%) and the most frequently reported injury was emotional stress (70%). A closer look at the method of verbal violence revealed general verbal violence (68%), verbal violence using slurs and hate speech (45%), and graphic threats (39%) as the top three types of verbal violence encountered. We wish to amplify the discussion of verbal violence in the results of this study because it is often underestimated as a contributor to EMS responder stress. While physical violence may make the front page of the newspaper, it is dealing with the day-to-day insults and slights that accumulate psychologically in an EMS responder's mind. These moral injuries may find their equivalency with physical injuries and in fact may exceed them in terms of their longevity and impact on performance. The results from the EMERG reporting system can inform estimates of workplace violence in the fire and rescue service, however, to ensure useful surveillance, it remains likely that triangulation of multiple data sources will still be required to approximate the true burden. It would be helpful if other national data sources collecting violence exposure data collaborate to harmonize their methods and data dictionaries.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix. SAVER EMERG Violent Reporting Form data elements

Question	Response Categories
EVENT DESCRIPTION	
Event description/details (free response)	• Tell us what happened: [text box] * • Incident # (from your CAD system): [text box] • Date and Time of Incident: [text box]
Phase of call when violence occurred (select all that apply)	• On scene • Medical Treatment • Transportation • Emergency Department • Other: [text box]
Place of assault (select all that apply)	• Ambulance • Fire Apparatus or Emergency Vehicle • Home or Residence • Street or Highway • Healthcare Facility • Nursing Home • Prison or Jail • Firehouse • Office Building • Bar or Restaurant • Arena or Sporting venue • Retail store • School • Homeless shelter • Industrial place and Premises • Park or Public Area • Lake, River, Ocean, Beach, or Bay • Other Location: [text box]
Method of violence (select all that apply)	• Verbal violence

SAVER EMERG Violent Reporting Form data elements (*continued*)

Question	Response Categories
	• Intimidation • Property damage or theft • Sexual Harassment • Sexual Assault • Human Bite • Spit at • Peed on • Push/shove • Kicked • Grabbed • Choked • Struck/punched • Weapon: ambulance equipment • Weapon: mace, pepper, chemical • Weapon: club, bat • Weapon: knife • Weapon: firearm • Weapon: explosive • Other: [text box]
Event address (free response)	If you would like to provide the address of the incident, please do so here: [text box]
Did you have prior knowledge of this being a violent location and/or person? (Choose one)	• Yes • No
Did you receive this information from: (choose one)	• CAD • Dispatcher • Law Enforcement • Previous experience with Patient or Location • Other
ABOUT YOU	
Practitioner level (choose one)	• Single Role Firefighter • Single Role EMT • Single Role Paramedic • Firefighter/EMT • Firefighter/Paramedic • Supervisor/Manager
Experience (free response)	• How many total years of Fire/EMS experience do you have? • How many years have you been in this department? [text box]
Gender (choose one)	• Female • Male • Other
Race (select all that apply)	• Alaska Native • Asian • Black/African American • Caucasian • First Nation/Native American • Hispanic • Native Hawaiian/Pacific Islander • Other • Choose not to report
Injury type (select all that apply)	• Emotional Stress • Burn • Chemical exposure, including mace/CS, drugs • Gunshot wound, blast injury • Head Injury/Concussion • Infectious exposure, any route • Muscle or joint sprain/Strain • Stab, puncture, impalement • Sexual assault • Smother/suffocation/strangulation • Soft tissue • Other

(*continued on next page*)

SAVER EMERG Violent Reporting Form data elements (*continued*)

Question	Response Categories
Physical Injury Severity (select all that apply)	• Minor (no care required) • Moderate (medical care received) • Major (hospitalized) • None
Mental Injury Severity (select all that apply)	• Minor (e.g., bothered me, but no big deal) • Major (e.g., interrupted my ability to work, more) • None
Event consequences (select all that apply)	• Loss of work time (temporary) • Reassigned to light duty • Permanent injury/disability • Job resignation/dismissal • Professional mental health counseling/care • CISM debrief/defuse • Assault charges or suit filed • Substance abuse • Loss or inability to sleep • Loss of appetite • Anxiety • Fear • Nightmares • Unknown at this time • No consequences • Other
ASSAILANT INFORMATION	
Number of assailants (free response)	• Number of assailants: [text box]
Assailant description (choose one)	• Patient • Patient's family/household member • Bystander • Other
Assailant age (free response)	• Assailant age: [text box]
Assailant gender (choose one)	• Female • Male • Undetermined
Assailant race (select all that apply)	• Alaska Native • Asian • Black/African American • Caucasian • First Nation/Native American • Hispanic • Native Hawaiian/Pacific Islander • Other • Choose not to report
If the patient committed the violence you experienced, what was their underlying medical condition or state? (Select all that apply)	• Diabetes • Altered state of consciousness/mental status • Agitation • Seizures • Intellectual or behavioral disability • Intoxication or substance abuse (drugs or alcohol) • Trauma • Mental illness • None known • Other: [text box]
In your opinion, what was the intent of the violence you experienced? (Choose one)	• Unintentional • Intentional • Unknown or Unsure
GENERAL INFORMATION	
Did you report this incident to your department? (Choose one)	• Yes • No • Unknown
Was law enforcement notified of the incident? (Choose	• Yes

SAVER EMERG Violent Reporting Form data elements (*continued*)

Question	Response Categories
one)	• No • Unknown
Was law enforcement present on scene? (Choose one)	• Yes • No • Unknown
Was the assailant(s) arrested? (Choose one)	• Yes • No • Unknown • Other: [text box]
Cause of event (free response)	• Provide your opinion as to the cause of this violent event: [text box]
Event prevention (free response)	• Provide any suggestions that would prevent another similar event

* Indicates a required field

Online Supplement_Narratives by violence type

Verbal Violence Only

1 In the back of the rescue during patient care initially patient was being non compliant with cops. After trying to talking with patient, patient was being noncompliance with ems by refusing to answer questions about demographics using vulgar language. After saliva splatter from pronunciation and apology that followed with it, patient then became angry. Explained to patient it was an accident. Threatened to attack patient once he gets out of hand cuffs. Delaying care when wouldnt answer questions about age for 12 lead by saying things about attending mothers age and genitalia. After refusing medication that delayed care, patient threatened to look up attending address and attack patient. When talking to police after dropping patient off, patient began to intimidate attending medic

2 Verbally assaulted by the operator of a vehicle involved in a traffic accident

3 Verbally assaulted multiple times, threatened with violence

4 Patient told me "f@$! You" when I attempted to get identification from her

5 A male resident became irate towards us after I asked patient if he used any drugs and/or alcohol tonight. Male resident made various threats towards us with some being sexual in nature. We left apartment swiftly and male continued screaming at us and as we were assessing patient in the safety of the ambulance that male came outside and screamed more violent threats at us.

6 Male patient became combative swinging arms and legs and making verbal threats towards me and others at scene. Patient was found unconscious with cyanosis, Narcan was administered and high flow O2. When patient returned to an alert status verbal and physical barrage occurred.

7 Received call for unresponsive male in auto on scene was found several people standing around a parked car as I approached the vehicle a Women who claimed to be an ER nurse said that the person in the car had OD just then the woman in the car got out and I asked her if she was alright and she said she was fine that she was sitting in her car waiting for her food order. I then said alright and started to walk away when the first woman got angry and said that's it your not going to do anything and I said first of all I don't know who you are and second there was nothing for me to do. Then she asked my name and said I would be hearing from a Battalion Chief. She was very angry I felt threatened by her actions. Again she said that I didn't know her but I would. The other woman got in her car because she was clearly afraid of the other woman and drove off.

8 Dispatched for a sick person. On arrival the patient said he wanted to go home, he said call me a fucking cab. We informed him we can take him to the hospital but we can't call him a cab. The patient stated "don't get wise with me mother fucker. I'm a marine and I will kick your fucking ass." The EMT calmly told the patient to calm down there is no need for that. That we are here to help him. He sat back down and did not speak until the arrival of the medic unit.

9 Father of patient verbally abusive and confrontational with engine company and medics. Crews remained professional and were eventually able to calm down father.

10 This afternoon one of my dispatchers received a 911 caller from a irate male asking her to tell him about "Frazzledrip." She wasn't familiar with the term and asked him for clarification. He began yelling and using foul language and requested the supervisor. At the time I wasn't available and she tried to get his information so I could call him back, he was barely listening to her and continued to yell, curse, and began using racial slurs including the N word. Eventually he disconnected the line. A couple hours later he called again and another dispatcher answered the phone and it was much of the same asking her about Frazzledrip, cursing and racial slurs. Fortunately I was available to take his call at this time once he was transferred to me it was more of the same. Just in case there was a possibility Frazzledrip was somehow fire related I did google the term while he was on the line. Once I realized it referenced political conspiracy theories I advised the caller that this isn't fire related which resulted in more slurs and verbal abuse and eventually he disconnected. He called back a short time later and again got a dispatcher who immediately transferred the call to me, and when I answered he disconnected again.

11 While assessing a patient we were approached and interrupted by multiple bystanders. We were victims of verbal abuse while caring for a patient.

12 Rescue was dispatched to a medical emergency. When we arrived we found a patient that was complaining of having a nosebleed.

(*continued on next page*)

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During assessment of the patient the patient got extremely agitated and continued to threaten to assault EMS crew for asking questions. Patient then started to urinate next to EMS and yell at EMS that he could do whatever he wanted. EMS tried to calm patient and further assess and treat him but patient continued to yell and threaten crew until he left the scene. No further assessment, treatment or altercations occurred after patient left scene.

13 Medic crew was dispatched for a seizure. Patient walked down in no distress. Told EMS and Engine crew he had abdominal pain. Upon asking questions related to why he said seizures. Patient said F You guys. Flicks us off and walks out of ambulance in no distress. Verbally abusing us and 911 system.

14 Responder was about to leave when a male employee approached the ambulance driver, causing him to stop transportation to the Emergency Room. The male employee appeared agitated informing the responder of how the paramedics did not get a temperature check when entering ‘‘His” establishment. Responder assured the male employee that emergency personnel, routinely and daily, check for fever, and that the responder was not aware of their own fever check routine. The male employee became agitated and accusatory, asking for quite a bit of information. Meanwhile, the paramedic, after realizing that they were not transporting the patient, went to the front of the ambulance to find out why the ambulance was not going to the emergency room for adequate patient care. At that time the male employee became even more agitated. After the paramedic advised the ambulance driver to proceed with transportation, the male yelled at the two medics, saying ‘‘Get the **** off my property. Take yall’s **** off my property.”

15 After the run the patient was walking away, the boyfriend walked up to the window of the rescue asking what the patient told ems. EMS asked the boyfriend to back up because he was not wearing a mask. The patient then states ’I am going to shoot you.’ EMS drove away from boyfriend.

16 Upon rejoining the medic crew the patient was muttering something. I told him ‘‘I don’t know what that means” and was immediately verbally abused with a profanity laced diatribe labeling me both ‘‘the devil” and ‘‘racist cracker”

17 Responder arrived on scene to find a female leaning on the bed dry heaving. As responder walked into the room her daughter told us she has had this before and that she has a ‘‘gastrointestinal thing” and ‘‘it’s worse than an ulcer.” Her daughter kept telling us ‘‘She needs to go STAT”. Responder attempted to ascertain more information from both the woman and her daughter to better understand her condition and how best to treat it. Her daughter continued to interrupt the responder saying ‘‘they don’t care about you”. She told us ‘‘she coded the last time this happened” and ‘‘That hospital can’t do anything for her, she needs to go to a different hospital.” Responder told her if her condition is that serious we would need to take her to the closest appropriate facility. Her daughter then got verbally aggressive with responder saying ‘‘you can get the f*** out of my house,” and ‘‘you are a racist son of a b****.” Responder was never even able to speak to the patient. Patient’s daughter chased EMS outside screaming once again.

18 Patient was verbally abusive to EMS. Patient repeatedly cussed at EMS during patient assessment.

19 Upon making patient contact the suspected patient began cursing and using racial slurs towards responders without provocation.

20 EMS was called for medical emergency by police at airport baggage claim. 3 EMS arrived on scene to find caregiver of patient very irritated and mad that EMS was called out. Patient has insulin issues and we were called for evaluation. Patient was alert and oriented he is not considered a patient at this time. Caregiver gave EMS and police very verbal abusive treatment to the needs and concerns at this time we together were verbally assaulted and made me feel insufficient towards work. Engine crew had patient sign and we left.

21 EMS was attempting to treat a patient w/ shortness of breath when the patient’s wife began to verbally abuse EMS continually interrupting EMS and shouting at EMS stating that we were refusing to help the patient. When asking for ID, the wife shoved it at EMS and yelled ‘‘There! Thats what you wanted!” When asked to please put out her cigarette due to patient’s shortness of breath, wife yelled at EMS ‘‘I can do what I want!!” and continued to smoke.

22 This call was a respiratory failure patient that coded on us before we could stabilize/transport. Throughout the incident, the patient’s wife, identifying as a former nurse, berated responders and repeatedly attempted to dissuade them from providing care in the field, per protocol. The woman did not respond to therapeutic speech or attempts to explain current resuscitation science, and threatened to ’make you regret it’, as far as not immediately transporting the patient.

23 Verbally abused by patient’s family because we took the patient to the closest facility instead of the hospital of his choice

24 Patient was cursing and threatening me

25 Patient verbalizing threats with racial slurs, aggressively charging towards EMS, spitting at providers

26 Patient stated I looked mean and called me a cunt. He repeated this 3x. I did not say 2 words to this man. He treated my male partner with respect and kept calling me names.

27 Verbal abuse from patient using profanity. Called dumb/stupid because of our routing to the hospital.

28 Patient verbally abused and threatened crew member. Patient stated he is going to crack crew member’s ribs and repeatedly calls crew ’stupid’and ’idiot’

29 While finishing up an against medical advice at the scene, a elderly woman who appeared homeless walked up and spat at the ambulance. As a crew we did not engage the woman. We left the scene and was dispatched to another call.

30 Responded to a man down in the alley - upon arrival found a male passed out drunk with a large pitbull - patient awoke and became agitated towards crews and non-compliant. Patient was intoxicated and was also aggravated at a bystander with two large dogs. He refused to comply and back down, yelling and acting irrational towards both my crew and the bystander. We found ourselves in the middle of the argument with the bystander. Police were not at scene. Patient had no chief complaint, he was only sleeping and etoh. Police arrived after calling for a no code cover and took the patient into custody.

31 Patient made several verbal threats against me and my partner. He was doing the same thing to the engine crew when we arrived to the scene.

32 When we were trying to ask the patient what was going on he would yell ’just take me to the f***ing hospital’ and called us a Motherf***er.

33 Responder arrived on scene to find a 52 year old male, lying in bed, complaining of lower leg pain in both legs for a week. Patient was alert to EMS and stated he had been to the doctor twice but they did not do anything and the swelling is getting worse and so is the pain. Responder evaluated patient. Responder offered transport to hospital. Patient's brother stated he wanted him to go to another hospital. Responder attempted to talk to patient and explain that we did not want to travel to hospitals further away when the patient's brother began yelling at us saying we did not want to take him to the hospital. Responder attempted to calm the brother down saying that we wanted to take him but the brother began yelling at us to get out. Responder attempted to speak to the patient but the brother continued to yell and curse at responder. Responder told the patient we wanted to transport him but the patient told us to leave because he did not want to argue with this broither. Responder attempted to speak to the brother so that could transport but the brother yelled for us to leave. Audio of the brother yelling was obtained.

34 My partner and I were verbally assaulted and threatened with physical harm by the son of our patient. No physical harm came to either of us

35 I'm reporting on behalf of one of our female employees. She was left a highly inappropriate note on her vehicle at her work station by an unknown person. It was sexually explicit and harassing which greatly upset her.

36 I noticed a women on the beach who hadn't moved her position of laying down all day, I asked a Park Ranger to check on her level of consciousness and he noticed she had several cans of alcohol by her side and the park ranger flagged down the Police Department. The Police notified me she was citied once early in the day for having an alcoholic beverage on the beach and the they would escort her off the beach. She than become verbally aggressive not only to me but as well as the police officers. She called me multiple derogatory words and complained for being disturbed on the beach. She called me a "bitch" and also stated, " That stupid, ass lifeguard needs to mind her own business". She was than escorted off the beach by police and was arrested on scene.

37 I received a 911 call in which the caller became very aggitated after being asked her phone number. Upon asking clarification as to why she believed the patient was on drugs, she began swearing at me and became verbally abusive in a continuous rant, and hung up before any description of the patient or triage could be conducted.

38 Patient was verbally aggressive with our crew. She cussed at us and threatened us. She took our cleaning spray and threw it outside the rig. She flipped tables and chairs over at the hospital. She charged at me and at hospital security very loudly and aggressively.

39 Patient was being verbally aggressive with police and medics. Patient called me a 'cunt'. Not cooperative with personnel.

40 We ran on a mixed race female after she was involved in an altercation. We tried to assess her injuries and she kept yelling at us to fix the situation. She repeatedly cut EMS off while we attempted to ascertain the extent of her injures, saying we weren't listening and what were we going to do about it. She then started acting like we were calling the cops on her with the intent of getting her arrested (our crew was all Caucasian). At one point she knelt down and put her hands behind her back despite us continuing to try and assess her physical needs. Eventually she just walked away...So basically she called us there, yelled at us, accused us of being racist, and then left.

41 Patient mother yelling at EMS and getting into EMS personal space. With patient on stretcher mother continued to increase verbal violence towards crew while physically barricading the door with her body but yelling at EMS to take patient to hospital.

42 The patient became violent and began to curse and threaten me. Saying "Fuck you, Imma get you touched you! What the fuck are you doin?" Finally, we got to the ER and went to place the patient in the bed in the hallway. Patient began to violently lash out at everyone, cursing and threatening me and everyone around him, "Imma get y'all touched, Fuck y'all! I'm from the streets! I don't wanna get in the bed, Imma sue the city." Patient said racial slurs at others. Patient almost got out of the stretcher threatening to hurt someone. Security was able to pull him back onto the stretcher. Patient continued to yell and curse at everyone for 10 mins.

43 Verbally abusive homeless person refused to leave train station by transit police. States unable to walk and forced EMS to carry him out. Walked without assistance once at hospital. Transit shut down all handicap entrances and exits. Transit police called EMS to clear homeless people from train station.

44 A homeless person with no apparent life threatening illness refused to walk upstairs for police. Person told police to "get that chair the ambulance has". No elevator access was available to get to the patient. Police advised patient be carried up the steps. Ladder crew called to assist medic unit to carry person up 3 flights of steps. The ladder captain called for a transit supervisor to come on scene to figure out why the train station has no elevator access and why station was fenced off from entry. Patient was verbally abusive to EMS and self ambulated himself in triage at hospital.

45 Patient was extremely belligerent towards crew.

46 Medic unit responded to a sick female, Ladder company also responded for forced entry. After Ladder made entry into patient's apartment, EMS made patient contact. Patient was sitting upright unassisted. Patient complaining of right arm and right leg numbness following a flu shot. Once fire personnel left scene patient began insulting EMS crew. Patient demanded EMS crew find multiple different wigs and clothes and demanded EMS dress the patient. Patient states they urinated on themselves and the floor so EMS needed to clean it. When EMS explained they would cover the patient appropriately with sheets while moving them to the ambulance the patient lashed out calling EMS unprofessional and ignorant. Patient stated EMS was there to do what she wants. Patient states they are unable to walk or move limbs however they are able to bear weight, pivot, use cellphone, etc without issue. While attempting to obtain demographic information patient was extremely hostile and belligerent towards crew. Patient transported to hospital without complications. Upon arrival patient expressed she was very displeased with the hospital she was taken too. Patient care and report given to ER nurse and ER Dr.

47 A large crowd was cursing at Ladder company and Medic unit, threatening them while trying to tend to a patient

48 Lifeguard co-worker and I noticed a surfer under the pier. I asked to go out and make a warning but was told to stand-by so the Main Tower could contact him with a PA over the intercom. The surfer seemed to not hear the PA or ignored it because he

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continued to surf waves in the swim zone. The main tower than dispatched a downstairs guard to contact him on the board but by the time they got out on the board, the surfer made it into the designated surf zone. Approximately 15 minutes later the surfer started paddling back north into the swim zone making his way towards the pier. My lifeguard co-worker asked me to contact the surfer to inform him of the rules of the surf and swim areas. I took out my rescue board and paddled out to contact the man. As I approached him, I waved him towards me to notify him that I was trying to speak with him and he yelled, 'I know what I'm doing! I approached him closer and when I was a few feet away I stated, 'Hi Sir, did you happen to hear the PA earlier?' I could immediately tell he was agitated, and he aggressively stated, 'Where the fuck are you from? You have no idea what the fuck you are talking about. I have been surfing here for (some amount) years!' At this point we were both laying prone on our boards with my board pointed at a right degree angle towards his, I noticed I was getting close to hitting his board so I sat up to turn counter clock wise but the nose of my board swiped the right rail of his board. I stated,'Sorry about that sir' and he became increasingly angry and aggressive with his body language and tone. He sat up on his board, lunged with his body as if he was going to swing at me and pointed at me saying, 'That's fucking assault, you just assaulted me you stupid bitch, I'm going to press charges against you bitch'. In hopes of deescalating the situation I replied to him saying, 'Sir please calm down, I'm not trying to cause an issue. He continues on insulting me, by saying things like 'You're an asshole I'm going to sue you', 'You fucking bitch, you just assaulted me', 'I'm pressing charges against you', all while physically pointing at me and being very aggressive with his body language. At this point I raised my hand into the air for assistance in fear that he may become physical with me in some way. I heard the Main Tower say something over the intercom and I immediately decided to paddle back into the beach on the board. As I was paddling away I could hear him continuing to curse at me. I retreated to my tower and met with crews to assess the situation. The surfer than continued to paddle to the North side of the pier, a different unit handled the situation from there.

49 I asked the caller on the phone to verify her address. She then got upset and stated I was yelling at her and was rude and continuously screamed profanities at me. I attempted to continue on with the call, however, the caller continued to cuss at me and eventually hung up without getting through to the triage questions. She then called back multiple times but hung up before anybody was able to get any information.

Physical Violence Only

1 PCP patient spit in my face as he was being loaded into ambulance on stretcher
2 Patient punched me in face as we tried to place him in the stair chair. Male was intoxicated.
3 Patient intentionally coughed into my face several times
4 Male high on k2. Rolling around in street. 2 female medics together. Bystanders had to help us get him on the stretcher. While he was throwing himself around he kicked me in the face. Once in the squad he spit multiple times on the floor and back doors. He had to be restrained at the hospital
5 Entered a home for a pregnancy/miscarriage to find a patient in bed with a large caliber handgun in bed next to them. This house is a known drug house. Police were not assigned or at scene of this incident. Patient did not threaten to use the weapon on us, but it surprised us all and made us very uneasy because we all realized that if she had wanted to she could have easily used it against us and we would have been defenseless. We removed the patient from the room to ambulance as quickly as possibly and departed scene due to several other individuals in the home that were acting suspicious of our presence.
6 While transporting a lucid post seizure patient, the patient turned towards me and stated he wanted out of the ambulance and began to punch me in the face and continue to hit and attack me. I was able to get on top of the patient and restrain him until my partner and assistance arrived.
7 While in the observation tower, I observed a male citizen lying on his side, high and dry on the rocks at a specific beach. The citizen was continuously swinging his arm against the jetty rocks. I sent a Lifeguard Unit to investigate the disposition of the person, aware that it could be a psychiatric patient. Unit responded and made contact with the citizen then requested medics and police to respond because the male was altered. An additional lifeguard responded to back up the unit. They gained general compliance and walked the patient to the unit. While sitting on the tailgate, the male attempted to get up. At that time, our lifeguard stood in front of him and directed him to stay seated, advising he had nothing to worry about. At that time, the male remained seated, put his arms behind his back, then rocked forward to stand up. The male swung and missed with his right hand, then swung with his left and struck our lifeguard on his right cheek. There was a large amount of blood on the male's fist that made contact near our guard's mouth. The male continued to go after guards while they maintained safe distances. Police elevated their response to Code 3 until the male began to walk south bound and was not an immediate threat to lifeguard safety. Police responded and detained the male on the beach and remained combative throughout the assessment and transport. The medic unit transported to the hospital, accompanied by PD.
8 While on scene of a medical aid for a patient under the influence of alcohol the patient punched my firefighter/paramedic in the stomach while helping the patient to the gurney.
9 Patient grabbed/struck my face while securing her to the gurney.
10 Male patient covered in vomit from presumed overdose became combative flailing arms and legs, to the point of striking EMS providers to the point where he was sedated and chemically restrained during transport
11 A possibly high female became combative outside of her residence. She hit and kicked us. We had her on the stretcher and had to restrain her until help arrived out of fear for our and her safety. During that time i repeatedly was kneed in my torso over several minutes.
12 Medic crew was physically assaulted by a male patient found down on the street after smoking PCP
13 While assessing a patient who was intoxicated and involved in a motor vehicle accident, he grabbed my butt. He also attempted to grab my breast after that incident
14 While responding to a 911 call, a presumed homeless man threw a decent sized rock estimated the size of a closed fist at our ambulance. The vehicle struck somewhere on the ambulances front right side.
15 We responded to a parking lot for a 30s year old male that was unconscious on the ground. Security guard at scene reported to us

that he had seen the patient drinking alcohol throughout the day. When we got to scene we attempted to arouse the individual using verbal and painful stimuli. Patent responded by making grunting sounds. We proceeded to take vital signs as the ambulance arrived. We loaded the patient on to the gurney by lifting him and he began to speak and complained that his knee hurt. In the back of the ambulance he became more agitated so we attempted to calm him and explained to him that he can leave if he wishes. He eventually exited the rear of the ambulance, extremely agitated and verbally assaulting crew on scene. He then started moving towards two of the crew members who were attempting to calm him down. He got within arms reach and appeared as if he was going to physically assault the crew members. Crew members brought him to the ground and restrained him until police arrived. Patient was transported to the hospital with police officer and fire department personnel restrained, and continued to be aggressive and verbally assault crew members.

16 Medic crew was responding to a level one, code response call, when a male made a running start and threw, a beer bottle at our moving apparatus.

17 Medic crew arrived at emergency room to take patient to another facility for further care with dementia and weakness. On scene CNA notified EMTs that patient was previously combative. RN also stated patient was combative. Patient sheeted to gurney. I was bucking in it to gurney when he kicked me in the abdomen.

18 Altered and restrained patient after using unknown drugs and being awoken by narcan: patient grabbed my hand with a restrained hand and squeezed my fingers awkwardly. Almost broke a finger but luckily squirmed out of his grip. Then patient sat up abruptly and headbutted my shoulder while we were still restraining him. No lasting injuries sustained.

19 My partner and I were wheeling in our patient into the emergency room when we passed by a guy who was verbally assaulting someone with security behind him. The person waited for me to pass then shoved me on my left shoulder causing me to let go of my gurney at that moment I turned around and shoved him back and security took him to the ground.

20 Patient was given Narcan. Patient became increasingly verbally abusive towards EMS personnel. Patient began throwing equipment at EMS and police was on scene when called over to the rescue they arrested the patient for a parole violation.

21 A male patient repeatedly hit on me while I was doing my medical assessment and treating his hypoglycemia. He continued to make uncomfortable sexual comments even after his sugar was raised to within normal limits.

22 I was assessing an elderly lady with dementia who was agitated and combative. I needed to dress the patient and lift her onto the stair chair. The patient was very agitated when I dressed her, grabbing and pinching my arms and hands, and trying to hit me. When I lifted the patient into the stair chair, she grabbed my left forearm and scratched me, digging her fingernails in, breaking the skin and causing an inch long laceration which bled. Patient continued to squeeze my arm and dig the fingernails in, causing further bruising. I was unable to remove her hand from my arm as I was lifting her.

23 I got punched a couple of times in the stomach and chest in the back of the ambulance by a combative patient.

24 Engine crew responded for a patient at the lifeguard tower who was feeling suicidal. Police were not at scene yet, only lifeguards. As we arrived, the patient reached down into the lifeguards medical bag and pulled out a pair of scissors and began cutting himself, then standing up waving the scissors in a threatening manner towards the crews. Patient was agitated, erratic, not making sense or following instructions. The lifeguard at the scene was able to place handcuffs on the patient while we called for a "cover now" for police. No crewmembers or lifeguards were injured.

Both Verbal and Physical Violence

1 Patient was outside in the middle of the street attempting to physically assault random people as well as verbally attacking them. Police were called and attempted to calm the patient with no success. EMS was called for a male high on narcotics. The male was walking all around in the middle of the street yelling and screaming in Spanish. Once in the ambulance and on the stretcher, the patient began spitting at crew members, pinching, and began kicking and swinging his arms towards police and EMS. The patient continued to scream and yell. Police rode with patient and EMS to hospital for safety.

2 Intoxicated female kept trying to bite EMS, biting one provider without breaking the skin. Also she kept threatening to throw up on crew. Also verbally abusive

3 Male patient was aggressive and violent towards EMS. Base command contacted and patient was given a sedative to calm him and help us get him out of the facility. Patient then began sexually harassing me. He was very graphic and then threatened to grab and touch me in a sexual manner. Patient had to be physically restrained for my safety. During entire ride to hospital and in ER patient continued to sexually harass me.

4 Family and friends of patient became violent with EMS on scene while providing emergency treatment for seizing patient. While treating patient in hotel room family yelled at EMS, pushed between EMS and seizing patient and made verbal threats. Once patient was treated she began spitting at EMS and family verbally threatened violence again toward EMS. While attempting to extricate patient from hotel family pushed EMS and Fire crew while attempting to pull patient off stretcher. Once EMS left scene three cars with family members attempted to follow medic unit while operating at emergency speed. Family ran red lights and stop signs chasing ambulance.

5 Was open hand slapped by an intoxicated patient. No injuries

6 An intoxicated woman wanted to kill herself. She was insulting my partner and being aggressive. Once calmed down patient was moved to the truck and placed on the stretcher. During transport she pulled out a switch blade style knife. No one ended up getting hurt because knife was taken away.

7 Had to restrain a patient that was violent and combative towards EMS and police. Patient was also verbally abusive towards EMS

8 Medic crew verbally assaulted and spit on by assault victim.

9 We were in transport to the hospital with an individual who was in custody for ingesting 40g of heroin (per the patient and officer). We picked the patient up at the jail. The officer stated he was going to be following the ambulance to the hospital because

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he was a single officer in his car and no one else was available to ride in the ambulance. Prior to transport while still at scene with police, the patient was placed in soft restraints due to behavior and concern of EMS safety. The patient was moved to the ambulance where transport continued to hospital. Once the ambulance began traveling, the patient told me to remove the restraints. The restraints remained and were not adjusted. Patient was able to, at one point, unbuckle his shoulder straps. Once patient was able to unbuckle the straps, he leaned forward and began trying to bite the restraint knot on the gurney. Patient was stopped from this act. The patient was able to remove his legs from under the seatbelt buckle. Patient swung his legs over to the bench seat and was able to kick a pair of trauma shears loose from the bench seat seatbelt harness. This act, once noticed of what his intentions were, was also immediately stopped. Paramedic went to jump seat in the ambulance to stand by and monitor the patient. The patient was able to kick the IV tray and have items from the IV tray go loose. At this time, partner pulled the ambulance over and requested police. Partner came to assist me in the ambulance and we noted the patient was able to gain control of a pair of scissors in the ambulance. A fight to seize the scissors from the patient began. The patient was in a sitting position on the side of the gurney with his legs off the side to his left. By now, the right arm restraint had broken and the patient had movement of his right arm freely, the strap on his left arm had pulled so hard that he had more movement to his left arm as well, unsure if the restraint on his left arm held up and kept him restrained. Once noted the patient had scissors in his hand, this was called out loudly in the back of the ambulance for the safety of my partner and I. A cover now was aired on the radio for immediate assistance from the police. OVER FOUR MINUTES WENT BY BEFORE THE FIRST OFFICER SHOWED UP AT SCENE. Dispatch on the fire dispatch medical had to confirm our location, they also sent a cover now and officers to the WRONG LOCATION as my partner and I attempted to restrain a patient with a deadly weapon. Patient held the scissors in an aggressive manner. I was able to grab one end of the scissors and repeatedly told the patient to release his hand but he did not. Patient was told SEVERAL times to relax and cooperate and did NOT. This gives me the impression he had a high intent of harming either himself or EMS crew. Patient was placed in a carotid restraint by me in the ambulance and was controlled from there forward. Patient dropped the pair of scissors in the ambulance. Patient was controlled until police arrival at scene. Once the police arrived, they took custody of the patient. Medic continued transport of the patient to hospital where he was evaluated. Entirety of the call is all recorded on our monitor.

10 We had to support a police officer who was engaged in hand to hand combat with a large drunk man. Man kicked my captain, captain fell onto his back. We all submitted the man. He repeatedly cursed at and threatened us from that point on. He went so far as to insist he'd remember our faces and attack us in the future.

11 While transporting a patient, he became verbally aggressive with me yelling profanities. Patient began to show signs of physical aggression. I dropped the head of the gurney to prepare to better control my patient when he swung his left hand upwards punching me in the face. Patient knocked my glasses and hat off me and it knocked me back into the captains chair. I immediately began trying to control and restrain my patient with my partners help until help arrived.

12 Units were called to a street corner for an intoxicated male with lacerations from punching parked vehicles. Patient was calm and read directable on scene no violent threats or behavior. Patient made comments about disliking female interns face and became violent punching and biting crewmembers. Cover now was called took three crewmembers and police officers to restrain patient.

13 Engine and medic unit were dispatched to a report of an unconscious person, intoxicated, next to a running vehicle in the alley. Engine crew made contact and the patient became combative and began swinging and kicking us. He was too drunk to get up on his own, so we backed off and decided to not touch the patient until police arrived. Due to poor communication between fire dispatch and police dispatch, police were never notified we were in the alley. After 10 to 15 minutes of waiting police arrived to assist. Once police stood the patient up for us to assess and move him to the gurney, he became extremely combative. Punching, kicking, spitting on police crews and medic and engine crewmembers. It took 8 of us to subdue the patient until police could handcuff him.

14 Wife accessed 911 for her husband who was on a four day 'alcohol binge.' Upon arrival, the patient threatened us if we didn't leave him alone. He advised us that he could open the door and get his weapons or have his dog attack us. We advised him that we had a legal obligation to treat him medically and that it was his wife's wish. As soon as we attempted to move him, he attacked us. We swiftly restrained him and called for police back up. While we were awaiting the police, he managed to bite and chew through the restrains.

15 As we attempted to assess our patient, the patient became verbally agressive and swung his arm at us as he yelled "Don't fucking touch me." We backed off and requested cover from police. Patient eventually eloped without further incident as we awaited police. We have a past history with this patient. Two months prior he threatened to kill us and we ended up in a physical altercation with him that included punches, kicking, and spitting.

16 Intoxicated patient was verbally abusive, became physically combative, and threw an empty liquor bottle at us without hitting anyone.

17 EMS arrived on scene to a male that has called EMS several times, mostly for arm pain received in an alleged work incident multiple years ago. Wife of patient is always on scene, and she is always very nice and very helpful. EMS did a full assessment on patient and when we told him his blood pressure, he said "check it again, that ain't what my machine said." EMS explained to patient that we did a manual blood pressure which is the most accurate. Patient became very agitated and began yelling curse words and racial slurs at EMS. EMS tried to calm patient down but he just became more angry, making violent threats towards medics and telling us to get out of his house. Patient continued yelling threats and racial slurs as EMS left. EMS called supervisor who met us at location and witnessed some of the behavior. Wife on scene also backed EMS stating that the patient started cursing and threatening EMS and was not provoked by EMS at all.

18 Male who was presumably intoxicated and under the influence of illegal substance was lying on train tracks. In an attempt to move him to safety, the individual began to kick and punch at our engine crew. Due to the safety for the patient and our crew he was wrestled to the ground to await for police.

19 This call was a response to an adult male high on 'wet' (cigarettes dipped in embalming fluid). We arrived to find this individual acting bizarrely. When we attempted to approach the male to make contact, he became agitated and charged at us, attempting to grab us. We avoided injury and requested police assistance. Shortly after police arrived the man fled the scene
20 Verbally and physically assaulted by intoxicated patient.
21 I was kicked in the face by a patient (on the ambulance) suspected to be on PCP. The patient was being brought in by another crew and I went to assist them as they asked for help. I had seen the patient for a minute before I was kicked.
22 Early Saturday morning on March 28th we responded to a house fire. With a report of an occupant still on the second floor. While attempting to get to the top of the steps and search for the occupant, the occupant himself tried to climb the steps and get upstairs to impede firefighting efforts. I told him he needs to go outside and let us do our jobs. With that said, he bull rushed me dislodging my mask and helmet and proceeded to fight me at the top of the steps. Where I was is known as above the smoke line, blinded by smoke, my dislodged mask, and helmet for anywhere from 10 to 12 minutes. I had minor smoke inhalation and some bruising to my cheek where the mask and helmet were dislodged. The occupant was below the smoke line. I was treated at the hospital and released the same day.
23 The patient admitted to alcohol use. The patient was combative while the crew was trying to help her to the ambulance with police. My partner was almost bitten and I was hit and scratched.
24 Patient was combative, kicking his legs and swinging his arms, cursing at EMS
25 A transient tore out a bush and used it to threaten my coworker and I. He was trying to intimidate us. We were just trying to get him to leave. He asked us very racially insensitive questions and pointed the tree branch at us saying he could use it as a weapon. He postured in my face saying he should knock my teeth out. I said I wouldn't go anywhere until he left. My partner came closer to back me up and he left while yelling expletives at us.
26 We had a patient spit at us during a medical aid. Her boyfriend had Covid symptoms and was in close contact with a coworker that was Covid positive.
27 During transfer from wheelchair to gurney of a combative psych patient coming out of a skilled nursing facility I was punched in the left jaw by the patient. He threatened to assault all personnel on scene and while I was trying to remove items from his lap so they wouldn't get dropped or broken during the transfer he swung on me and connected.
28 Called to private residence for a possible seizure. Patient was found down in bathroom, combative. Both crew members punched and kicked multiple times. Patient required 6 people to be fully restrained.
29 A member of the public was sexually harassing me for an hour. I asked him to leave several times, but he did not. I finally asked him to leave raising my voice and he began to shout at me, rubbing his genitals and came inches from me until another beach patron intervened to protect me. The cops were called, but they immediately released the man harassing me. He then began to stalk me the rest of the day while I was working (after changing his outfit and letting his hair down so he wouldn't be recognized). I had to be escorted to my car because he tried following me to my car after work.
30 Me, nothing. But my crew was involved in an altercation on scene of a motor vehicle crash.
31 Arrived on scene with police already talking with patient. Patient willing got into back of ambulance to be further evaluated. Once in back of ambulance. Patient became extremely hostile. Screaming at both myself and my partner. Patient stated, 'Fuck you and the police!' After that we explained that we are here to help and we asked her to calm down. She started swinging her arms and asked to leave the ambulance. I got out of the ambulance and watched her sit on the sidewalk until her girlfriend came and picked her up.
32 Person pulled knife on EMS while trying to secure him into ambulance
33 Aggravated assault by a patient high on PCP and pulled me from my ambulance. I was forced to defend myself and what followed was i was spit on twice, hit, scratched and bitten. I defended myself and my partner till law enforcement officials arrived.
34 Crew involved in verbal altercation with a patient, patient exited vehicle. patient returned and threw a chair at ambulance's passanger window shattering window.
35 I was attacked, punch in the ears with a cellphone
36 Patient on mentally disordered involuntary hold (5150) became combative. She then threatened to shoot me multiple times when she got out of the hospital.
37 Patient was agitated and combative, tried to bite, kick, hit, and spit on crews. Patient kept telling crew members they were raping her because she was being physically restrained. Patient kept calling transport crew, fire crew, and police, 'rapists.' Patient was oriented enough to ask that her restraints be removed, but kept yelling, swearing, verbally abusing, and trying to assault and batter ambulance and fire crew.
38 Patient made sexual advances towards EMT partner and yelled obscenities as well as stuck fist in my face
39 While working as a paramedic on an ALS ambulance, we had a female patient who threatened myself and the Mobile Intensive Care Nurse, charged at my EMT partner, threw ambulance equipment out of our ambulance, and flipped a table inside the emergency department waiting room hall. Patient made comments of a possible attack on ambulance personnel while 'walking from the ambulance to their car.' Patient has history of schizophrenia.
40 Pt became violent in the back of the ambulance without warning and attacked crews, kicking, spitting, hitting, wrestling.
41 Called to a private residence with a man in 80's who was behaving erratically and threatening his daughters. While assisting patient to gurney after explaining that he had to go (with assistance of police) patient struck me with hands and feet. Restrained patient in soft four point restraints shortly thereafter
42 I was verbally assaulted and my partner was sexually harassed.
43 Attacked with object, punched in the face 3 times, and bit on hands and legs.
44 Patient attempted to punch EMS provider when attempting blood pressure assessment.
45 Patient threatened provider with death and bodily harm and then patient attempted to assault providers

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46 Dispatched to intoxication with fall. Throughout contact, patient verbally harassed EMS and fire crews. While in the back of the ambulance, patient threatened to physically harm paramedic, and shortly after attempted to punch medic in the arm.
47 I've noted/noticed that near EVERY contact with the public can go sour more quickly than in the past years. I would not know the exact cause; as I vary my approach with each contact, depending on the situation/violation. I see not just "entitlement..." but open defiance. I expect one per day at this point, but many times it's been multiple events of racial slurs ,threats, non-compliance/ aggressive behavior, taunting, spitting. I'm aware that I "present" in a certain manner, (white male/bald/2010lbs/50's) so I vary my initial contacts; hands in pockets, removing my sunglasses/hat, a "greeting" and introduction. In general, I'm aware of the weight I carry so I tend to tread lightly. There have been several times/events that I was unable to use the bathrooms in a particular response area for fear of my safety.
48 Our patient we picked up from a private residence upon assessment, throughout medical treatment and during transport he made sexual advances towards and asked me if he could "put his Dick in my pussy, and did I want his tongue in my pussy". Then I asked what his birthday was for demographics and he stated "your mom" and then proceeded to say similar things as in "your mom loves my dick, she let's me 69 her all weekend". Etc.
49 Because of COVID we are treating stingray patients outside of the tower. I had a female patient wearing a bikini towards the end of the evening. Her female friend was with her. First an old man got himself involved by asking us for more water. I realized he was just trying to talk to the girls so I told him to go away. He stayed very nearby until I again told him to get lost. A couple minutes later a younger guy was inserting himself in between the patient and myself. I asked if he was a friend of the patients and he nodded and said, "Yeah." The patient and the female friend quietly shook their heads, "No." So I asked the female patient directly, "Do you know him?" She again quietly shook her head "no." So I got assertive and told the guy to get lost. He immediately became enraged and started yelling at me. He said, "What are you, gay?" So because I knew he was trying to insult me, I responded, "Super!" Then he called me homophobic. Which makes no sense at all so I just looked at him. He kept shouting so I kept pointing away from us and telling him to get lost. He pointed at me and made a fist and punched his other hand several times and pointed at me again. He did leave but it was pretty exhausting to have to keep creepy guys away from my patient and her friend.
50 Went to cite someone for failing to supply a personal flotation device to a baby on a water bike rental. Owner and his partner were non compliant, verbally abusive, and eventually physically assaulted 3 of my coworkers.
51 Patient yelling racial slurs, shoving and trying to force EMS away from him

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Exploring bias in incident investigations: An empirical examination using construction case studies

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ABSTRACT

Introduction: Incident investigation is a foundational tool of safety management. Determining the causal factors of any incident underpins organizational learning and subsequent positive change to processes and practices. Research of incident investigation has largely focused on what information to collect, how to analyze it, and how to optimize resultant conclusions and organizational learning. However, much less attention has been paid to the process of information collection, and specifically that of subjective information obtained through interviews. Yet, as all humans are biased and can't help being so, the information collection process is inevitably vulnerable to bias. *Method:* Simulated investigation interviews with 34 experienced investigators were conducted within the construction industry. *Results:* Common biases were revealed including confirmation bias, anchoring bias, and fundamental attribution error. Analysis was also able to unpack when and how these biases most often emerged in the interview process, and the potential consequences for organizational learning. *Conclusions:* Being biased to a certain degree will remain inevitable for any individual, and therefore, efforts to mitigate the effects of biases is necessary. Practical Applications: Increased awareness and insights can support the development of processes and training for investigators to mitigate its effects and thus enhance learning from incidents in the field prevent reoccurrence.

1. Introduction

Conducting effective incident investigations has long been recognized as a vital means of improving safety within organizations. Investigations are necessary to ensure learning from incidents and to prevent reoccurrence by making continuous systemic improvements (Jacobsson, Ek, & Akselsson, 2012). Typically, the investigative process consists of collecting information, determining contributory factors by analyzing that information, developing corrective measures, communicating the findings and, finally, implementing and following-up on the implemented measures and assessing their effectiveness (Lindberg, Hansson, & Rollenhagen, 2010).

Despite the perceived importance of incident investigation in high-hazard industries, much research to date has focused on studying why organizations fail to effectively learn from incidents (c.f. Drupsteen & Hasle, 2014; Gillman & Pillay, 2017; Stemn, Hassall, & Bofinger, 2020). Barriers to such learning include, amongst others, the lack of a culture of trust within an organization, time constraints and production pressures to complete the investigation, and a focus on single-loop learning (no feedback potential), rather than double-loop learning, which provides scope for providing feedback on the lessons learnt (*ibid*). To overcome these barriers, studies have often sought to develop new analytical techniques/methodologies that aid investigators to look for multiple causal factors leading to an incident (Baysari, McIntosh, & Wilson, 2008; Woolley, Goode, Salmon, & Read, 2020), improve the culture around conducting incident investigations (Dekker, 2009; Khatri, Brown, & Hicks, 2009), and develop models to successfully learn from incidents (Jacobsson et al., 2012; Lukic, Littlejohn, & Margaryan, 2012).

However, this body of work, whilst supporting the development of sophisticated analytical techniques and learning models, has actually paid much less attention to the very first step in the process: The collection of incident information itself. The information collection phase can involve obtaining objective and subjective data, including but not limited to photographs, training records, video evidence, witness statements, and interviews (Abdul Majid & Shariff, 2020; Thallapureddy et al., 2022). Yet, this information is not homogenous and collecting objective evidence (such as

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photos and training records) is arguably much more straightforward than the collection of information from interviews, which is inevitably subjective in nature.

Interviews with injured parties, witnesses, and other colleagues are critical for soliciting reliable and high-quality information about an incident (Vrij, Hope, & Fisher, 2014), but the way an interview is conducted often entirely depends on the interviewing skills of the investigator (interviewer). Consequently, the quality of the information collected is influenced by the fallibilities of cognitive processing: we are all biased (Tversky & Kahneman, 1974). This is true whether the individual is a layperson or a subject-matter expert (such as incident investigators; Kahneman & Klein, 2009). Indeed, MacLean (2022) has recently highlighted the potential problems bias inevitably brings to workplace investigations, noting the lack of literature on this subject and the need for further research in this area.

Interviews are inevitably subjective in nature, and so have the potential to be influenced by many different cognitive biases (Ryan, Hutchings, & Lowe, 2010; Novatsis & Wilkinson, 2016; MacLean, 2022). Bias can be defined as the systematic deviation from making a rational judgment (Kahneman, 2011). Bias can manifest in many ways during an interview, for example, through asking leading questions (Novatsis & Wilkinson, 2016), asking questions around a specific factor to elicit a confession (Rassin, Eerland, & Kuijpers, 2010), or making judgments based on personality or character (Strauch, 2017). When biases are present in an interview they can skew the conversation, thereby impacting the quality of the information obtained. This in turn then leads to poor quality analysis (i.e., garbage in = garbage out) with the potential to then lead to ineffective investigation outcomes, incorrect conclusions drawn, and a lack of optimal organizational learning.

Yet, despite authors suggesting that investigations are susceptible to bias, there is a lack of empirical research within any high-hazard industry able to provide insights around which biases most commonly emerge during the incident interview process, when they are likely to emerge, and how. This work addresses this gap specifically, focusing entirely on information collection from incident investigation interviews. The aim of the research is to determine which different biases commonly emerge during the information collection stage of incident investigations and how. Analysis of simulated interviews enabled the different biases common within incident investigation interviews to be revealed, with further insights of how and when they can hinder the investigative process at the information collection stage. Enhanced understandings of biases in this first stage of the investigative process can inform the training and education of investigators (as called for by MacLean, 2022) and thus enhance the process as a whole, leading to optimal organizational learning, more effective changes to work methods, and a reduction in repeat incidents in practice.

2. Literature review

2.1. Information collection

Incident investigation and learning is a familiar concept in safety research, and there is a wealth of literature to support effective incident investigations. According to Carter and Menckel (1990:125), 'Most accident prevention efforts are based on knowledge gained from accidents and, consequently, it is important to learn as much as possible from each accident.' However, as noted above, most of the associated literature focuses on the deficiencies associated with ineffective learning at the end of the investigative process, rather than ineffective action at the start. Yet as Drupsteen and Hasle (2014) point out, one of the greatest bottlenecks that hinders effective learning is the *quality* of the information obtained after an incident occurs.

Although the information collection phase of the process serves as the foundation for all subsequent stages of an investigation, research of this first step is limited. Studies focus on the types of data to be collected (Abdul Majid & Shariff, 2020; Stemn & Joe-Asare, 2021), guidance on the types of questions to be asked (MacLean, Stinson, Kelloway, & Fisher, 2011; Reinach, Viale, & Green, 2007; Wu & Steckelberg, 2012), and strategies for conducting interviews (Fisher & Geiselman, 1992; Ryan et al., 2010). MacLean et al. (2011) provide a little more guidance, for example encouraging the use of open-ended questions in interviews that are broad in nature, as investigators can secure more accurate information than by using a closed questioning approach. Fisher and Geiselman (1992) concluded that asking questions in a non-leading way and not interrupting the interviewees was also helpful in eliciting high quality information, and the interview process should always start by building rapport with the interviewees. Without applying such strategies, interviews can turn into a police interrogation (Kelloway, Stinson, & MacLean, 2004). This is highly problematic as the goal of a police interview is often to secure a confession or find the guilty party, rather than to comprehensively understand what led to the incident and make continuous systemic improvements. Whilst Ryan et al. (2010) point out the importance of *unbiased* approaches to interviews, they do not explore in depth what biases are most common in the process, and where vulnerabilities to bias emerge. The constructions-specific work of Heraghty, Dekker, and Rae (2021) also raises concerns of the influence of different biases within investigations, including during the interview process where confirmation bias is to be overcome by open-ended questions and neutral framing, yet this remains theoretical within Heraghty et al.'s (*ibid)* wider considerations of a restorative justice approach to incident investigation as a whole. That bias is a key issue in incident investigations has most been recently raised by MacLean (2022), who explores this concept through the first detailed overview of the problems bias has the potential to cause in investigations in occupational environments, with suggestions for mitigation including bias management strategies, standardized approaches, and investigator training.

2.2. Cognitive biases

It is widely acknowledged and accepted that as human beings, we all are biased (Tversky & Kahneman, 1974). We often tend to believe that we are rational and consciously aware of the decisions that we make in our everyday life, but that is simply not the case. Unconscious cognitive biases are unavoidable for all human beings.

Having biases is not *de facto* a bad thing but being able to recognize them is often the key to saving ourselves from making any unfavorable decisions as a result of their influence. Humans often use mental shortcuts (also called heuristic strategies) to make decisions or judgments (Gilovich, Griffin, & Kahneman, 2002; Kahneman, Slovic, Slovic, & Tversky, 1982). Often, these heuristics are useful to make predictions or solve problems quickly and efficiently, with minimal mental effort. However, overreliance on heuristics can lead to systematic and predictable errors in judgment, known as cognitive biases (Kahneman, 2011; Tversky & Kahneman, 1974). Since the initial work by Tversky and Kahneman (1974), over 180 biases have been identified that interfere with how we process data, think critically, and perceive reality. In recent years, a number of studies have examined biases that are known to influence decision-making processes across different domains including aviation maintenance (Illankoon & Tretten, 2020), medical practice (Buckingham & Adams, 2000), and criminal investigations (O'Brien, 2009), to name a few. Experts

are susceptible to biased cognitive processing (i.e., evaluations and judgments) as they seek to find patterns and apply existing knowledge to find reasonable and plausible solutions (Kahneman & Klein, 2009).

2.3. Bias in investigations

As all humans are prone to bias, those undertaking incident investigations are also vulnerable to their inevitable influence. These biases can form through conscious and subconscious thought processing (Gilovich et al., 2002). Thus, as incident investigations are unavoidably susceptible to bias from the very first stage of information collection, the quality of the outcomes obtained from the investigation are also questionable (Ryan et al., 2010; MacLean, Brimacombe, & Lindsay, 2013) and can ultimately hinder optimal organizational learning. Despite a general acceptance of the need to collect information in an unbiased manner, and the recent concerns around bias specifically in incident investigations raised by MacLean (2022), there has been a lack of empirical work exploring this phenomenon. In fact, to the authors' knowledge, there has been no empirical study carried out to identify the most commonly emerging biases during interviews specifically within the industrial incident investigation domain.

The wider literature does, however, suggest some biases that will likely have influence on the incident investigation process. For example, Fundamental Attribution Error (FAE; Nisbett, Caputo, Legant, & Marecek, 1973) is a bias through which the investigator could use character-based evidence to make judgments regarding the cause of an incident. When an investigator falls prey to FAE, they tend to attribute a person's behavior to a personal characteristic, rather than trying to understand any external situational factors that made them behave the way they did at the time of the incident. When FAE is considered alongside the endurance of 'unsafe acts' as a casual factor in incidents (Smith, Sherratt, & Oswald, 2017), and thus the continued prominence of error and even blame in investigations, some interesting considerations emerge around the influence of this bias (and likely others – see MacLean, 2022 who adopts the term 'human error bias') on investigative practice.

Another bias of potential influence is hindsight bias, which is the tendency for investigators to believe that the incident would have been avoided if only person X had taken action Y (Henriksen & Kaplan, 2003). Hindsight bias often results in investigators expecting people to anticipate the event in foresight (Henriksen & Kaplan, 2003). As a result of hindsight bias, investigators can be prone to draw easy conclusions about an incident, usually focusing on an individual at fault, whilst ignoring the interactions between myriad alternative factors that could also have contributed to the incident.

Investigators might also show confirmation bias, a tendency to look for information that supports their preconceived notions about an incident (Nickerson, 1998; O'Brien, 2009). Confirmation bias influences investigators to seek information based on what they already believe to be true, and thus inevitably end up finding 'causal factors' that confirm their beliefs. In fact, Lundberg, Rollenhagen, and Hollnagel (2009) coined the term 'What You Look For Is What You Find' to highlight this specific phenomenon within the field of incident investigation. Experience bias is another associated bias, through which investigators make judgments based predominantly on their previous experience (Koriat, Goldsmith, & Pansky, 2000). Experience bias can result in investigators to stop looking for information when they think they have found enough evidence to determine the causal factors based on their own experiences of similar situations, however as each incident is unique this often results in the neglect of alternative information that might also have relevance to the present incident.

2.4. Biases in industrial incident investigations

Among the relatively few studies that have contributed to the literature on biases that impact incident investigations is the work of Burggraaf and Groeneweg (2016). In their study they were able to identify outcome bias, hindsight bias, and the 'curse of knowledge' by re-evaluating nine incident analysis reports. The investigation involved studying the original facts from the incident reports, applying the tripod method to identify the causation trees, and iteratively developing criteria for conducting a quality incident analysis.

Sampling undergraduates and professional investigators, MacLean et al. (2013) found that participant's decision-making abilities were impacted by 'tunnel vision.' In this study, participants underwent a simulated exercise to identify the root causes of an incident, wherein the incident was introduced to them through a slide show and the participants had to determine what happened. In this randomly controlled experiment, a sample of the participants also received tunnel vision education and upon the completion of the slide show, all participants completed a survey to rate their confidence levels, supportiveness of additional information, investigative conclusions, and the influence of safety reports in coming up with the direct causes. Although the authors concluded that tunnel vision impacted incident investigations, there was no further exploration around how the various biases that contribute to 'tunnel vision' emerged at the information collection phase, and if there were also other biases that could impact investigations.

Woodcock, Drury, Smiley, and Ma (2005) reviewed several 'case study' experiments to explore the use of simulations in accident investigation research, one of which was focused on the exploration of biases in causal determination by $n = 15$ investigators. Interestingly, they found no indication of consistent biases within the process. A quantitative, reductionist approach was made to the data, with % proportions of factors noted by the investigators acting as a proxy for their rigor. However, the *process* of information elicitation was not examined – likely due to the focus of the paper itself which was firmly methodological. Indeed, the authors note that analyzing '. . .indications of bias in the investigator's lines of inquiry was cumbersome' which may have been influenced by the ultimate quantification of the qualitative data, which would make such nuance hard to unpack.

The notable recent work by MacLean (2022), although theoretical, provides a comprehensive overview of bias within incident investigation. MacLean unpacks the potential sources of bias throughout an investigative process including those based in human nature, in the local environment, culture and experience, and from case-specific information. She discusses how bias could become embedded at the different stages of an investigation, with brief notes on which biases may have most influence in the process. This work is broad in scope and so is unable to focus in depth on any particular stage of the investigative process.

MacLean (2022) does, however, highlight the role and importance of specific workplace contexts in the emergence of bias in investigations. The training provided, the base-rates of different incidents and the case-specific information all have the potential to bias investigations in different industries in very different ways. This highly situated nature of incident investigations puts demands on those seeking to research bias within such processes; notably that any empirical investigation should also itself be specific and situated. Our area of interest is the construction industry, which remains one of the most dangerous in the world and results in many serious injuries and fatalities year on year. It is also a complex space, fundamentally peripatetic with relatively unique working conditions incorporating high-hazard activities undertaken by long subcontracted supply chains (Sherratt, 2016). That incident investigations in this industrial space are as effective as possible to support effective organizational learning is therefore critical.

Illumination and enhanced understanding of the role of bias at the information collection stage is therefore a robust first step in improving investigative processes overall to support the reduction of accidents on jobsites.

3. Methodology

Fundamentally, this research adopts a realist ontology and post-positivistic epistemological position in order to avoid philosophically 'overcomplicating' the human interaction that occurs during an incident investigation interview. As the existing body of knowledge around bias within incident investigations is small, this approach is most appropriate for exploratory research of this phenomenon, as it enables the identification and explanation of the biases that emerged from the data at their most elementary level, through their most common manifestations and contexts. Post-positivism requires the acceptance of an objective truth and thus that the participants in the study were also 'telling the truth' throughout their interactions. The data are therefore considered to be 'the truth' and analyzed as such without further interpretation. As a result of this objective position, bias within the research design itself was carefully considered through adherence to the clearly defined experimental protocol explicated below and was mitigated as far as possible within the study. There do, however, inevitably remain limitations to this methodological approach, which are discussed at the conclusion of this paper.

3.1. Approach

To secure insights of the role of bias in incident investigation interviews in the construction industry, a role-play simulation method was adopted in which industry practitioners with experience in incident investigations participated in two mock case-study incident interviews as if they were investigating a real incident on site.

The simulation method is a technique that reproduces a real-life situation under experimentally controlled conditions. Within the body of behavioral and psychological research, especially the legal domain, the simulation method has been adopted as a research tool to study decision-making and judgment amongst jurors (Bornstein, 1999; Devine, 2012). In this field, the simulation method is widely applied as it has a number of advantages as it allows for an understanding of both processes and outcomes, a high degree of experimental control is ensured, thereby leading to a higher internal validity, and thus can be used as a "stand-in" method for studying real world behavior (Bornstein & McCabe, 2004). Woodcock et al. (2005:11) also concluded that simulations are also a robust approach to research, and of incident investigations specifically, and that experienced investigators were happy to participate, stating that '. . .their approach to simulations resembled a real investigation' thus ensuring ecological validity within what is otherwise inevitably situated work.

In this study, during each simulation the participant investigated one of two different incidents within the simulation setting, with the goal of determining the contributory factors of the incident by interviewing the injured person (IP) and the witness. The investigators were randomly assigned to an incident and tasked to determine the contributory/causal factors of the incident presented to them.

3.2. Sample

A total of 34 practitioners participated in this study, each taking the role of investigator. The sample represented various specific fields within the construction industry: oil and gas (n = 11), service and utility work (n = 11), heavy civil construction (n = 4), nuclear (n = 2), and industrial construction (n = 6). The investigators on an average had 20 years of experience either conducting or participating in incident investigations within their respective organizations, resulting in a total of over 300 years of experience within the sample. This purposive sampling approach enhanced the ecological validity and to a certain extent generalizability of the findings presented here, due to the composition and experience of the sample as a whole.

3.3. Simulation incidents

In the footsteps of Woodcock et al. (2005:4), an incident story was developed for use by the actors in the simulated interviews. Actual court depositions provided the information to develop the incident scenarios, with details surrounding the incidents modified to ensure anonymity of those involved. Keeping the main story of the incidents intact (i.e., type of incident, how it happened, the people involved), the names of those involved, any personal and location details were censured for ethical purposes. The two incidents were *The Staircase Incident* and *The Concrete Form Incident*.

Both incidents had two actors, an Injured Person (IP) and a witness, with each role-played by a student. To enhance reliability and internal validity, the same two students participated in one acting role for all 34 simulations. A script was developed for both the incidents and was used by the students to maintain consistency in their descriptions of the incidents and interactions with the interviewers. Although it was impossible to anticipate all potential questions in advance, the script was developed in such a way to provide the students with proscribed responses to the most common questions, yet also enabled them to improvise consistently in all other instances. Any unplanned answers and questions were added to the scripts after each simulation interview, to maintain consistency in future simulations, should anyone ask them again. To enhance internal and ecological validity, the students underwent three trial runs with experts from the field who provided feedback on response strategy, demeanor and tone, and experimental setup.

3.3.0.1. The Staircase Incident

This incident involved a superintendent (IP) and a carpentry foreman (witness) working on a residential construction project. In one of the homes, the foreman was completing a staircase running up from the basement to the first floor. The superintendent reported there was nothing out of the ordinary about the day other than a client visit scheduled for the afternoon, and there was pressure to complete the work beforehand. The foreman was running behind schedule on the staircase because their crew had been recently fired by the superintendent for safety violations, meaning the foreman was working alone on the stairs. The incident occurred early afternoon when the foreman was near the staircase cutting lumber, and as the superintendent descended the stairs to the basement they collapsed. The superintendent alleged that the staircase simply 'gave out,' and they fell approximately 9 ft. to the basement floor. The foreman stated that the stairs that collapsed under the superintendent had temporary supports that should still have held the superintendent – and indeed the stairs had been used in that state earlier in the day by other workers. As a result of the incident, the superintendent sustained injuries to the hand and had two broken legs.

3.3.0.2. The Concrete Form Incident

This incident involved a superintendent (IP) and a laborer (witness) working on an industrial construction project. The laborer was stripping round concrete shuttering forms for light pole base installations. The typical process of stripping consists of slicing

the cardboard forms using a utility knife or an electrical saw, which means the form can then be peeled back from the cured concrete. The laborer had only been working on the site for a month but had been trained by their employer to perform this task using the utility knife method. During this period, the laborer had cut themselves with the knife, resulting in an injury requiring 2 stitches. On the day of the incident, there were two laborers in the area stripping the forms ahead of a concrete pour later that day, but the laborer in question was running behind schedule and was under pressure to speed up their work. The incident occurred in the afternoon when the superintendent suggested that they should use a hammer to release the form instead of the knife, stating it was a quicker and safer method of work. When the superintendent was assisting the laborer with this new method, the laborer hit the superintendent's hand with the hammer. After the incident, the superintendent required five operations to correct the damage done to their hand.

3.4. Simulation protocol

Prior to each simulation interview, a 2-minute video describing the basic details of the allocated incident was sent to the investigators to provide an initial outline briefing – similar to the phone call that would be made following an incident in real life. The use of a video ensured consistency of information provided, and thus reliability in this stage of the process. A survey accompanied the video and asked participants for their initial opinions of the contributing factors of the incident, based on the details provided via the video. These initial survey responses were useful in evaluating the lines of questioning followed during the interview, and to compare the conclusions made initially with those ultimately drawn at the end.

Due to Covid-19, the simulated interviews were conducted via Zoom, during which the investigator interviewed both the victim and the witness individually in turn, with the opportunity to ask any follow-up questions to either of them as many times as they liked. At the start of the simulation, the participants were given brief instructions to their task (i.e., to investigate the incident provided to them by interviewing the people involved). To avoid any demand characteristics (e.g., observer-expectancy effects), the aim of this simulation (i.e., the study of biases) was not revealed to the participants beforehand. The order of the interviewees was randomized, to avoid any undue ordering effects that can themselves embed bias in the experimental process. The lead researcher observed each simulation and upon completion of the interviews to the satisfaction of the interviewer, asked additional questions of their perceptions of the contributing factors of the incident, as well as any other additional details they wished to share. Some of the questions asked to aid this conversation included:

- What are your general thoughts on what may have happened?
- What analysis do you make of the people involved in the incident?
- Was there anything surprising or unexpected piece of information?

All the simulation interviews, and responses to the surveys, were subsequently transcribed for further analysis.

3.5. Method of analysis

Descriptive qualitative analysis allows for an exploration of a research topic that is limited in literature (Creswell & Poth, 2016). To illuminate and better understand the different types of biases that investigators are prone to, an inductive and thematic approach was made to the transcribed simulation interview generated data. Following Braun and Clarke (2006), the key steps in the thematic analysis undertaken were: becoming familiarized with the data, generating initial codes, determining the common themes, and reviewing and defining the themes. Thematic analysis allows for an inductive examination of data, with themes derived by identifying patterns across the data (Braun & Clarke, 2006), the iterative approach enabling new themes/ categories to emerge from the data as they are revealed.

An initial set of codes were generated by searching for patterns in the line of questioning, representing known biases. The data were coded in such a way that each theme consisted of a series of questions to show how the bias emerged from the conversation. For instance, in the staircase incident, if an interviewer repeatedly asked questions about the structural configuration of the stairs, all the questions related to the structural components/configuration asked were coded together under the theme "Fixation to a specific aspect" which itself was associated with anchoring bias (a bias in which the individual becomes fixated within a situation, the anchor becoming the 'frame' for subsequent enquiry; Tversky & Kahneman, 1974). Once the initial set of themes were identified, the process of searching for additional themes was revised and reiterated to account for any more nuanced themes identifiable in the data. A constant comparison approach (Silverman, 2019) was taken to the data, with repeated passes made of the data until no new themes emerged. Taking this approach allowed for a 'bird's eye view' of the patterns emerging from the data (Aronson, 1995) and ensured the analysis reached saturation. All coding and analysis were conducted using NVivo qualitative data analysis software.

In addition to the thematic analysis, the results from the pre-simulation survey were used to compare the results to the interview data. A spreadsheet was created to organize the conclusions drawn for the incidents by each participant. This enabled detailed analysis of whether the lines of questioning followed during the interview were based on preconceived notions about the incident generated by the initial video, or more associated with the eventual findings generated from the interviews. For example, if a participant stated unstable stairs to be the contributory factor in the initial survey, this was noted in the spreadsheet and evaluation made with the transcripts to determine if they had asked most of the questions around this factor, and ultimately arrived at the same conclusion after the interviews.

Holistically, the analysis of the survey data, the simulated interviews and subsequent questioning of the interviewers, revealed the manifestations of various biases throughout the process. The approach to analysis enabled the most common and prominent biases that emerged throughout the process to be highlighted, with the associated data informing when and how they most frequently influenced the process. The findings have been presented here in a way that contextualizes the biases within the investigative process itself, and thus also enables discussion of how they emerged and potential consequences for practice. Where quotes are used, they are exemplars that reflect the theme as a whole.

3.6. Limitations

As with all research, this study has a number of limitations.

The small sample from a specific industry limits generalizability. However, the purposive nature of the sample and experience consequently contained therein enhances the ecological validity of the work, which in turn supports external generalization to some extent. Although the sample was specific to the construction industry, and thus the discussion is also somewhat sited, the findings remain both applicable and relevant to any other industry in which incident investigations are undertaken.

The methodological foundations for the work, and the use of simulated interviews raise further limitations. There is the potential for the 'Hawthorn Effect' to manifest resulting in a change in

behavior by those who know they are under scrutiny. However, the work of Woodcock et al. (2005) and others reassures that simulation mitigates this effect as participants become more engaged in the activity they are undertaking, and thus the Hawthorn effect is less impactful in simulations as it is in other forms of research such as participant observation within a real-life setting (e.g., Oswald, Sherratt, & Smith, 2014). The practical ability to undertake this research without a simulation should also be considered, as to undertake this work using real-life incident investigations would raise considerable ethical challenges for both the researchers, participants, and firms involved.

A further bias-related challenge was the potential for confirmation bias within the research team itself – we were looking for biases and therefore we found them. Whilst this possibility cannot be fully designed out of the analytical process, it was mitigated through the use of a robust and fully explicated experimental protocol and a highly systematic, rigorous, and repeated approach to the analysis. Taking an inductive approach to the data allowed the different biases to emerge from within the data as a whole, and this was supplemented by discussions amongst the research team at regular points throughout the analysis to provide some measure of inter-reader reliability in the process. Another potential bias could have resulted from the use of the same two students role playing the IP and witness in all cases. This raises the potential for bias in the participants to have resulted from something specific, a trait or characteristic of one of the students, that consistently affected the interviews – thus resulting in something of a 'false positive' throughout the data in terms of a resultant bias. However, this must be balanced with the need for consistency in the stories and responses to questions during the role play, and across the experiment as a whole. Different students role-playing the IP and witness would have added more confounding factors to the experiment, and thus potentially added further bias to the experiment. On balance, the decision was made for consistency, and use the same two students throughout, albeit within two different simulation incidents, in order to minimize impact on the study as a whole.

Adopting a post-positivist methodological position necessitated an awareness of bias within the research in a number of different ways that were mitigated to best efforts as noted above. However, this early work into bias in incident investigation interviews specifically adopted this methodological position to provide a firm foundation for further work to adopt more nuanced methodological approaches to continue to unpack these different biases in greater depth. For example, adopting a constructionist epistemology could provide greater insight and understandings of the emergence and interaction of biases in a way that would overcome some of these limitations, although inevitably also raise others as a result.

4. Findings and discussion

4.1. What you look for is what you find: Confirmation bias

Findings showed that approximately 30% of participants (n = 10 investigators) structured their interviews based on the initial presumptions they had stated in their pre-simulation surveys. Their questioning focused on the contributory factor(s) they had mentioned in their surveys, with considerable proportions of the interview time – in some cases the entire interview – devoted to their examination and a quest for proof that their initial ideas were correct. The initial presumptions also mirrored the conclusions drawn post-interviews. For example, in the staircase incident, an interviewer noted the structural instability of the stairs as a contributory factor to the incident. Throughout the interview, most of their questioning focused only on this specific aspect, and in the debrief session they concluded that the incident occurred due to the stairs being unstable to use. Repetition was commonplace, as the interviewer circled back to the stairs in their questioning:

> *'How was, um, how was their structural stability? Did you find them shaking?'.*
> *'So, when were those stairs erected?'.*
> *'So, the stairs…were under construction?'.*

And when the interviewee raised other potential issues, for example: *'The stairs had temporary bracings…And* again, *there was no visual or verbal warnings……..'* The interviewer focused on the structural rather than the procedural aspects of the situation thus: *'Are these temporary braces that…they were installed?'* This indicates presence of confirmation bias, where people seek out information to confirm their preexisting beliefs, even when there are other potential factors to explore (Nickerson, 1998). While the questions on face value do not confirm presence or absence of confirmation bias, the series of questions asked by participants seeking to acquire particular evidence is suggestive of confirmation bias. Equally important, most participants did not ask questions to challenge their personal notions of what may have happened, which strengthens the evidence of confirmation bias.

According to Nickerson (1998), confirmation bias can manifest in many ways, including selective attention to a particular piece of information, grounded in strongly held beliefs about an event. Confirmation bias was to a large extent expected within the simulation, as it has been found in studies in other domains (e.g., Hill, Memon, & McGeorge, 2008; O'Brien, 2009) that also illustrate how people are selective towards seeking out information that they perceive to be true, useful, and credible. Even when there are other alternative explanations available, people tend to stick with their original hypothesis – making this situation the manifestation of "What You Look For Is What You Find," as coined by Lundberg et al. (2009).

Some participants (n = 10) also asked leading questions during the interview. This is another form of confirmation bias, wherein the specific framing of the question leads the interviewee to confirm what the interviewer wants them to confirm. For example, within the staircase incident the questions (verbatim) *'so how did you feel working on the stairs? Did you feel rushed at all? Did you feel any frustration because it seemed like you were the only one working on the stairs and also she wanted it done? It was on the critical path. Did that affect you, or did you feel like it might have?'* directing the interviewee to answer in the positive, thus enabling production pressures to be included in the list of causal factors. Within the concrete form incident, a similar cause was sought, with the interviewer asking: *'you know, talking to the laborer as well, there seemed to be a little bit of feeling of being rushed. And, you know, she said that you were frustrated that she was behind…you were letting her know you weren't very happy with that. Is that accurate?'* adding production pressures to other potential causes, albeit in a more accusatory way. Production pressure is an almost constant problem for construction safety management (e.g., Oswald, Sherratt, & Smith, 2019), but although it is therefore likely to have some influence on any incident on site, it should not be 'forced' into an investigation as a matter of course.

When questions are asked in such a way as to elicit a 'confession' from the people involved, an interview becomes more typical of a criminal investigation than an industrial investigation (Vrij et al., 2014). Although asking leading questions may be necessary at times to clarify information further or echo what the interviewee has said for confirmation, overreliance on such types of questions can be problematic. Embedding presumption in the interview limits enquiry and prevents the investigator from obtaining information on other aspects or factors of relevance in the incident.

The inevitable timing of information flow in an incident, from the first phone call no-one wants to receive, to some extent embeds confirmation bias in the process and paves the way for pre-conceived notions about the potential causes of the incident. Confirmation bias cannot be avoided; however, investigators could be trained to be aware of the impacts of this bias in their decision-making, that the first phone call can create a vulnerability in the process, and to be cautious in taking lines of questioning to confirm presumed facts.

4.2. That's why they did that: Fundamental attribution error

Most interviewers ($n = 21$) stated in the post-interview that they felt that the personal characteristics of the people involved, and subsequent associated behaviors, contributed to the incident. These interviewers relied on character as evidence to make judgments of what led to the incident occurring.

For example, in the concrete form incident one of the interviewers commented on the superintendent thus: *'I could tell her she could possibly be one of those personalities that could get abrasive and strong. . .and that fact that she thought it was a good idea to put her hands in an area where somebody's swinging a hammer.'* In this example, the interviewer has directly associated a 'strong personality' with what could be described as impulsive or arrogant behavior, ascribing causality to inherent traits. Yet this conclusion neglected to acknowledge explicitly stated time pressures previously noted by both the IP (superintendent) and witness (laborer) in this incident case due to a scheduled concrete pour later that day.

This is an example of Fundamental Attribution Error; the superintendent's behavior attributed to personality, rather than considering the situational context of the work surroundings. It has been shown that people rely on character-based evidence in interviews, because it is easier to explain and something that quickly comes to mind (Sanchirico, 2001). Such judgments are often reasonable observations on the surface, only revealed as bias when (or if) the misplaced prioritization of explanations becomes apparent as events unfold. For example, in court environments, character-based evidence is often used by juries to form judgments on guilt, and conviction of the defendant (Kurland, 2014). This finding is therefore consistent with legal research, but also has wider connotations in the construction industry where 'blame the worker' has been historically problematic in safety management (Frederick & Lessin, 2000). Incident investigations should not be undertaken to blame individuals, despite the lure of the relatively simple remedial actions that can result (i.e., dismissal) compared to the much more complicated task of addressing external situational factors that might have led to the undesired behavioral outcome (Dekker, 2009).

4.3. 'Nothing surprises me anymore': Past experience bias

People make judgments by relying on and interpreting their past experiences (Ghattas, Soffer, & Peleg, 2014), however, over-reliance can result in past experience bias. In the context of incident investigations, analysis showed that investigators can and do make decisions based on their previous experiences, where they perceive the current situation to be similar to an incident that occurred in the past. Past Experience Bias was identified in some of the interviews ($n = 7$), where it limited questioning and thus learning to the scope of the investigators' own experiences.

For example, an interviewer in the concrete form incident noted *'I think a lot to do with this is that, and I've seen this before, uh, actually we've had, I've been involved with serious accidents where a superintendent has come in and changed their complete plan in the field without notifying his foreman or, or, or supervisor under him, and then really bad things happen.'* Whilst this is a valid point in the construction industry, where 'workarounds' have been found to be a causal factor in many incidents (Sherratt, 2016), insights and information from this particular incident are lost if the interviewer concludes this to be the only root cause. All incidents are unique with multiple causal factors, yet experience can mean investigators constrain their questioning to confirm the re-emergence of their own past experiences and stop there, rather than approaching the situation as a tabula rasa.

4.4. Getting stuck somewhere: Anchoring bias

When collecting information via interviews, it is essential to consider a wide variety of factors to fully understand the complexity of the work involved (Dekker, Cilliers, & Hofmeyr, 2011). In construction, these factors include human, process, and technical aspects of the work, all of which require different approaches in questioning to elicit meaningful information. However, the data revealed that many interviewers ($n = 18$) fixated on just one aspect of the incident, as anchoring bias (Tversky & Kahneman, 1974) directed their questioning, to the detriment of the process as a whole.

Within the data, various factors provided the anchor, missing foreman (concrete form), schedule pressures (concrete form), the lack of a spotter (staircase), and structural instability of the stairs (staircase). Except for structural instability of the staircase, all of these were contributory factors to the incidents, yet they were amongst many others. By anchoring to one factor alone, the interviewers often failed to explore any alternatives or even additional causes. Leaving conclusions at just one 'root cause' means learning is lost about the wider context and situation and is unhelpful when seeking to prevent recurrence and make systemic improvements to practice. Within the data most interviewers ($n = 18$) demonstrated this phenomenon, asking questions to search for further information and explanations on the factor they had become anchored to.

As an example, all the following questions were asked by one interviewer in the staircase incident.

'What's a spotter's role?'.
'Was there anything special about this day where you didn't have a spotter?'.
'. . .how did you feel about not having a spotter?'.
'. . .this member of the crew being fired, were there other occasions where you were working without a spotter in a situation like this?'.
'. . .would you feel comfortable enough with [name] if you didn't feel comfortable with not having a spotter. Did you mention it or were there any discussions at all? There's no spotter. Is this okay, anything like that?'.
'Did you, uh, or right before the incident, did you notice whether there was a spotter, uh, at that location?'.
'. . .so it's, it's yeah, so that confirmed that there was no spotter at the location.'.

This interviewer became anchored to the fact that a spotter was not present on site on the day of the incident. They learnt of the spotter from the witness early in their first interview – as the first quote demonstrates this was new information for them as they sought to clarify the role – which then led to their return to the spotter, or more specifically the lack of a spotter, throughout both interviews. Whilst asking questions about a spotter is not necessarily an incorrect line of inquiry, overreliance on this factor lead the interviewer to confirm that the absence of spotter on site (i.e., the foreman working alone on the stairs, was the main contributory factor within this incident, which was incorrect).

Within incident investigation interviews, the timing of information can be critical as anchoring bias can lead investigators to focus

on a specific factor that is mentioned early in the process. Anchoring bias can hook onto the first or last piece of information received (Kahneman, 2011), or the unfamiliar, which is what has likely happened to the interviewer above.

4.5. It was preventable: Hindsight bias

Another common finding from the analysis was that most of the investigators viewed the circumstances of the incident as preventable (i.e., they believed that the incident could have been avoided if only a particular action was present or absent). Yet, this is a manifestation of hindsight bias, which often hinders organizational learning from incidents as it directs investigators to easy solutions rather than to fully explore the situation that led to the incident.

For example, one interviewer of the staircase incident stated *'I would have completely shut that area off and not allowed in engineered or put some sort of warning signs or braces or barricades to stop anybody from even utilizing the stairs. . ...I think that this is extremely preventable incident. Um, it should've never happened in the first place.'* This statement may well be 'true' – in that the incident may not have occurred if all these obstacles had been in place – yet in taking this hindsight perspective, other aspects of the incident remained unexplored, and the actual leading cause of the incident remained unexposed. Some of the participants ($n = 9$) demonstrated hindsight bias, which led them to reposition the incident in their own minds as avoidable, and in turn thus directed questions to the things they assumed would have prevented the incident. Drawing conclusions after collecting information is inevitable, however, predicting the outcome of an event before or during the interview tends to skew the line of questioning, thereby influencing the quality of the information collected.

4.6. Taking sides and sticking to them: Conservatism in belief revision

Typically, in an incident investigation, people have their stories to share, which might or might not differ from each other. Essentially, the role of an investigator is to remain objective to all those involved and to not favor one individual when making decisions. Yet analysis of the data revealed that most of the participants ($n = 23$) to some extent favored either the IP or the witness as they made judgments and asked questions about the cause of the incident.

For example, in the staircase incident, the witness (foreman) argues that they provided verbal warnings to keep anyone from using the stairs, however, the IP (superintendent) states that they received no such communication. When an investigator hears contradictory stories of the same situation, they should treat all such information carefully, explore alternatives and seek to triangulate information with other sources to avoid jumping to conclusions about who is telling the truth. Yet the data revealed that investigators do not always ask confirmatory questions of the other party or cross-check answers. Despite this being available and interviewers being asked specifically if they wanted to ask further questions of either interviewee, they often chose not to take this option and instead aligned their questions and conclusions to just one version of the truth they had heard.

When the witness had been issued first, the interviewers took the statement about a verbal warning as fact, one commenting: *'she did verbally warn people, for what good that is, right*?' In the second interview with the IP, their narrative stated no such warning had been given, but this was often not revisited by the investigators, and they did not cross-check this statement with the witness. In the counter situation, in which the IP said no warning was given in the first interview, and the witness stated there had been, the IP's narrative often took precedence; the statement of a warning was often ignored, and again no cross-check or further enquiry was made to seek clarification.

Despite such conflicting information embedded in the incident stories, investigators seemed reluctant to change their minds about a situation. This is suggestive of conservatism in belief revision, a bias that hinders a change in position or perspective, even in the face of contradictory or conflicting evidence. The tendency for people to cling onto such mistaken and perseverant beliefs even when presented with new evidence can lead to serious consequences (Anderson & Kellam, 1992). This occurs because of the fact that when the belief system is aligned with reality, belief perseverance coerces individuals to predict outcomes in advance, thereby clouding their judgment. This bias has the potential to encourage interviewers to valorize the information of the first interviewee over those that follow in terms of who is 'telling the truth,' but also to leave lines of fruitful questioning unfollowed when they emerge as such contradictions and conflicts are left unexplored.

4.7. Bigger than the sum of their parts: Biases working together

A final notable consideration that emerged from the data as a whole was that although each bias could be identified independently within the data to the extents as noted above, they did not always emerge in isolation and in several instances, biases worked in conjunction to exacerbate their individual effects. This notion is referred to as the *Combined Cognitive Biases Hypothesis* and was conceptualized by Hirsch, Clark, and Mathews (2006). According to this theory, Hirsch et al. (2006) argue that different cognitive biases interact and have a greater influence on each other and do not operate in isolation. For example, in the staircase incident, an interviewer who became anchored early within the interview process to the structural configuration of the stairs, then also became vulnerable to confirmation bias as they sought out information to reinforce that anchor, whilst also suffering from conservatism in belief revision and a reluctance to change their mind when new information was received that challenged their original thinking (i.e., verbal warning given by the foreman). This only serves to embed the original anchor even more deeply in the interviewer's mind, exacerbating its impact, which is enhanced through the influence of other biases as the interview progresses. Different combinations of biases could be identified across the data, and in combination they often served to increase the potential for misdirection, omission, and thus the limitation of learning from any incident.

5. Conclusions

The information collection phase, being the foundation of any investigation process is of the utmost importance, as all subsequent stages depend on the quality of the information obtained in that first step. Interviews, being subjective in nature, are unavoidably susceptible to be biased as that is simply human nature – all investigators will inevitably be biased, and it is therefore critical to understand which biases most commonly manifest in incident investigation interviews, how and when. Through simulated interviews, sited in a construction industry context, confirmation bias, FAE, past experience bias, anchoring bias, hindsight bias and conservatism in belief revision were identified as the most common biases that emerged. The manifestation of these biases was linked to the timing of information received, as well as more 'psychologically familiar' situations – such as the receiving of novel information, the emphasis of person over context, and the (again inevitable) past experiences of the investigators. Bias directs and shapes interviews through the lines of questioning taken by interviewers, which can lead to limited investigations, and the omission

of questions able to reveal more nuanced information about the incident. As accidents are unique, multi-causal and situated, so to limit investigations in this way from the very first step, and thus stymie organizational and industrial learning and resultant positive change, is something to be avoided.

This study offers a unique contribution to this field to date. From a theoretical perspective, these findings contribute to the small yet growing body of literature on biases in industrial incident investigations. From a practical standpoint, these findings can be used to inform strategies or underpin interventions to mitigate the effects of bias in the specific practice of incident investigation. For example, as suggested by MacLean (2022) these findings could support the development of specific education and training tools to help investigators remain mindful of biases both during interviews and when reaching conclusions to optimize learning from incidents and their reduction in practice.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Personality, perceptions and behavior: A study of speeding amongst drivers in Victoria, Australia

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ABSTRACT

Introduction: Road crashes present a serious public health issue. Many people are seriously or fatally injured every year in avoidable crashes. While these crashes can have multiple contributing factors, including road design and condition, vehicle design and condition, the environment and human error, the performance of illegal driving behavior, including speeding, may also play a role. The current study aimed to examine the mediating influence that four potential deterrents (perceptions towards enforcement, crash risk, social norms and disapproval, and negative personal/emotional affect) have between the Big Five personality traits (conscientiousness; extraversion; agreeableness; neuroticism; openness) and expectations to speed. *Methods:* A total of 5,108 drivers in Victoria, Australia completed an online survey in 2019. A mediated regression analysis was used to examine pathways in a conceptual model developed for the study. *Results:* The results showed that perceptions towards the four potential deterrents examined did mediate the relationship (either completely or partially) between personality and expectations to speed. *Conclusions:* The results of this study suggest that if interventions to deter illegal driving behavior are to be successful, one factor that could be taken into account is the personality traits of drivers who may be at greatest risk of the performance of illegal driving behaviors.

1. Introduction

Road trauma is a significant public health issue that affects countries all over the globe (Peden et al., 2004; World Health Organisation, 2015). Worldwide, around 1.35 million people die annually as a result of crashes that occur when they are utilizing road transportation (World Health Organisation, 2020). Many more sustain serious injuries (Peden et al., 2004; World Health Organisation, 2013). The incidence of road trauma can occur as a result of a range of contributing factors. These include road and roadside design and condition (e.g., Holdridge et al., 2005; Stanton & Salmon, 2009; Stigson et al., 2008; Zein & Navin, 2003), vehicle design and condition (e.g., Bedard et al., 2002; Blows et al., 2003a, 2003b; Stanton & Salmon, 2009; Zein & Navin, 2003), environmental factors (e.g., Stanton & Salmon, 2009; Zein & Navin, 2003), and human error (e.g., Salmon et al., 2005; Stanton & Salmon, 2009; Wierwille et al., 2002; Zein & Navin, 2003). Each of these contributing factors require countermeasures to be developed and evaluated, in order to reduce the road toll. The performance of illegal driving behavior has also been identified as a factor that may contribute to road crashes (Blows et al., 2005; Penmetsa & Pulugurtha, 2016). This includes behaviors such as drunk driving (e.g., Borkenstein et al., 1974; Dingus et al., 2016; Keall et al., 2005; Peck et al., 2008; Voas et al., 2012), driving after using an illicit drug (e.g., Ashbridge et al., 2014; Ch'ng et al., 2007; Drummer et al., 2003, 2012; Hels et al., 2013; Li et al., 2013; Schulze et al., 2012; Van Elslande et al., 2012), exceeding the speed limit (e.g., Aarts & van Schagen, 2006; Alavi et al., 2014; De Pauw et al., 2014; Kloeden et al., 1997; Moore et al., 1995), using a handheld mobile telephone while driving (e.g., Ashbridge et al., 2013; Ige et al., 2016; McEvoy et al., 2006, 2007; Redelmeier & Tibshirani, 1997), and failing to stop at a red light (e.g., Retting et al., 1995, 1999). In response to this, in many jurisdictions, drivers who perform illegal behaviors on the roads may receive a legal sanction.

The primary purpose of traffic sanctions is deterrence. Deterrence theory is based upon the premise that individuals undertake a rational decision-making process prior to the performance of a behavior, weighing up the costs and benefits of obeying or not obeying the law (e.g., Hucklesby, 2004; Kennedy, 2009a; Muncie, 2004). In order to be deterred from performing an action, an individual must come to the conclusion that the potential costs that would result if they are apprehended and sanctioned will outweigh the benefits they would experience from performing the action

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(e.g., Hucklesby, 2004; Kennedy, 2009a; McLaughlin, 2006). Effective deterrence requires that penalties must be certain, swift, and severe (Akers & Sellers, 2004; Paternoster & Bachman, 2012).

Researchers have applied deterrence theory to illegal driving behavior, with competing evidence that supports and places doubt on the effectiveness of legal sanctions to deter further illegal driving behavior, as well as reduce crash risk (e.g., Daigneault et al., 2002; Davis et al., 2018; Factor, 2014; Goldenbeld et al., 2013; Imberger et al., 2019; Li et al., 2011; Redelmeier et al., 2003; Studdert et al., 2017; Walter & Studdert, 2015; Watson et al., 2015; Weatherburn & Moffat, 2011).

In addition, some research has examined factors beyond legal sanctions that may influence the performance of illegal driving behaviors. These expanded models of deterrence have shown that there are many factors that may influence offending behavior, and these factors are far broader than legal sanctions (e.g. Mann et al., 2016; Nagin & Pogarsky, 2001; Piquero & Tibbetts, 1996).

Expanded models of deterrence have been applied to illegal driving behaviors, including drunk driving (e.g., Baum, 1999; Berger & Snortum, 1986; Freeman et al., 2006a, 2006b, 2016; Freeman & Watson, 2009; Grasmick & Bursik, 1990; Green, 1989; Homel, 1988; Loxley & Smith, 1991; Meesman et al., 2015; Nagin & Pogarsky, 2001; Piquero & Paternoster, 1998), driving after using an illicit drug (e.g., Davey et al., 2008; Freeman et al., 2010; Jones et al., 2005), driving while unlicensed (e.g., Watson, 2004), speeding (e.g. Bradford et al., 2015), and running a red light (e.g., Bradford et al., 2015). In addition to considering legal sanctions (the classical idea of deterrence), research using expanded models of deterrence has found factors such as perceptions of crash risk (e.g., Freeman & Watson, 2009; Homel, 1988; Jones et al., 2005), perceptions of social attitudes and norms (e.g., Berger & Snortum, 1986; Meesmann et al., 2015), and concerns about the potential social consequences that may follow performance of an illegal driving behavior (e.g., Baum, 1999; Freeman et al., 2010; 2016; Grasmick & Green, 1980) in many cases have the potential to influence patterns of illegal driving behavior.

Other studies have taken expanded models of deterrence a step further, by also considering personality, and whether personality traits have an influence on drivers' attitudes and perceptions toward both legal and non-legal sanctions (e.g., social consequences of performing illegal behaviors), and subsequently their driving behavior (e.g., Lucidi et al., 2014; Machin & Sankey, 2008; Mallia et al., 2015; Steinbakk et al., 2019; Ulleberg & Rundmo, 2003). While each of these studies used different personality scales, attitudes and/or perceptions indicators and driving behavior outcomes, in general, the results show evidence of attitudes and perceptions having a mediating influence between personality and driver behavior. Furthermore, these studies highlight the value of considering multiple factors together, and the additional insights they can provide to understanding driver behavior.

In this study, we sought to build upon the existing body of research that has considered personality, expanded models of deterrence, and the performance of illegal driving behavior. While expanded models of deterrence have become more popular over time and have established that there are factors beyond legal sanctions that may influence engagement in illegal driving behavior, it is important to recognize that perceptions toward road safety continue to change and evolve (Kennedy, 2009b). Continued research that applies expanded models of deterrence in the area of road safety can provide us with understandings and knowledge that reflect current circumstances. Thus, in this study we developed and applied a new conceptual model that examined the mediating influence of legal and-non-legal sanctions between personality and expectations to perform illegal driving behavior. The illegal driving behavior of interest in the current study was expectations to drive at up to 10 km/h above the speed limit (termed 'speeding' for the remainder of this manuscript) in the following 12 months. Low level speeding was selected given it is a highly prevalent behavior and accounts for the majority (approximately 79%) of crashes that result from speeding on Victorian roads (Alavi et al., 2014) and is also the most commonly sanctioned category of speeding offenses (State Government of Victoria, 2023). The study sought to examine four key research questions:

1) Does personality have an influence on expectations to speed in the following 12 months?
2) Does personality have an influence on perceptions towards potential deterrents, in relation to speeding?
3) Do perceptions towards non-legal sanctions have an equal to or greater influence than perceptions towards legal sanctions on expectations to speed in the following 12 months?
4) Do perceptions towards potential deterrents have a mediating influence on the relationship between personality and expectations to speed in the following 12 months?

2. Conceptual model – personality, perceptions and behavior model

Fig. 1 shows the '*Personality, Perceptions and Behavior Model*' developed for examination in the current study. The model shows a series of pathways that may exist between personality, perceptions of potential deterrents, and behavioral expectations. The following section provides details of each construct in the *Personality, Perceptions and Behavior Model* (termed 'the conceptual model' throughout this paper).

2.1. Personality

Previous research demonstrates that personality influences drivers' attitudes and perceptions to both legal and non-legal sanctions, and subsequently their driving behavior (e.g., Lucidi et al., 2014; Machin & Sankey, 2008; Mallia et al., 2015; Steinbakk et al., 2019; Ulleberg & Rundmo, 2003). The Five Factor model of personality was therefore included in the conceptual model developed for the current study. The Five Factor model measures individuals on five personality traits: (1) conscientiousness; (2) extraversion; (3) agreeableness; (4) neuroticism; and (5) openness (Digman, 1990; Goldberg, 1993; John et al., 2008; McCrae & John, 1992; John & Srivastava, 1999).

2.2. Perceptions of enforcement

This construct was included in the conceptual model to understand deterrence from its classical perspective. It has been noted that it may not be the specific penalties in place that have a deterring effect, but instead the perceptions held by people towards the penalties (Kennedy, 2009b). This construct therefore sought to examine the perceptions that drivers have about the certainty and severity of legal sanctions.

2.3. Perceptions of crash risk

One approach road safety campaigns have taken is to highlight the potential risk of crash, and subsequently, risk of injury, that may result from illegal driving behaviors (e.g., Elder et al., 2004). Thus, given this is used as a strategy to promote safe driving behavior, perceptions of crash risk was included in the conceptual model to examine the beliefs drivers have about illegal driving behavior and crashes.

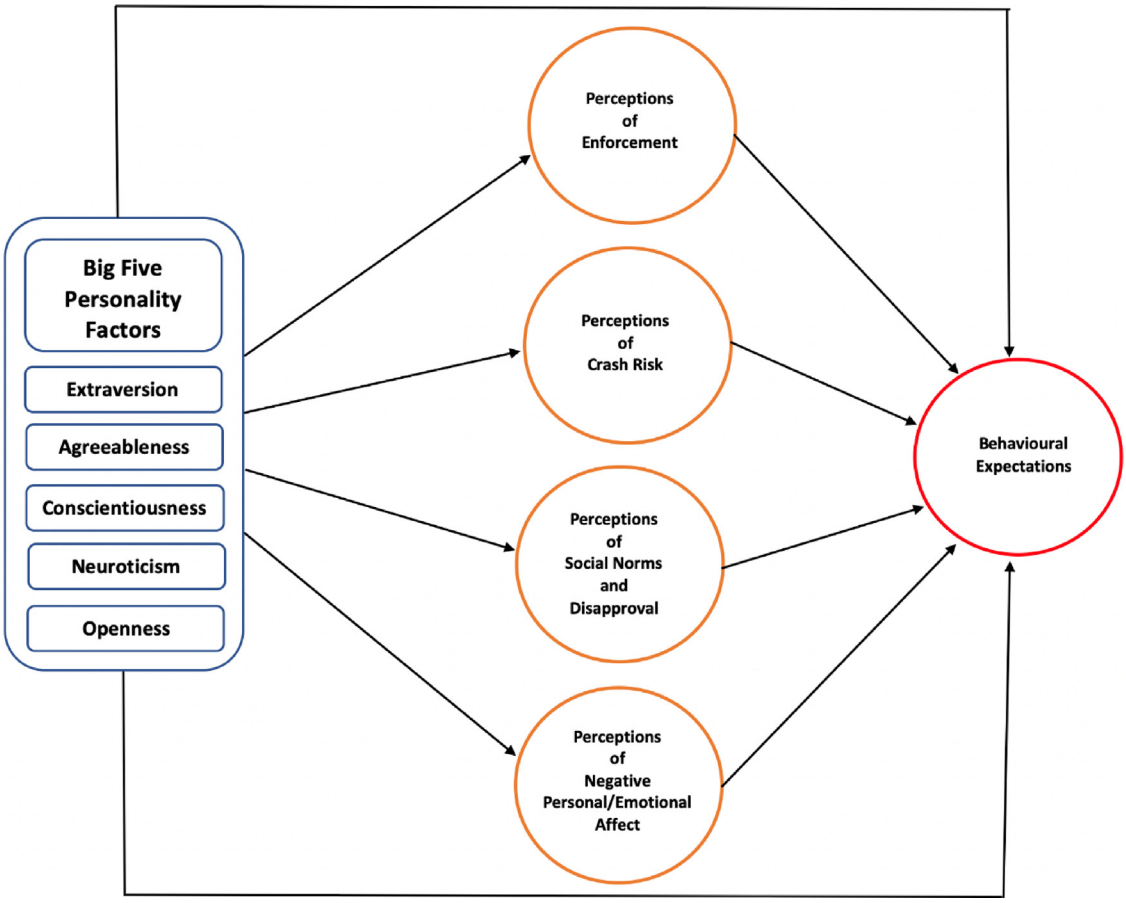

Fig. 1. Personality, perceptions and behavior conceptual model.

2.4. Perceptions of social norms and disapproval

Social sanctioning has been recognized as potentially the most significant form of sanctioning for an illegal driving behavior (Gottfredson & Hirschi, 1990). This construct was therefore included in the conceptual model to understand the perceptions drivers have toward the potential social consequences of illegal driving behavior.

2.5. Perceptions of negative personal and emotional affect

Anticipation of feeling negative emotions influences the decision to engage in illegal behaviors (e.g., Sandberg & Conner, 2008; Svensson et al., 2017). Indeed, the emotions of shame (Freeman et al., 2006a; Sherman et al., 2000) and guilt (e.g., Freeman et al., 2006b; Grasmick & Bursik, 1990) have been examined in existing road safety research. For example, Freeman et al. (2006b) asked repeat drunk drivers if they feel guilty after drinking and driving, finding 42.2% did. Similarly, Grasmick and Bursik (1990) asked individuals if they would feel shame or guilt if they were to drink and drive (the words shame and guilt were used interchangeably in their research). They found that expectations of experiencing shame was associated with significant patterns of deterrence. This construct was therefore included in the conceptual model developed for the current study to understand whether drivers believe that the performance of illegal driving behavior can have personal and emotional consequences for them as an individual.

2.6. Expectations to perform an illegal driving behavior

Expectations to perform an illegal driving behavior was the outcome variable in the conceptual model. Intentions to perform a behavior have been identified as a good indicator of the actual patterns of behavior in the future (e.g., Ajzen, 2005; Bachman et al., 1992; Nagin & Paternoster, 1994). In the current study, however, the outcome variable was framed as an expectation rather than an intention. This is due to the likelihood that illegal driving behavior is not necessarily a planned behavior. For example, a driver may unintentionally exceed the speed limit when overtaking, merging, or traveling down a steep incline. By using expectations rather than intentions, the aim was to capture the level of acceptability towards illegal driving behavior.

It is important to note that this study does not seek to provide an all-encompassing model of deterrence, nor try to explain all the factors that may underlie the performance of illegal driving behaviors, such as speeding. Rather, the conceptual model seeks to present another perspective from which deterrence and illegal driving behavior can be considered. Enhancing our understanding of factors that may deter the performance of illegal driving behaviors presents an opportunity to potentially reduce the incidence of crashes that are a result of these behaviors.

3. Methods

3.1. Data collection

A survey was designed to collect data to examine the pathways that may exist between the constructs, as shown in the conceptual model. The survey included validated scales, questions adapted from existing research, as well as newly developed questions.

The Big Five Inventory (BFI) was used to collect data on personality. This is a 44-item scale that collects data on extraversion, agreeableness, conscientiousness, neuroticism, and openness on a

5-point scale ranging from 'Disagree Strongly' to 'Agree Strongly' (John et al., 2001, John et al., 2008; John & Srivastava, 1999).

Two questions were used to collect data on each of perceptions of enforcement, crash risk, social norms and disapproval and negative personal and emotional affect. While all questions were phrased to be relevant to the current study, they were adapted from studies that have used expanded models of deterrence (e.g., Davey et al., 2008; Freeman et al., 2006a, 2006b, 2010, 2016; Freeman & Watson, 2009; Grasmick & Bursik, 1990; Grasmick & Green, 1980; Szogi et al., 2017). Enforcement questions focused on certainty of being apprehended for speeding and severity of sanctions for speeding offenses. Crash risk questions focused on worry about having a crash when speeding and worry about speeding behavior potentially leading to injuries of oneself or others. Social norms and disapproval questions asked respondents to indicate how much of the time they think it is wrong to speed and how they think those closest to them would respond if they were to speed. Negative personal and emotional affect questions focused on beliefs of feeling shame and guilt following a speeding offense. A 7-point Likert scale ranging from 'Strongly Disagree' to 'Strongly Agree' was used for all questions, with the exception of the first social disapproval question that asked how much of the time it is wrong to speed. This question was asked on a 5-point Likert scale ranging from 'Never wrong to do it' to 'Always wrong to do it.'.

For expectations to perform an illegal driving behavior, which in this study was speeding, one question was asked. Respondents were asked to indicate how likely they think it is they would speed in the 12 months that followed. This question was asked on a 7-point Likert scale ranging from 'Extremely Unlikely' to 'Extremely Likely.'.

A number of other questions were asked to collect data on the profile of survey respondents. These included gender, age, current employment status, and highest level of education achieved.

The survey was administered online using the online data collection platform *Qualtrics* (Qualtrics, 2022a). Data collection took place between July-August 2019. The survey took approximately 15 minutes to complete. The study received ethics approval from the Monash University Human Research Ethics Committee (MUHREC).

3.2. Selection criteria

To be eligible to participate in the study, respondents had to meet the following selection criteria:

1) Hold a driver's license in Victoria, Australia that allowed operation of a car (learner drivers were not eligible)
2) Resident of Victoria, Australia at the time of completing the survey
3) Had driven at least once on Victorian roads in the 12-month period prior to participating in the study

3.3. Participant recruitment

In order to recruit study participants, *Qualtrics* online sample research panel service was used (Qualtrics, 2022b). As part of this service, *Qualtrics* has access to individuals who have agreed to complete research studies relevant to them. Following completion of a survey, an individual receives credit points, which can then be used toward a reward, most often a gift card. *Qualtrics* were provided with the selection criteria developed for this study and sample size requirements. They then invited potential participants to complete the survey. A total of 5,108 responses were included in the final dataset.

3.4. Data analysis

SAS® Version 9.4 (SAS Software, 2014) was used to obtain descriptive statistics while MPlus Version 8.4 (Muthén & Muthén, 1998-2017) was used to examine the pathways in the conceptual model. To answer research questions one, two, and three, correlation and bivariate regression was used. To answer research question four, a mediated regression was used (Baron & Kenny, 1986). Mediated regression models were run separately for each personality trait across each of the four perceptions toward the potentially deterring factors. Therefore, given there are five personality traits and four perceptions constructs, 20 mediated models were run. The mediator variables in the current study were the four perceptions factors. The predictor variable was personality. The outcome variable was expectations to speed. For each model a direct, indirect and total effect is reported. The direct effect is the relationship between the predictor variable and the outcome variable, when the mediator variable is held constant. In the current study, this was therefore the relationship between the personality indicators and expectations to speed, when the perceptions variables were held constant. The indirect effect is the relationship between the predictor variable and the outcome variable, when values differ on the mediating variable. In the current study, this was therefore the relationship between the personality indicators and expectations to speed, when scores on the perceptions variables differed. The total effect is the sum of the direct and indirect effects, and provides an overall quantification of the relationship between the predictor and outcome variables (Hayes, 2013). Standardized results are reported.

Mediation effects are also reported. The mediation effect could either be complete, partial, or non-significant. Complete mediation was identified where the indirect effect was significant, but the direct effect was non-significant. Partial mediation was identified where both the direct and indirect effects were significant. Non-significant mediation was identified where the indirect effect was non-significant.

4. Results

4.1. Demographic profile

The demographic profile of individuals who completed the study is shown in Table 1. The largest group of study participants were aged 30–39 years (n = 1021, 20.0%). More females (n = 2682, 52.5%) completed the survey than males (n = 2410, 47.2%). Most respondents were engaged in some form of employment, either full-time (n = 2032, 39.8%) or part-time (n = 1223, 23.9%). Respondents were relatively likely to have completed high levels of education, with over two fifths (n = 2162, 42.3%) holding a university qualification.

4.2. Personality and expectations to speed

Table 2 shows the correlations between each of the constructs included in the conceptual model, and addresses research questions one, two, and three. The first research question focused on the relationship between personality and expectations to speed. Significant correlations (albeit weak) were found between all personality traits and speeding expectations, with all showing a negative association, with the exception of neuroticism, where the association was positive. This meant that higher scores on neuroticism ($r = 0.10$, $p < 0.001$) were associated with expressing higher expectations to speed in the following 12 months. Conversely, scoring highly on agreeableness ($r = -0.14$, $p < 0.001$) and conscientiousness ($r = -0.11$, $p < 0.001$) were associated with lower

Table 1
Demographic profile of study sample.

Demographic Profile	n	%
Age Group (years)		
18–19	152	3.0
20–24	512	10.1
25–29	455	8.9
30–39	1021	20.0
40–49	736	14.5
50–59	784	15.4
60–69	876	17.2
70–79	497	9.8
80+	61	1.2
Gender		
Female	2682	52.5
Male	2410	47.2
Current Employment Status		
Unemployed	343	6.7
Employed full-time	2032	39.8
Employed part-time or casual	1223	23.9
Home duties	346	6.8
Retired	979	19.2
Disability pension	117	2.3
Other	42	0.8
Do not wish to respond	26	0.5
Highest level of education achieved		
Did not complete school (left before Year 12/Form 6)	593	11.6
Completed High School (completed Year 12/Form 6)	982	19.2
Completed an Apprenticeship/TAFE/Technical College	1241	24.3
Completed a University degree (Bachelor/Graduate/Post Graduate)	2162	42.3
Other	102	2.0
Do not wish to respond	28	0.6

expectations to speed. These results indicate that personality has a relationship with expectations to speed, with the size and direction of the association differing depending on personality trait.

4.3. Personality and perceptions

The second research question focused on the relationship between personality and perceptions toward the four potentially deterring factors under examination – enforcement, crash risk, social norms and disapproval, and negative personal/emotional affect. As shown in Table 2, across all four perceptions constructs, drivers scoring highly on agreeableness expressed perceptions that were consistent with higher levels of deterrence, ranging from $r = 0.16$, $p < 0.001$ for perceptions of crash risk, up to $r = 0.33$, $p < 0.001$ for perceptions of social norms and disapproval. Drivers scoring highly on conscientiousness also expressed perceptions that were consistent with higher levels of deterrence. Again, neuroticism emerged as an exception. Higher scores on neuroticism were associated with perceptions that were indicative of lower levels of deterrence. Thus, these results indicate that personality is associated with perceptions toward factors that may act as deterrents to speeding.

4.4. Perceptions and expectations to speed

The third research question focused on examining whether perceptions of the non-legal sanctions under examination (perceptions of crash risk; perceptions of social norms and disapproval; perceptions of negative personal/emotional affect) have at least an equal to or even greater influence on speeding than perceptions of legal sanctions (perceptions of enforcement) in relation to speeding. As shown in Table 2, the correlation between social norms and disapproval and expectations to speed had the strongest correlation when considering the four perceptions factors ($r = -0.72$, $p < 0.001$). This can be compared with the results that emerged for the other three perceptions variables – perceptions of negative personal/emotional affect ($r = -0.51$, $p < 0.001$), perceptions of crash risk ($r = -0.50$, $p < 0.001$), and perceptions of enforcement ($r = -0.49$, $p < 0.001$). These results suggest there are factors other than legal sanctions that may have a deterring influence.

4.5. Mediating influence of perceptions between personality and expectations to speed

The final research question focused on examining how perceptions toward the four potentially deterring factors *mediate the relationship* between personality and expectations to speed. As indicated previously, 20 models were run.

4.5.1. Mediating influence of perceptions of enforcement

Table 3 provides the results for the models that examined the mediating influence of perceptions of enforcement. The results showed that the relationship between extraversion and expectations to speed was completely mediated by perceptions of enforcement, with the direct effect non-significant ($\beta = -0.02$, $p = 0.18$) and the indirect effect (mediated by perceptions of enforcement) statistically significant ($\beta = -0.05$, $p < 0.001$). For agreeableness, conscientiousness and openness, while the results revealed that their relationship to expectations to speed was not completely mediated by perceptions of enforcement, the larger indirect effects indicated that the association between these personality traits and expectations to speed still did occur primarily through perceptions of enforcement. Thus, drivers scoring highly on each of these four personality traits expressed low expectations to speed, and this was primarily a result of their agreement that the risks of enforcement for speeding are high. This can be compared with neuroticism where the indirect effect was non-significant, and the direct effect large and statistically significant ($\beta = 0.11$, $p < 0.001$). Drivers scoring highly on neuroticism reported greater expectations to speed.

Table 2
Correlations between personality traits, perceptions of enforcement, crash risk, social norms and disapproval, negative personal/emotional affect and expectations to speed.

	1	2	3	4	5	6	7	8	9
Extraversion									
Agreeableness	0.19**								
Conscientiousness	0.22**	0.55**							
Neuroticism	−0.31**	−0.40**	−0.45**						
Openness	0.34**	0.24**	0.23**	−0.10**					
Perceptions of enforcement	0.10**	0.22**	0.14**	0.01	0.12**				
Perceptions of crash risk	0.10**	0.16**	0.09**	−0.03*	0.05**	0.63**			
Perceptions of social norms and disapproval	0.10**	0.33**	0.26**	−0.13**	0.06*	0.70**	0.80**		
Perceptions of negative personal/emotional affect	0.08**	0.19**	0.13**	−0.04*	0.07**	0.74**	0.74**	0.78**	
Expectations to perform the behavior	−0.07**	−0.14**	−0.11**	0.10**	−0.03*	−0.49**	−0.50**	−0.72**	−0.51**

*<0.05; **<0.001.

Table 3
Direct, indirect and total effect for the relationship between personality and expectations to speed, mediated by perceptions of enforcement.

Personality Trait	Expectations to drive at up to 10 km/h above the speed limit			
	Direct Effect	Indirect Effect	Total Effect	Mediation Effect
Extraversion	−0.02	−0.05**	−0.07**	Complete
Agreeableness	−0.03*	−0.11**	−0.14**	Partial
Conscientiousness	−0.04*	−0.07**	−0.11**	Partial
Neuroticism	0.11**	−0.01	0.10**	Non-significant
Openness	0.03*	−0.06**	−0.03*	Partial

*<0.05; **<0.001.

4.5.2. Mediating influence of perceptions of crash risk

Table 4 provides the results for the models that examined the mediating influence of perceptions of crash risk. Again, the relationship between extraversion and expectations to speed was completely mediated by the perceptions variable, with the direct effect non-significant ($\beta = -0.02$, $p = 0.14$) and the indirect effect (mediated by perceptions of crash risk) statistically significant ($\beta = -0.05$, $p < 0.001$). A similar pattern was observed for openness, with the relationship of this trait with expectations to speed being completely mediated by perceptions of crash risk ($\beta = -0.03$, $p < 0.05$). Thus, drivers scoring highly on each of these two personality traits expressed low expectations to speed, and this was primarily a result of their agreement that the risks of crash when speeding are high. For agreeableness, conscientiousness and neuroticism, the direct effects between these personality traits and expectations to speed were equal to or greater than the indirect effect, indicating that perceptions of crash risk only partially mediates the relationship. For neuroticism, perceptions of crash risk only partially mediated the relationship with expectations to speed. However, the positive indirect effect ($\beta = 0.02$, $p < 0.05$) indicates that the higher expectations to speed amongst drivers scoring highly on this trait was due in a small part to them perceiving the risk of crash associated with speeding is not high.

4.5.3. Mediating influence of perceptions of social norms and disapproval

Table 5 provides the results for the models that examined the mediating influence of perceptions of social norms and disapproval. The models that examined extraversion, neuroticism, and openness all had non-significant direct effects, but statistically significant indirect effects, indicating that the relationship between these personality traits and expectations to speed was completely mediated by perceptions of social norms and disapproval. In the case of extraversion and openness, higher scores meant drivers perceived speeding would have negative social outcomes, and subsequently lower expectations to speed. Conversely, in the case of neuroticism, higher scores meant drivers' perceptions of speeding having negative social outcomes was lower, and subsequently their expectations to speed were higher. In the case of agreeableness and conscientiousness, while the direct relationship to speeding was positive, the indirect effect was so strong ($\beta = -0.25$, $p < 0.001$ for agreeableness; $\beta = -0.19$, $p < 0.001$ for conscientiousness) that deterrence from speeding was ultimately observed.

4.5.4. Mediating influence of perceptions of negative personal/emotional affect

Table 6 provides the results for the models that examined the mediating influence of perceptions of negative personal/emotional affect. The models that examined extraversion and openness were completely mediated by perceptions of negative personal/emotional affect, with significant indirect effects. In the case of agreeableness and conscientiousness, perceptions of negative personal/emotional affect had a partial mediating effect. However, in both cases, the indirect effect was larger ($\beta = -0.09$, $p < 0.001$ for agreeableness; $\beta = -0.07$, $p < 0.001$ for conscientiousness) than the direct effect ($\beta = -0.05$, $p < 0.001$ for agreeableness; $\beta = -0.05$, $p < 0.001$ for conscientiousness) indicating a greater part of the total effect was operating through perceptions of negative personal/emotional affect. For all four of these personality traits, drivers perceived that speeding could potentially result in them experiencing negative emotions, and subsequently their expectations to speed were lower. Comparatively, in the case of neuroticism, both the direct ($\beta = 0.08$, $p < 0.001$) and indirect effects ($\beta = 0.02$, $p < 0.05$) were significant, although they were positive. Drivers scoring highly on neuroticism perceived there to be a lower risk of experiencing negative emotions from speeding. They also had higher expectations of speeding.

5. Discussion

This study aimed to understand factors that may deter the performance of speeding. This was achieved by examining a series of pathways in the *Personality, Perceptions and Behavior Model*, which proposed that perceptions of enforcement, perceptions of crash risk, perceptions of social norms and disapproval, and perceptions of negative personal/emotional affect mediate the relationship between personality and expectations to speed. Direct pathways between constructs in the model were also examined.

All personality traits were found to be significantly associated (it must be noted weak, in most cases) with expectations to speed. High scores on agreeableness and conscientiousness, in particular, were associated with lower expectations to speed. Thus, these drivers showed patterns of deterrence. This is consistent with existing

Table 4
Direct, indirect and total effect for the relationship between personality and expectations to speed, mediated by perceptions of crash risk.

Personality Trait	Expectations to drive at up to 10 km/h above the speed limit			
	Direct Effect	Indirect Effect	Total Effect	Mediation Effect
Extraversion	−0.02	−0.05**	−0.07**	Complete
Agreeableness	−0.07**	−0.07**	−0.14**	Partial
Conscientiousness	−0.07**	−0.04**	−0.11**	Partial
Neuroticism	0.09**	0.02*	0.10**	Partial
Openness	−0.01	−0.03*	−0.03*	Complete

*<0.05; **<0.001.

Table 5
Direct, indirect and total effect for the relationship between personality and expectations to speed, mediated by perceptions of social norms and disapproval.

Personality Trait	Expectations to drive at up to 10 km/h above the speed limit			
	Direct Effect	Indirect Effect	Total Effect	Mediation Effect
Extraversion	0.00	−0.07**	−0.07**	Complete
Agreeableness	0.11**	−0.25**	−0.14**	Partial
Conscientiousness	0.08**	−0.19**	−0.11**	Partial
Neuroticism	0.01	0.09**	0.10**	Complete
Openness	0.01	−0.04*	−0.03*	Complete

*<0.05; **<0.001.

Table 6
Direct, indirect and total effect for the relationship between personality and expectations to speed, mediated by perceptions of negative personal/emotional affect.

Personality Trait	Expectations to drive at up to 10 km/h above the speed limit			
	Direct Effect	Indirect Effect	Total Effect	Mediation Effect
Extraversion	−0.02	−0.04**	−0.07**	Complete
Agreeableness	−0.05**	−0.09**	−0.14**	Partial
Conscientiousness	−0.05**	−0.07**	−0.11**	Partial
Neuroticism	0.08**	0.02*	0.10**	Partial
Openness	0.00	−0.03**	−0.03*	Complete

*<0.05; **<0.001.

research that found individuals scoring higher on agreeableness and conscientiousness had lower levels of cell-phone use while driving (Molnar et al., 2021). In comparison, high scores on neuroticism were associated with higher expectations to speed. Thus, these drivers showed less positive patterns of deterrence. Similar patterns were observed between personality and the perceptions variables, with drivers scoring highly on agreeableness and conscientiousness expressing perceptions more consistent with deterrence. These results are consistent with existing research on personality and risky behaviors (e.g., Riendeau et al., 2018; Shen et al., 2018; Starkey & Isler, 2016; Taubman-Ben-Ari & Yehiel, 2012; Zhang et al., 2018). Further, the results that emerged in relation to high scores on neuroticism being associated with higher expectations to speed is consistent with research beyond the area of road safety. Research has shown that higher scores on neuroticism may be associated with other negative behaviors, including, but not limited to, perpetrating workplace bullying (e.g., Wilson & Nagy, 2017), the risky consumption of alcohol (e.g., Lyvers et al., 2019), and work absenteeism (e.g., Störmer & Fahr, 2013).

Despite the consistencies with existing research noted above, the current study also produced findings that are inconsistent with earlier research. Hong and Paunonen (2009) and Starkey and Isler (2016) have found evidence to suggest that individuals scoring highly on neuroticism display lower levels of risky driving behavior. It is difficult to determine what may be behind the differences between studies that have looked at personality and driving behavior, including the current research. One possible explanation that has been proposed is the influence of cultural differences (e.g., Hofstede & McCrae, 2004). It is possible that the patterns that emerged in the current research may be in part a reflection of the cultural and social norms that operate in Victoria, Australia.

Considering the four perception factors that were examined – enforcement, crash risk, social norms and disapproval, and negative personal/emotional affect, the results showed that all four had a deterring influence. These results are consistent with many existing studies that have applied models of deterrence in the road safety area, and have found that non-legal sanctions, in particular social sanctions, have an equal to, or even greater influence on the performance of illegal driving behaviors (e.g., Baum, 1999; Berger & Snortum, 1986; Freeman et al., 2016; Freeman & Watson, 2009; Grasmick & Green, 1980; Green, 1989; Loxley & Smith, 1991; Piquero & Paternoster, 1998). Similarly, a study undertaken in the United States that classified drivers as non-speeders, sometimes speeders, and speeders, also found differences in attitudes toward speeding, including how risky the different groups viewed the behavior (Schroeder et al., 2013). Thus, the previous research, as well as the current research, supports attitudes and perceptions as a factor underlying illegal driving behavior, including speeding.

The final focus of this study was to examine whether perceptions toward the four potential deterrents have a mediating influence on the relationship between personality and expectations to speed. The results showed perceptions of enforcement, perceptions of crash risk, perceptions of social norms and disapproval, and perceptions of negative personal/emotional affect in many instances mediated the relationship between personality and expectations to speed.

Together, these results suggest that personality influences the perceptions drivers have towards enforcement, crash risk, social norms and disapproval, and negative personal/emotional affect, which in turn go on to influence expectations to speed. This result is consistent with previous research that examined personality and road safety attitudes (e.g., Lucidi et al., 2014; Machin & Sankey, 2008; Mallia et al., 2015; Steinbakk et al., 2019; Zhang et al., 2018). While the previous research used different personality scales to the Big Five, it is evident that the inclusion of multiple theoretical perspectives within a conceptual model can further our understanding of factors that may interact to influence driving behavior.

The results of the current research can aid efforts to enhance road safety in a number of ways. First, while legal sanctions are the primary means to respond to illegal driving behaviors, other options to encourage safe driving may have greater effectiveness, for some drivers. This could include incentivizing good driving, through for example, a system of free license renewals for drivers who have a displayed patterns of safe driving behavior in the period prior to their license renewal, as evidenced by an absence of any traffic sanctions. Like all new initiatives, the effectiveness of such a system would require evaluation.

Second, another option that could encourage safe driving may be to highlight the social consequences of illegal driving behavior. Given the role that social norms and disapproval were found to have in the current study, future road safety campaigns, both in Victoria and in other jurisdictions may find value in highlighting

the social consequences of illegal driving behavior. For example, in Victoria, Australia, the Transport Accident Commission is a government with an interest and responsibility for improving road safety, and engages in the development of social marketing campaigns to promote safe driving behavior. These advertisements seek to communicate the potential consequences of engaging in dangerous driving behavior, including the risk of being involved in a serious crash. Future campaigns could focus on promoting how illegal driving behavior may result in disapproval from family and/or friends, for example.

Third, while personality is not a factor that can be influenced to lead to changes in driving behavior, the current study points to personality traits of drivers who do not respond positively to deterrents, and therefore may be at higher risk of offending. Understanding these traits presents a possible point of intervention. Research suggests that different personality types learn in different ways (Bidjerano & Dai, 2007; Vincent & Ross, 2001; Zhang, 2003). Using knowledge and understandings of the way in which different personality types absorb information may be useful when developing interventions to respond to drivers with lengthy offending histories. The careful development and testing of interventions targeted to personality types may provide another option for enhancing safety on the roads.

While the current study has many strengths, including use of a large sample size, use of a diverse group of drivers (e.g., males and females, drivers of all ages, drivers with different levels of experience) and use of a wide range of variables (including combining two theoretical perspectives), there were some limitations. First, participants were recruited from Victoria, Australia, and therefore the results may not be applicable to other jurisdictions. Given road rules are enforced at a jurisdictional level, it is possible that the perceptions drivers expressed in the current study are a result of their experience driving in Victoria. Future research could be conducted to apply the *Personality, Perceptions and Behavior Model* in other jurisdictions.

Second, this study only examined the *Personality, Perceptions and Behavior Model* in relation to speeding up to 10 km/h above the speed limit. It is unclear whether the results found in this study are consistent with what would be found if other illegal driving behaviors were examined. Future research could examine other offense types, or take a comparative approach and consider multiple offense types in the same study. By understanding the factors that may deter specific driving behaviors, there may be greater opportunity to ensure that strategies put in place are tailored so they have the greatest chance to achieve success.

Third, this study used self-report data. There are some limitations with self-report data that may have had an influence on the quality of the data. Respondents may have rushed through the survey and given little thought to their responses, misread, or misunderstood questions. Respondents may have also not been truthful, or have limited self-awareness of their own patterns of driving behavior. Furthermore, asking drivers their expectations to speed does not necessarily mean they will ultimately behave in this way. Future research could be conducted using official data from licensing authorities, linking these data with personality and perceptions data collected via survey. Finally, some respondents may have participated, despite not meeting the eligibility criteria. For example, they may not have been residents of Victoria, Australia.

Fourth, this study only sought to consider the pathways in the *Personality, Perceptions and Behavior Model* for drivers in Victoria overall. Separate analyses were not undertaken for different groups of drivers (e.g., based on age, gender, years of driving experience, education level achieved, employment status, license type). It is possible that results may differ between groups. Future research could examine the pathways in the *Personality, Perceptions and Behavior Model* for specific groups of drivers, or alternatively, seek to compare and contrast driver groups.

Fifth, it is important to note that previous research has found the environment that surrounds a road, such as road width and the absence of trees and structures, can influence drivers' speed (e.g., Antonson et al., 2009, 2014; Wan et al., 2018; Yu et al., 2019). The current research did not provide any differentiation between different traffic environments or conditions, and drivers expectations to speed. Future research may like to explore the *Personality, Perceptions and Behavior Model* with various outcome variables related to speeding. This could include speeding in areas around schools, roads with low speed limits, roads in poor condition or with poor infrastructure, quiet roads and/or busy roads, wet and icy roads, and roads where the environment is significantly built up. It is possible some drivers may accept exceeding of the speed limit in some situations, but in other situations, may have a strong recognition of the risks posed or the likelihood of being apprehended.

6. Conclusion

This study showed that personality and the perceptions toward enforcement, crash risk, social norms and disapproval, and negative personal/emotional affect all have an influence on *expectations to speed*. Perceptions toward enforcement, crash risk, social norms and disapproval, and negative personal/emotional affect also generally mediated the relationship between personality and expectations to speed. These results potentially characterize drivers who may be at a greater risk of offending. This information may help to develop strategies to encourage these individuals to drive in a responsible manner and has the potential to enhance safety on the roads.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Safety voice climate: A psychometric evaluation and validation

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ABSTRACT

Introduction: Speaking up about safety issues, termed "safety voice," is a proactive response where people across all levels of the organization express their concerns to prevent physical hazards. An understanding of safety voice requires insight into its antecedents. A perceived need to fit in with the organization and fear of consequences can trump the courage to speak out about safety concerns. Safety voice climate can be seen as a manifestation of the social exchanges in an organization and functions as a roadmap of which speaking out behaviors are encouraged and which behaviors are not. This study conceptualizes safety voice climate, presents the Safety Voice Climate Scale (SVCS) as a measurement tool, and gathers initial evidence for its validity. The study also assesses the associations between the SVCS and safety voice behavior. *Method*: The SVCS and the measurement of safety voice behavior were derived from the Trends in Risk Level in the Norwegian Petroleum Activity questionnaire. The SVCS includes the two theoretical dimensions *Work colleagues' encouragement of safety voice* and *Leaders' attitudes towards safety voice*. Psychometric properties were tested with a representative sample from the Norwegian petroleum sector (n = 7,624). *Results*: Confirmatory factor analyses supported the proposed two-factor model, and the internal consistency of the factors was good. Furthermore, a structural equation model including the SVCS as predictors of safety voice behavior showed a good fit, indicating acceptable criterion validity, although only the *Work colleagues' encouragement of safety voice* variable was significantly associated with safety voice behavior. *Conclusion and practical application*: The SVCS can be used as a tool to detect some of the barriers and supporting elements relating to safety voice and guidance on the efforts needed to foster work climates that promote communication of safety issues.

1. Introduction

Employees' active communication about safety-related issues is vital for maintaining safe work environments and preventing injuries (e.g., Christian, Bradley, Wallace, & Burke, 2009; Nahrgang, Morgeson, & Hofmann, 2011; Neal & Griffin, 2006). In light of this, the concept of safety voice (understood as a proactive response where people across all levels of the organization express their concerns to prevent physical hazards) has received considerable attention during recent years (Curcuruto, Strauss, Axtell, & Griffin, 2020; Noort, Reader, & Gillespie, 2019). Safety voice can be about rule or policy violations, action errors, and other safety violations and can be crucial in providing preventive actions to avoid accidents, injuries, and even catastrophes (Mathisen, Tjora, & Bergh, 2022). Speaking out about minor incidents could prevent the development of larger accidents or injuries. Nevertheless, employee silence remains a common reason for communication breakdowns and errors (Haerkens, Jenkins, & van der Hoeven, 2012), and studies indicate that 50–80% of work-related injuries and accidents go unreported (Bienefeld & Grote, 2012; Probst, Brubaker, & Barsotti, 2008), while a more recent systematic review estimated that 44% of people raise safety concerns (Noort et al., 2019). Considering this, it is important to understand the factors that encourage employee safety voice, and organization–employee relationship quality has repeatedly been suggested as a potential important antecedent (Chamberlin, Newton, & Lepine, 2017; DeJoy, Della, Vandenberg, & Wilson, 2010; Morrison, Wheeler-Smith, & Kamdar, 2011; Tucker, Chmiel, Turner, Hershcovis, & Stride, 2008). Various theories have been applied to describe the exchange relationship between organizations and employees, and different organizational climate theories are prevalent among these (Schneider, Ehrhart, & Macey, 2013). This paper presents the safety voice climate concept as a specific type of organizational climate connected to safety voice behavior. This line of research is extended by introducing the Safety Voice Climate Scale (SVCS) and examining the relationship between safety voice climate and safety voice behavior.

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1.1. Definition of safety voice climate

Safety voice climate refers to whether speaking out about safety concerns in the workplace is perceived to be encouraged (see Frazier & Bowler, 2015; Morrison et al., 2011). Thus, the safety voice climate is a facet-specific climate suggested as a precursor of safety voice.

Safety voice is characterized by "(a) communication motivated toward changing perceived unsafe working conditions that have implications for individual and organizational health, (b) can flow through formal and informal channels, and (c) can be directed toward numerous targets (e.g., supervisors/managers, coworkers, union officials, government officials)" (Tucker et al., 2008, p. 320). Safety voice can be intended to improve general safety levels on the one hand, or to prevent hazards in emergency situations on the other (Noort et al., 2019). Examples of safety voice include providing constructive suggestions for change, reporting possible safety risks or violations of safety practice, and challenging the status quo (Conchie, 2013; Conchie, Taylor, & Donald, 2012; Tucker et al., 2008; Turner, Tucker, & Kelloway, 2015). The concept of safety voice could be distinguished from other related concepts like "voice," which is a more general concept that includes expressions of organizationally relevant content (Chamberlin et al., 2017); "safety citizenship behavior," which is also a broader concept that refers to prosocial employee activities essential for managing risk (Curcuruto, Conchie, & Griffin, 2019); and "safety participation," which involves employees' voluntary exhibition of extra-role behaviors in the context of safety beyond their roles (e.g., Bayram, Arpat, & Ozkan, 2022). Alternatively, safety voice could be categorized as one specific type of safety participation behavior. In support of this suggestion, Morrow, Gustavson, and Jones (2016) defined safety voice as employee willingness to proactively participate in communication-related behaviors for the purpose of improving workplace safety. The conceptual distinctiveness of safety voice from the above-mentioned concepts has also been thoroughly discussed elsewhere and will not be further addressed in the current article (e.g., Curcuruto et al., 2020; Krenz & Burtscher, 2021; Morrison, 2011; Morrison et al., 2011; Morrow, Gustavson, & Jones, 2016; Noort et al., 2019). An understanding of safety voice requires insight into its antecedents. Voice behavior is driven by intentional and motivational aspects. A perceived need to fit in with the organization and fear of consequences can trump the courage needed to speak out (Etchegaray, Ottosen, Dancsak, & Thomas, 2020; Manapragada & Bruk-Lee, 2016; Martinez et al., 2015). For instance, lessons from the aviation industry indicate that subjective beliefs about what, when, and to whom it is appropriate to speak out determine voice behavior (Bienefeld & Grote, 2012). These beliefs seem to be influenced by group norms and can be considerably different across contexts. Manapragada and Bruk-Lee (2016) distinguished between a number of motives for staying silent about safety concerns, including self-based (speaking out could lead to negative repercussions such as being perceived as annoying by colleagues), other-based (speaking out could hurt others, e.g., they could get fired), relationship-based (speaking out could hurt relationships with others, e.g., causing conflicts), and climate-based (norms, managerial practice, and support do not encourage voice). Furthermore, a systematic review of safety voice literature that included a total of 50 studies found that the most frequently studied individual antecedent factor was fear of consequences, which was generally negatively associated with safety voice (Noort et al., 2019). Among the most studied group-related antecedents were openness (positive) and good (positive) or fragile (negative) relationships with receivers. On the organizational level, structural factors (e.g., hierarchical structure as a negative factor) and cultural factors (e.g., supportive culture as a positive factor) were frequently studied. Most of the factors identified in the above-summarized studies involve social exchanges and relationships and reflect a recognition that safety at work is part of a dynamic interaction between the members of an organization (DeJoy et al., 2010; Laurent, Chmiel, & Hansez, 2018; Reader, Mearns, Lopes, & Kuha, 2017). Social exchange theory offers a theoretical foundation for understanding these interactions and suggests that individuals will reciprocate benefits (e.g., goods, friendly environment, attitudes, emotions, etc.) with benefits and respond with either indifference or hostility (e.g., threat, dishonor) to harm (Cropanzano, Anthony, Daniels, & Hall, 2017; Cropanzano & Mitchell, 2005; Blau, 1986; Gouldner, 1960). When leaders and colleagues show their attentiveness to safety by valuing concerns and suggestions for improving safety, employees develop a belief that their organization has a positive orientation toward safety, which may increase the probability that they will participate in safety-related behaviors (Tucker et al., 2008). Thus, drawing on the social exchange theory, safety voice can be understood as an extra-role behavior that employees are likely to engage in when they believe the organization rewards and supports them (Rhoades & Eisenberger, 2002; Wayne, Shore, & Liden, 1997). Reflecting this suggestion, in their review study of safety voice, Noort et al. (2019) identified five studies measuring support, all having positive associations with safety voice. In terms of social exchange theory, organizational climate can be seen as a manifestation of the social exchanges in an organization and functions as a roadmap of which behaviors are expected and which are not. In this regard, safety voice climate refers to perceptions of whether speaking out about safety issues is being encouraged and reflects management' as well as colleagues' values and attitudes regarding safety voice behavior. This study proposes that important origins of safety voice behavior may be found in the safety voice climate. For example, where a manager does not have a priority for safety voice, it is expected that safety voice is not often being performed at the workplace.

1.2. Safety voice climate and related constructs

Since the introduction of the concept of organizational climate in the 1970s, several types of organizational climates have emerged in the literature, including service climate, climate for creativity, and safety climate (Kuenzi & Schminke, 2009; Schneider et al., 2013), each of which has its own specific facets and outcomes. In the current study, the focus is on safety voice climate, which is a more specific type of climate than the now well-established concept of safety climate (He, Wang, & Payne, 2019; Zohar, 2010, 2011) and the concept of voice climate (Frazier & Bowler, 2015; Knoll, Neves, Schyns, & Meyer, 2020; Morrison et al., 2011). The related concept of speak-up-related climate has also been introduced, but this is specifically related to patient safety (Richard, Pfeiffer, & Schwappach, 2017; Schwappach & Richard, 2018). Moreover, Sexton et al. (2006) presented safety attitudes as being a climate concept, and it includes a number of subtopics like teamwork climate, perceptions of management, and safety climate, but no subtopics related to safety voice.

Whereas voice climate is concerned with general types of voice, such as communication about issues of production, efficiency, and performance (Frazier & Bowler, 2015; Tangirala & Ramanujam, 2008), safety voice climate is about the promotion or hampering of voicing safety concerns (see also Noort et al. (2019) for a discussion on the distinction between voice and safety voice). It is possible that the expression of safety voice is perceived as more challenging than general voice because there may be larger social risks involved. As its contents are generally about prohibiting risky behaviors that may lead to incidents and accidents, it is likely that recipients may perceive the message as negative critique (Detert & Burris, 2007; Tucker et al., 2008). On this basis, the need for

encouragement to speak out may be stronger for safety voice than general voice. Thus, the emphasis on encouragement to speak out may need to be even stronger in a safety voice climate than in the case of general voice climate.

Whereas safety climate is widely defined as the "shared perceptions with regard to safety policies, procedures and practices" in an organization (e.g., Zohar, 2011, p. 143), safety voice climate refers to whether speaking out about safety concerns in the workplace is perceived to be encouraged (see Frazier & Bowler, 2015; Morrison et al., 2011). Measures of safety climate include a combination of formal aspects, such as policies for safety, and more informal behavioral aspects (i.e., practices; Zohar, 2008), whereas the safety voice climate concerns more specifically perceived levels of encouragement to speak out about safety issues. Moreover, whereas safety climate is often conceptualized at the team or organizational level (Zohar, 2008, 2010), this study considers safety voice climate as mainly manifested by subjective perceptions. The level of conceptualization and analysis of climate is a continuing debate among researchers; climate can be investigated at different levels of the organization (Rousseau, 1985). Subjective safety voice climate, which is the main focus of the present study, reflects individual perceptions that speaking out about safety concerns in the workplace is encouraged. Thus, when considered from an individual perspective, safety voice climate represents a cognitive interpretation of a work group or organization (James, James, & Ashe, 1990). Proponents of the subjective climate perspective suggest that individuals react to these cognitive and subjective representations of environments rather than to actual and objective work climates (James & Sells, 1981). Subjective climates can be regarded as dynamic products of the employees' experiences and can differ as a function of diverse contexts and workgroup processes (bottom-up emergent phenomena; Kozlowski, 2015).

Hypothesis 1. *Most of the variance of safety voice climate is explained on the individual level.*

1.3. Safety voice climate dimensions

In their presentation of a group voice climate, Morrison and colleagues (2011) suggested a two-dimensional construct. The first dimension, group voice safety beliefs, is the belief about whether speaking out is safe or dangerous. The second dimension, group voice efficacy, is the belief about whether group members have the capability to voice effectively. Numerous empirical studies have included this model in different settings (e.g., Duan, Xu, & Frazier, 2019; Knoll et al., 2020). Richard et al. (2017) and Schwappach and Richard (2018) suggested a three-dimensional model of speaking out climate related to patient safety consisting of the variables "psychological safety for speaking up," "encouraging environment for speaking up," and "resignation towards speaking up." Possibly, work environments that encourage speaking out behavior will also facilitate safety for speaking out so that they could be overlapping dimensions. A possible limitation of the above-mentioned voice climate models is that they don't include leadership encouragement or support as a dimension even though leaders play a central role in the development of climates and as role models. For instance, Momeni (2009) found that more than 70% of employees' perceptions of organizational climate were shaped directly by their leader's style of leadership and behavior.

Based on these considerations, this study conceptualizes safety voice climate as having two dimensions. The first, *Work colleagues' encouragement of safety voice*, combines the abovementioned factors "voice safety beliefs" and "encouraging environment for speaking up." Thus, the dimension comprises a perception of whether there is a work environment among colleagues where it is safe to speak out and that this type of behavior is encouraged. The dimension involves an evaluation of outcome expectancy and is consistent with studies suggesting that employees often believe that they will be punished if they speak out, particularly about sensitive issues such as safety concerns (Detert & Burris, 2007; Morrison et al., 2011). The dimension concerns whether employees perceive pressure against or encouragement for speaking out about safety concerns and to what extent they perceive it as uncomfortable or difficult to speak out. Work colleagues' encouragement of safety voice possibly relates to psychological safety, which is a separate stream of research with a focus on perceived safety to engage in interpersonal behaviors influencing learning and performance or beliefs about whether a particular context is safe for interpersonal risk-taking (Edmondson, 1999). However, work colleagues' encouragement of safety focuses specifically on the perceived psychological safety of voicing safety issues as opposed to other forms of interpersonally risky behavior.

The second dimension is a perception of *Leader's attitudes toward safety voice*. A key factor that influences whether employees have the courage to speak out is the signals that the leader sends. Leaders may stimulate their employees to voice safety concerns by actively appreciating and inviting input (Alingh, van Wijngaarden, van de Voorde, Paauwe, & Huijsman, 2019). In their analysis of organizational silence, Morrison and Milliken (2000) suggested that managers played a key role and proposed two important factors that would suppress voicing behavior. First, managers' fear of receiving negative feedback, particularly from subordinates. Consequently, they will avoid getting negative feedback or ignore, dismiss, or attack the sender when they receive negative feedback. Second, managers hold implicit beliefs about employees as self-interested and untrustworthy, that management knows best, and that dissent is bad while unity is good. Findings from several studies resonate with these suggestions. For instance, transformational leadership (that represents the adverse leadership thinking than described above, characterized by intellectual stimulation and inspirational motivation) is positively associated with employee safety voice (Bazzoli, Curcuruto, Morgan, Brondino, & Pasini, 2020; Conchie et al., 2012). In addition, studies have documented that voice behavior, not specifically related to safety, is positively associated with leadership behaviors such as supportive leadership (Elsaied, 2019), servant leadership (Chughtai, 2016; Yan & Xiao, 2016), inclusive leadership (Chen, Liang, Feng, & Zhang, 2023; Lee & Dahinten, 2021), self-sacrificial leadership (Zhang, Li, & Huang, 2020), and empowering leadership (Jada & Mukhopadhyay, 2018). Thus, encouraging leadership is a vital factor in the promotion of voice as well as safety voice.

Moreover, Zohar and Luria (2005) suggested that focal climate facets could represent competing operational requirements in relation to other facets (e.g., safety vs. service, creativity vs. efficiency). Therefore, the best indicators of an organization's true priorities as distinguished from their formally stated counterparts are the actual prioritizations leaders give to safety voice, and these should be more important parts of an organizational climate than the formal rules and policies (Zohar, 2008). Thus, the dimension "Leader's attitudes towards safety voice" reflects whether the leaders listen when safety concerns are presented, take the message seriously, and express that they appreciate safety voice behavior.

A few studies have applied items to assess voice climate. However, most of these (Duan et al., 2019; Frazier & Bowler, 2015; Hsiung & Tsai, 2017; Knoll et al., 2020; Lee, Wang, & Liu, 2017; Liu, Mao, & Chen, 2017; Morrison et al., 2011) were based on a voice *behavior* scale developed by LePine and Van Dyne (1998), and the distinction between voice behavior and voice climate was unclear. Moreover, these studies measured general voice climate and not safety voice climate. A scale has been developed to measure the related, but broader, concept of safety citizenship

behavior that incorporates items similar to safety voice (e.g., "I make suggestions to management to improve the safety of the work environment;" Reader et al., 2017). However, this is not a climate measure. A few scales have been specifically developed to measure safety voice or speaking out climate in the health sector, but they contain few items with unclear theoretical basis (Nembhard, Yuan, Shabanova, & Cleary, 2015), items that specifically concern patient safety (Richard et al., 2017; Schwappach & Richard, 2018) or the target response group for the scale were patient groups (Martinez et al., 2015). In the current study, a safety voice climate measure is presented, named the Safety Voice Climate Scale (SVCS), which can be applied across sectors. In testing the reliability and factor structure, the study offers a psychometric validation of the SVSC.

Hypothesis 2. *The Safety voice climate scale (SVCS) is identified by two sub-factors: "Work colleagues' encouragement of safety voice" and "Leader's attitudes towards safety voice."*

1.4. Associations between safety voice climate and safety voice behavior

The relationship between climate dimensions and voice behavior is not straightforward. Results from two simulation studies from the health sector showed conflicting evidence regarding whether trainees' voice behavior toward their supervisors could be manipulated by supervisors displaying encouraging or discouraging communication (Friedman et al., 2015; Salazar et al., 2014). Furthermore, studies on the organizational level indicate that the relationships between climate, psychological safety, and voice behavior are also somewhat unclear (Etchegaray et al., 2020; Gilmartin et al., 2018). While several studies show that the complex relationships between organizational climate and voice behavior are still not clearly understood, this can also be interpreted in light of how the main concepts are defined, operationalized, and assessed. While safety voice behavior is closely linked to safety concerns connected to specific events that trigger these concerns and are thus highly context-sensitive, perceived climates (including the more specific safety climate) are more generalized perceptions of procedures and behaviors among coworkers. As Zohar (2008) commented, personnel develop attitudes and related behaviors that are domain-specific for organizational functioning. Within high-risk industries, there will typically be attitudes and behaviors developed that are specifically related to safety. A study from the health sector explored more specific measurements of speak-up-related climate and speaking-up frequency (Schwappach & Richard, 2018). This study concluded that perceptions of a speaking-up climate reduced decisions to remain silent among staff in hospitals. Still, there is a need for a measure that can be applied across sectors to identify differences in safety voice climate and for studies that can detect the process link between safety voice climate and safety voice behavior.

Hypothesis 3. *Safety voice climate is positively associated with safety voice behavior.*

2. Method

2.1. Sample

The Trends in Risk Level in the Norwegian Petroleum Activity (Risiko Nivå i Norsk Petroleumsvirksomhet; RNNP) questionnaire has been distributed to employees in the Norwegian petroleum industry every other year from 1999/2020. The present study is based on data from 2019, in which there was a response rate of 22.2% (n = 7,624) (Petroleum Safety Authority Norway, 2019b). Despite a rather low response rate, the sample has proved to be relatively stable from year to year over variables such as gender, age group, facility, and the area of work ratio between operators and entrepreneurs, permanent and temporary employees, and proportion with managerial responsibilities. For more information, see Petroleum Safety Authority Norway (2019b). The sample includes occupations such as craftsmen/operators, electricians, mechanics, institutional cleaners, crane operators, and logistics operators. The sample includes employees at offshore oil rigs as well as at land-based plants. Of the participants, 916 (12%) were females, and 2,752 (36.1%) were under 41 years, 2,214 (29.1%) between 41 and 50 years, 2,642 (34.7%) were 51 years or older and 16 (0.2 %) did not report age.

2.2. Instrument

The Safety Voice Climate Scale (SVCS) and the measurement of safety voice behavior were derived from the RNNP survey. Key stakeholders in the petroleum industry (trade unions, employees, and authorities) have collaborated in developing the RNNP over the years. The RNNP monitors personal risk, risk of acute emissions, incidents that can cause major accidents, and working environment factors. All items use a five-point Likert scale ranging from 1 (fully disagree) to 5 (fully agree).

2.2.1. Demographic variables

Age was measured with one question, and the response options included: "20 years or younger," "21–24 years," "25–30 years," "31–40 years," "41–50 years," "51–60 years" and "61 years or older." Age was divided into three groups, detailed above. Gender was also reported. Leader responsibility was measured with one question: "Do you have management responsibility?" and the response options were "No," "Yes, with personnel responsibility" and "Yes, without personnel responsibility." Union representation was measured with one yes/no question: "Are you currently an employee representative?" The authors constructed a role variable by coding all non-leaders as 0, all leaders as 1 and all union representatives as 2. Facility was reported with a free text field. Data-owner has coded these facilities and given them random numbers to keep confidentially. As the question was free text many have not reported facility or it has been difficult to code facility connection, which have resulted in more missing data (detailed in results).

2.2.2. Safety Voice Climate Scale (SVCS)

The internally consistent (Cronbach's $\alpha = 0.81$) SVCS included eight items as reported in Table 3. All eight items used the same five-point Likert scale. Five of the items were negatively worded questions resulting in a negative scale ranging from −5 to 4.33. Negatively worded items were reversed in the aggregated scale. The item allocation to each of the two factors, "*Work colleagues' encouragement of safety voice*" and "*Leader's attitudes towards safety voice*," is reported in Table 3.

2.2.3. Outcome factor: Safety voice behavior

The fairly internally consistent (Cronbach's $\alpha = 0.63$) safety voice behavior index included three items, as shown in Table 4.

2.3. Analyses

Initial analyses and data management were performed using Stata 15.1 for Windows. To test H1 and calculate basic descriptive results, one-way ANOVA was used to compare means across role and/or gender and facility. Posthoc Tukey tests were also used to pairwise investigate statistical significance across all combinations

of role and gender. The study used the alpha command to calculate the scales and the collapse function to calculate the mean SVCS score of gender and role (Fig. 1).

Confirmatory factor analyses (CFA) and structural equation modeling (SEM) were performed using Mplus version 8 for Windows. First, the study calculated Cronbach's α in Stata using the alpha command. Second, the study performed a CFA splitting the SVCS into two factors (M1, Table 2, Fig. 2) to test H2. All eight variables were defined as categorical and the Mplus default WLSMV estimator was used. The study also used Mplus to calculate the average variance extracted (AVE) to measure discriminant validity. The ML estimator was used when calculating AVE. Third, the authors performed SEM to calculate the SVCS' ability to predict safety voice behavior (M2, Table 2, Fig. 3) to test H3. The authors also defined the three items (detailed above) in the safety voice behavior factor as categorical and used the Mplus default WLSMV estimator in M2.

3. Results

The SVCS mean for all participants was 4.49 (SD = 0.84, range = 0.00–9.33). There was a larger within-group variance than between-group variance between all facilities (SS = 2418.26 vs. SS 143.95, F = 4.33, p < 0.001), supporting H1. Females (mean = 4.61, SD = 0.81) had a significantly higher mean compared to males (mean = 4.48, SD = 0.84, Table 1). There was a larger within-group variance than between-group variance in gender (SS = 5198.83 vs. SS 14.21, F = 20.49, p < 0.001), supporting H1. Leaders had the highest mean (4.66, SD = 0.80), union representatives had the lowest (4.31, SD = 0.85), and the remaining employees were in the middle (mean = 4.43, SD = 0.84, Table 1). There was a larger within-group variance than between-group variance in role (SS = 5114.83 vs. SS 106.97, F = 53.48, p < 0.001), supporting H1. A pairwise Tukey test showed that all three combinations were significantly different from each other. Being a leader had a moderate effect on the SVCS mean (Cohen's d = −0.26, CI = −0.31 – −0.21) compared to all others. Being a union representative had an opposite moderate effect on the SVCS mean (Cohen's d = 0.25, CI = 0.17 – −0.33).

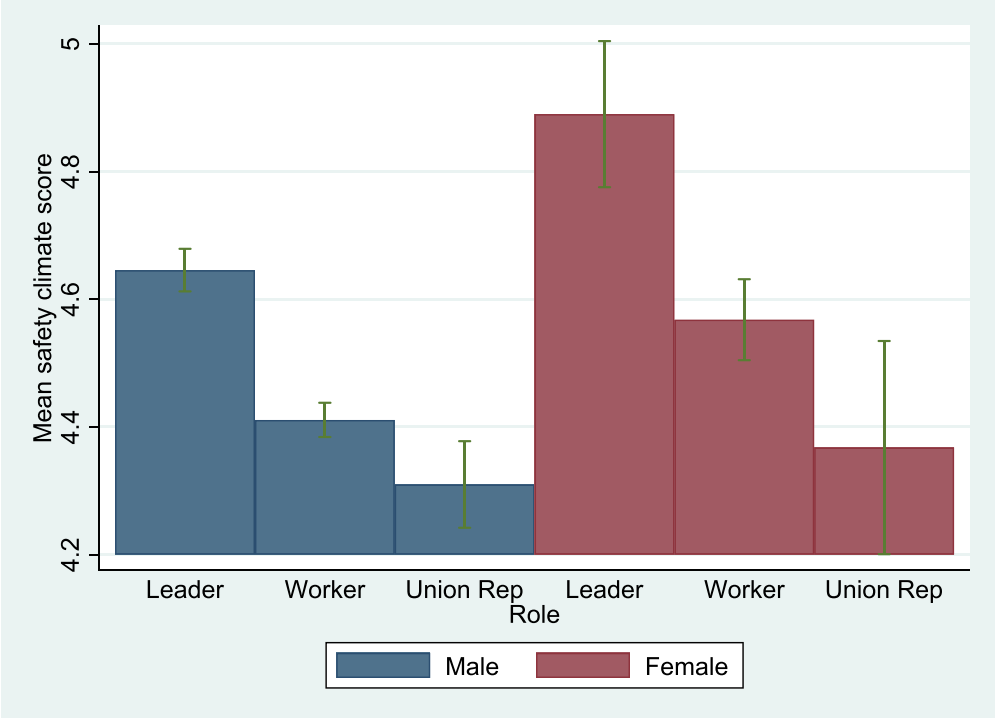
When roles and gender were combined, findings were more mixed, and 10 of 15 pairwise comparisons were significant. However, female leaders were the only group significantly different from all others, with the highest mean of all combinations: 4.89 (SD = 0.78). Male leaders were significantly different from both male employees and male union representatives and had the highest mean amongst males (mean = 4.65, SD = 0.84). Male employees (mean = 4.41, SD = 0.84) differed significantly from female employees (mean = 4.57, SD = 0.81), however female union representatives (mean = 4.37, SD = 0.78) did not differ significantly from male union representatives (mean = 4.31, SD = 0.85, Table 1 and Fig. 1). There was a large within-group variance than between-group variance also when role and gender were combined (SS = 5056.62 vs. SS 130.35, F = 26.07, p < 0.001), supporting H1.

3.1. Confirmatory factor analysis (CFA)

The CFA splitting the SVCS into two factors, one reflecting work colleagues' encouragement of safety voice and one reflecting leader's attitudes towards safety voice, gave fair fit (M1: RMSEA = 0.066, CFI = 0.980, Table 2, Fig. 2).

Factor 1: Work colleagues' discouragement of safety voice.

The loadings of the four items of the variable are reported in Table 3 and Fig. 2. Three of the four items were negatively worded but positively loaded on factor 1, resulting in factor 1 being negative in relation to safety voice climate. The factor had poor discriminant validity (AVE = 0.343). Still, AVE is a conservative estimate of the validity of the measurement model, and according to Fornell and Larcker (1981), "on the basis of p_n (composite reliability)



Note: The sum of the two SVCS scales is shown.

Fig. 1. Scores on the SVCS across demgraphic groups. Note: The sum of the two SVCS scales is shown.

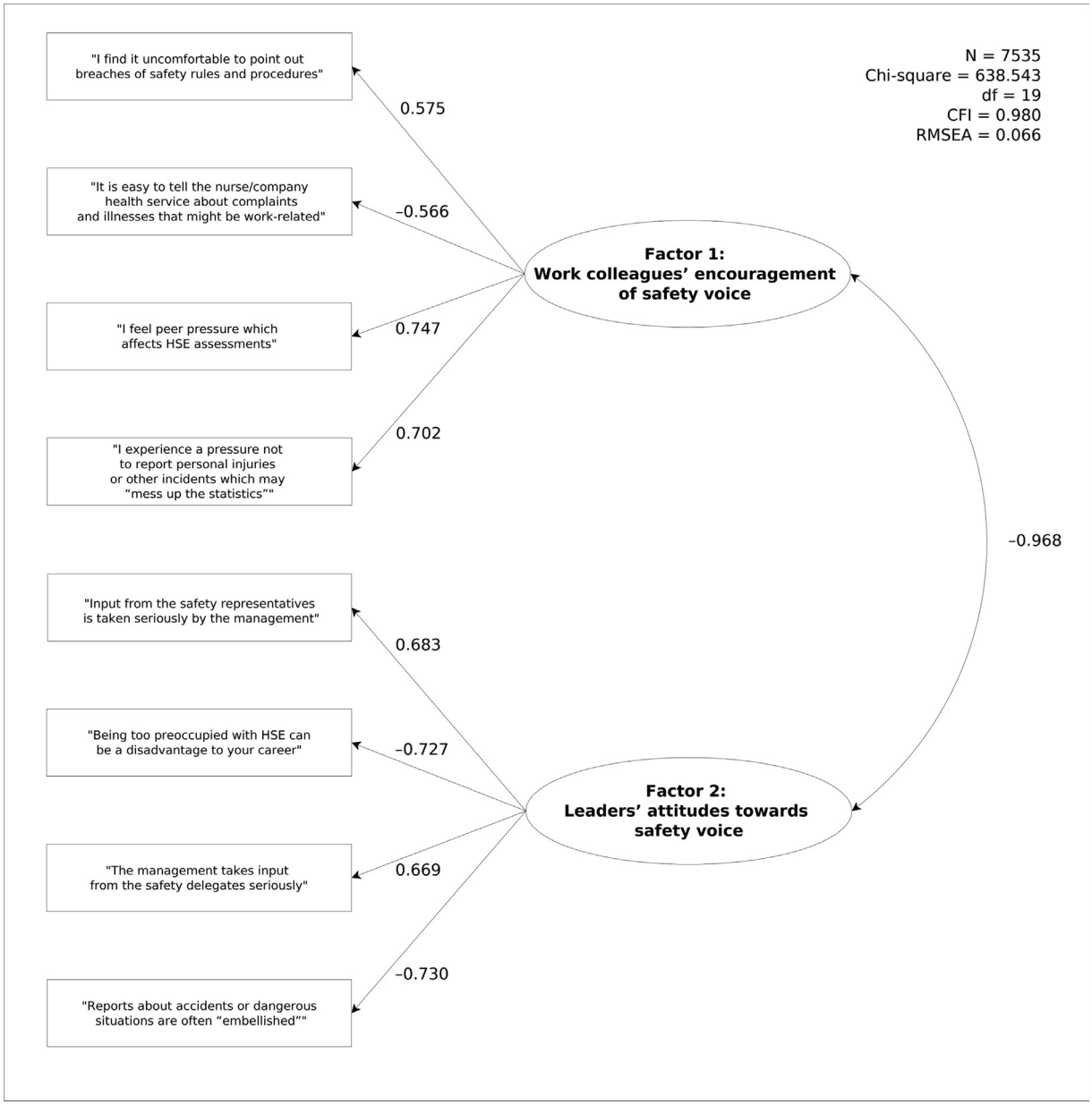


Fig. 2. Model 1. CFA shows standard estimates and fit indices.

alone, the researcher may conclude that the convergent validity of the construct is adequate, even though more than 50% of the variance is due to error" (p. 46).

Factor 2: Leader's positive attitudes toward safety voice.

The loadings of the four items of the variable are reported in Table 3 and Fig. 2. Two of the four items were both negatively worded and negatively loaded on factor 2, resulting in factor 2 being positively associated with safety voice climate. The factor had fair discriminant validity (AVE = 0.411).

Factors 1 and 2 were strongly negatively associated ($\beta = -0.968$, $p < 0.001$, Table 3, Fig. 2), a finding that was expected as three of the four items in factor 1 were negatively worded. The R^2 value of the eight observed variables in the model ranged from 0.321 to 0.558; hence, the residual variance ranged from 0.442 to 0.679.

Overall, the two-factor CFA model gives some support to H2, claiming that the Safety voice climate scale (SVCS) is identified by two sub-factors: "Work colleagues' encouragement of safety voice" and "Leader's attitudes towards safety voice." The model fit is fair, and the average explained variances (AVEs) are low. Thus, H2 is moderately supported.

3.2. SEM

The structural equation model using the SVCS variables to predict safety voice behavior factor gave a good fit (M2: RMSEA = 0.068, CFI = 0.969, Table 2, Fig. 3). The factor loadings for the CFA part of model 2 are reported in Table 4 and Fig. 3.

There was a negative regression path from factor 1, work colleagues' encouragement of safety voice, to the safety behavior factor ($\beta = -0.630$, $p < 0.001$, Table 4, Fig. 3). The regression path from factor 2 to the safety behavior factor was not significant ($\beta = 0.129$, $p = 0.489$, Table 4, Fig. 3). The high negative correlation between factor 1 and factor 2, in combination with the significant regression path on factor 3 gives support to H3, that Safety voice climate was positively associated with safety voice behavior.

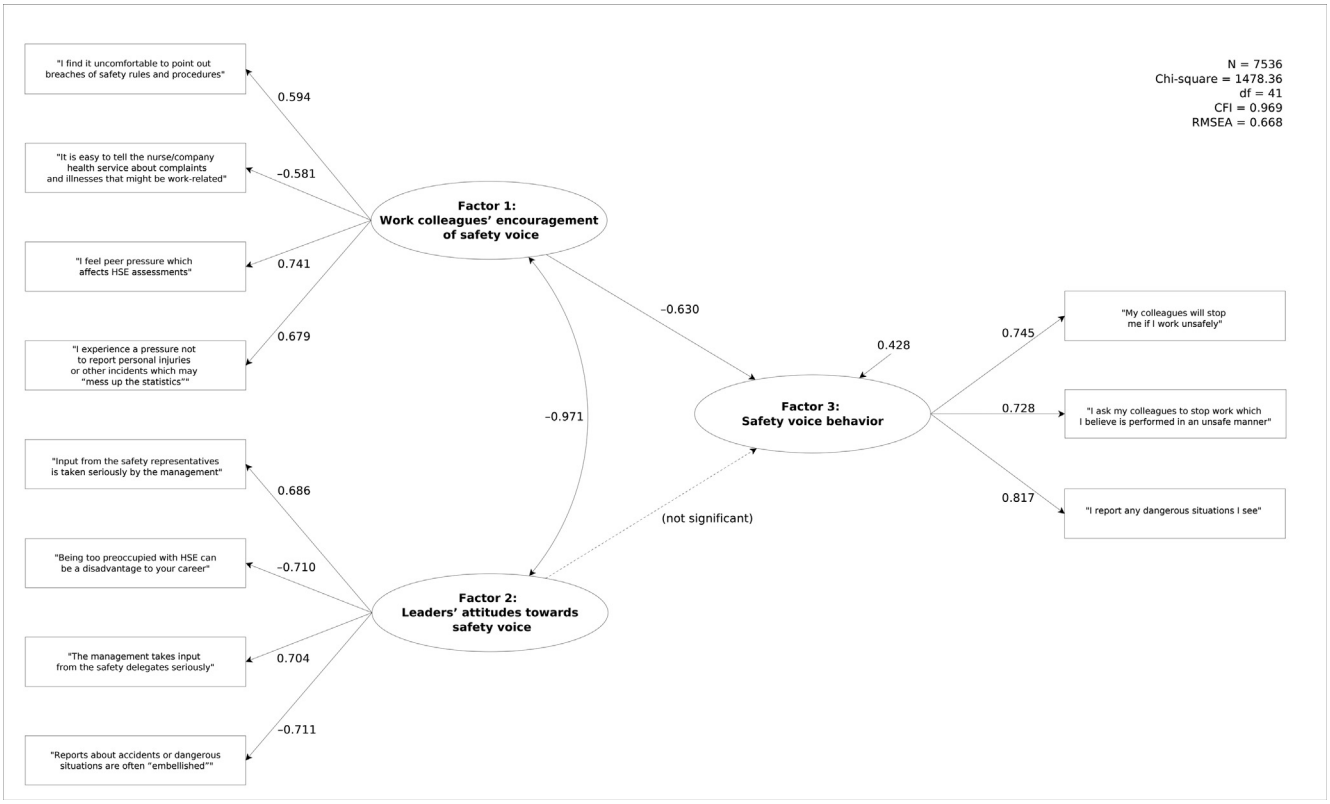


Fig. 3. Model 2 (M2). CFA showing standard estimates and fit indices.

Table 1
ANOVA and pairwise comparison across gender, roles, and the combination of gender and roles.

Gender	Role	Mean	SD	n	Sig
Male	All roles	4.48	0.84	6,601	*
Female		4.61	0.81	901	*
Both gender	Leader	4.66	0.80	2,395	*
	Employee	4.43	0.84	4,408	*
	Union Rep	4.31	0.85	697	*
Male	Leader	4.65	0.80	2,206	
	Employee	4.41	0.84	3,758	
	Union Rep	4.31	0.85	609	
Female	Leader	4.89	0.78	180	*
	Employee	4.57	0.81	630	
	Union Rep	4.37	0.78	87	

*$p < 0.05$ compared to all other categories pairwise Tukey test.

Table 2
Fit indices for the tested models.

Model	N	χ^{2***}	df***	CFI	RMSEA
M1: 2-factor CFA* Safety Voice Climate Scale	7535	638.543	19	0.980	0.066
M2: SEM**: Predicted safety behavior	7536	1478.36	41	0.969	0.068

* CFA = Confirmatory factor analyses.
** SEM = Structural equation modeling.
*** Chi-square test of model fit.

The residual variance of the safety behavior factor was 0.428, indicating that factors 1 and 2 combined explained 57.2% of the variance (Table 4).

4. Discussion

The overall objectives of this study were to conceptualize safety voice climate, present the SVCS as a tool to measure it, and gather initial evidence for the validity of the SVCS as a measurement of subjective climate. As predicted in H1, it was found that SVCS varied mostly on an individual level; however, there was a significant variation in gender and role.

Based on a theoretical approach, the SVCS was split into two variables, one reflecting work colleagues' encouragement of safety voice and the other reflecting leaders' attitudes towards safety voice. The scales' psychometric properties, the CFA model fit, and

Table 3
Model 1 (M1). Item loadings of the two SVCS variables.

Factors	Items	Standardized β weights	R^2	Standard error	Residual variance	P
Factor 1: Work colleagues' encouragement of safety voice	I find it uncomfortable to point out breaches of safety rules and procedures	0.575	0.467	0.011	0.533	<0.001
	It is easy to tell the nurse/company health service about complaints and illnesses that might be work-related	−0.566	0.330	0.011	0.670	<0.001
	I feel peer pressure which affects HSE assessments	0.747	0.528	0.011	0.472	<0.001
	I experience a pressure not to report personal injuries or other incidents which may "mess up the statistics"	0.702	0.448	0.012	0.552	<0.001
Factor 2: Leaders' attitudes towards safety voice	The management takes input from the safety delegates seriously	0.683	0.533	0.010	0.467	<0.001
	Being too preoccupied with HSE can be a disadvantage to your career	−0.727	0.321	0.012	0.679	<0.001
	My manager appreciates me pointing out matters of importance to HSE	0.669	0.558	0.012	0.442	<0.001
	Reports about accidents or dangerous situations are often "embellished"	−0.730	0.492	0.012	0.508	<0.001
	Factor 1/Factor 2 association	−0.968		0.006		<0.001

Note. HSE: Health, Safety, and Environment.

Table 4
Model 2 (M2). Item loadings of the two SVCS variables and the safety voice behavior variable.

Factors	Items	Standardized β weights	R^2	Standard error	Residual variance	P
Factor 1: Work colleagues' encouragement of safety voice	I find it uncomfortable to point out breaches of safety rules and procedures	0.594	0.470	0.011	0.530	<0.001
	It is easy to tell the nurse/company health service about complaints and illnesses that might be work-related	−0.581	0.353	0.011	0.647	<0.001
	I feel peer pressure which affects HSE assessments	0.741	0.503	0.011	0.497	<0.001
	I experience a pressure not to report personal injuries or other incidents which may "mess up the statistics"	0.679	0.495	0.012	0.505	<0.001
Factor 2: Leaders' attitudes towards safety voice	The management takes input from the safety delegates seriously	0.686	0.506	0.010	0.494	<0.001
	Being too preoccupied with HSE can be a disadvantage to your career	−0.710	0.338	0.012	0.662	<0.001
	My manager appreciates me pointing out matters of importance to HSE	0.704	0.549	0.012	0.451	<0.001
	Reports about accidents or dangerous situations are often "embellished"	−0.711	0.461	0.012	0.593	<0.001
Factor 3: Safety voice behavior	My colleagues will stop me if I work unsafely	0.745	0.555	0.014	0.445	<0.001
	I ask my colleagues to stop work which I believe is performed in an unsafe manner	0.728	0.529	0.014	0.471	<0.001
	I report any dangerous situations I see	0.817	0.668	0.016	0.332	<0.001
Regression paths	Factor 1 regressed on Factor 3	−0.630		0.187		0.001
	Factor 2 regressed on Factor 3	0.129		0.187		0.489
Associations	Factor 1 association to factor 2	−0.971		0.006		<0.001
Residual variance	Factor 3: Safety voice behavior		0.572	0.015	0.428	<0.001

Note. HSE: Health, Safety, and Environment.

average explained variance (detailed in results) combined gave some support to H2.

It was also found that SVC was associated with safety voice behavior in a model with good fit (detailed in results), supporting H3 that safety voice climate is related to safety voice behavior. Thus, the findings from this study support the importance of a climate that encourages safety voice. There is a greater chance that employees will speak out about safety issues when their general perception is that this type of behavior is encouraged and supported within their organization. However, a surprising finding is that it appears that leaders' attitudes toward safety voice are inferior to colleagues' encouragement of safety voice, as only the latter was significantly associated with safety voice behavior. A possible explanation of this finding could be that keeping good relationships with close colleagues is more important than with one's leaders' as coworkers are a vital part of the social environment (Chiaburu & Harrison, 2008). Consequently, employees will be reluctant to speak out when this can be perceived as annoying, hurting others, and causing conflicts among colleagues (see Manapragada & Bruk-Lee, 2016). Still, the two variables are strongly associated, and one could therefore argue that colleagues encourage safety voice as a consequence of their leaders' positive attitudes toward safety voice and that the effect of leaders' attitudes toward safety voice on safety voice behavior "go through" work colleagues' encouragement of safety voice.

The findings show that leaders, particularly female leaders, perceive the climate to be more supportive of safety voice than employees and union representatives do. Leaders are generally expected to show commitment and positive attitudes toward their organization. According to social exchange theory, actions that provide benefits to another party will generally be reciprocated in the future, for instance, by bonuses or promotions (Blau, 1986). Thus, a psychological contract may develop between leaders and top management where leaders are expected to emphasize the positive aspects of the job climate, and negative perceptions may generally be repressed. Furthermore, since leaders are generally less involved in hands-on work operations, there is a risk that they are not aware of possible shortcuts and rule violations conducted during operations. Consequently, they might believe that safety voice climate is stronger than it really is. Thus, leaders and their

employees can develop different perceptions of safety voice climate. Other studies on the more general concept of safety climate show similar perceptual differences between leaders and employees (e.g., Huang et al., 2014; Marin, Lipscomb, Cifuentes, & Punnett, 2019).

The union representatives scored lowest on the SVCS. Union representatives may, to a greater extent than other employees, observe or be informed about elements at work that can harm employees. Their psychological contract will be to alert management when they observe safety issues. However, management can sometimes perceive union representatives to be annoying and may not support them when they speak out about safety issues. In a study that supports this argument, Gormley (2011) found that union-represented staff nurses reported significantly lower mean scores than other members of the organization on all work environment variable measurements.

4.1. Research contributions and practical implications

The current study contributed to the advancement of the theory on safety voice climate by differentiating two distinct factors: *Work colleagues' encouragement of safety voice* and *Leaders' attitude towards safety*. In testing the psychometric properties and criterion validity of the SVCS, this study was the first to offer a general measure of safety voice climate applicable across sectors and testing it in a large sample of industrial employees. The sample is derived from the petroleum sector and covers both offshore rigs and land-based plants as well as numerous occupations, and thus it is possibly relevant across sectors, at least in the high-risk industries.

Ultimately, the purpose of developing the SVCS is to aid in the continuous improvement of safety in high-risk organizations by helping to identify why employees speak out (or do not) about safety issues witnessed at work. The SVCS can be used as a tool to detect some of the barriers and supporting elements relating to safety voice and to guide the efforts needed to foster work climates that promote communication of safety issues. When SVCS scores are low, organizations should initiate preventive efforts such as training leaders to be more encouraging of safety voice and safety participation. However, as these findings indicate that colleagues' encouragement of safety voice is more closely linked to safety voice behavior than how they perceived their leaders' attitudes toward safety voice, organizational efforts to improve safety voice behavior could emphasize the enhancement of collegial support of speaking out.

This study contributes to high-risk industries and specifically to the offshore petroleum sector. The Petroleum Safety Authority Norway emphasizes that an effective reporting culture is vital to prevent accidents (Petroleum Safety Authority Norway, 2019a). Still, a study on the related concept of whistleblowing in Norwegian organizations reported that there had been a reduction in reporting behavior (Trygstad & Ødegård, 2019). A cause for worry in this regard is that the Petroleum Safety Authority has registered an increasing number of reported concerns and incidents, 80% of which are related to offshore activities (Ministry of Labour and Social Affairs, 2017). These reports underline the need for monitoring and follow-up on safety voice climates in the petroleum industry and other industries. The current study contributes by presenting an instrument to assess the safety voice climate.

4.2. Limitations and future research avenues

The present study is not without its limitations. Even though the sample covered many occupations and settings within the petroleum sector, the SVCS requires further validation on different types of samples across time. Future studies should examine safety voice climates across high-risk industries such as mining, construction, and aviation. Furthermore, as the current study was performed in Norway, where the national culture may influence safety voice climates, studies from other countries are needed. A limitation is that the response rate was low (22%) and could be biased by selective non-response. However, the RNNP samples have proven to be relatively stable from year to year over variables such as gender, age group, facility, and the area of work ratio between operators and entrepreneurs, permanent and temporary employees, and proportion with managerial responsibilities, increasing the likelihood for acceptable external validity.

The current study argued for operationalizing safety voice climate on the individual level. Nevertheless, other researchers have proposed that groups or organizations can develop climates about speaking out or not speaking out, which refer to shared perceptions of the group or organization (Morrison & Milliken, 2000). Thus, a group or organizational safety voice climate could be operationalized by aggregating the individual perceptions, given that there is sufficient perceptual consensus (Chan, 1998). The current study also tested safety voice climate as a group or organizational climate in the initial analyses of the data. That is, the authors tested a level 2 model by running a two-level confirmatory factor analysis. However, the study was not able to get a satisfying model fit on this Multilevel CFA. Possibly, a reason for this is that the level 2 data were on oil rig / land-based plant level as these industries are not necessarily organized in teams or groups but often projects or contractors working individually for some time on an installation. Consequently, operationalizing safety voice climate on the individual level is most suitable, at least for the type of sample that was available. Other studies in other types of industries that are organized differently could test whether the level 2 climate model would be more suitable for these industries.

As this study applied a cross-sectional design, conclusions concerning causality are impossible regarding the safety voice climate and safety voice behavior variables. It is possible that the levels of safety voice behavior shape safety voice climate. A reciprocal relationship between the variables is also likely so that a perceived safety voice climate leads to safety voice behavior that, in turn, increases the perception of safety voice climate. Longitudinal studies would provide more knowledge on reciprocal relationships.

This study did not include any effect measures such as operational risks or safety indicators; because the intention of this study was mainly to explore the associations between the SVCS and safety voice behavior, operational effect measures were not prioritized. Future studies on this topic should introduce models that also include effect measures. Furthermore, future studies could apply more objective measures of safety voice behavior than the self-reports used in this study. Thus, the safety voice behavior measure captured reports of behavior, not behavior itself.

There is a need for future studies that test the discriminant and incremental validity of the SVCS. Particularly, safety climate, voice climate, and safety voice climate are "close relatives," and the authors would expect safety climate scales and the SVCS to be moderately correlated.

Finally, the unexpected finding that only *Work colleagues' encouragement of safety voice* was associated with safety voice would need attention in future studies to investigate whether the finding would be replicated, and the theoretical framework would need to be adapted accordingly.

4.3. Conclusion

A climate that encourages safety voice is an important component of a safe work environment. When employees perceive that voicing safety concerns is encouraged, organizations have better opportunities to correct safety issues and take preventative actions against accidents and injuries. Studying the motives behind safety

voice can help researchers understand why employees choose to speak out so that targeted interventions can be developed to nurture these elements. The current study contributes, in this regard, by presenting a validated instrument to assess one of the motives behind safety voice—safety voice climate.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Statistical analysis of the severity of occupational accidents in the mining sector

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ABSTRACT

Introduction: The aim of this paper is to understand the causes of occupational accidents in Spain's mining sector in order to propose action plans and improve future accident rates. *Method:* This research analyzed a pool of data on 15,032 accidents occurring in the mining sector and reported to authorities between 2013 and 2018. Accidents are divided into three levels of severity: light, serious, and fatal. We study the influence of 12 variables on the accident severity rate in our sample. *Results:* The results show that accident severity is related to age, gender, nationality, length of service, economic activity, company size, accident location, days of injury leave, day of the week, deviation, injury, and specific Spanish region. This sector produces a high rate of serious accidents compared to all other sectors; has a male-dominated, older and experienced workforce; and employs mainly Spanish workers. Its activity is concentrated in larger companies and the work involves the use of heavy machinery and dangerous materials. We offer conclusions and future lines of research to help regulators, companies and workers to improve worker safety.

1. Introduction

Minerals are the base element of most industries, and some type of mining is carried out in practically every country in the world. This activity has important economic, environmental, labor, and social repercussions, both in the countries or regions in which it is carried out and on a global scale (Amstrong, & Menon, 1998).

"Mining" refers to the selective extraction of rocks and minerals from the earth's crust, in such a way that it is economically profitable (Directorate General for Energy Policy and Mines, 2022). In a broad sense, it includes, in addition to underground and open-pit operations, those necessary for the treatment of extracted materials, such as crushing, sizing, washing, and concentration. This paper focuses on underground and open-pit extraction activities, as they are the ones that concentrate a greater number of accidents within this sector.

Mining is not an important generator of employment. Indeed, only 1% of the world's workforce, around 30 million people, work in this sector. In Spain, according to mining statistics from the Ministry for the Ecological Transition and the Demographic Challenge (Directorate General for Energy Policy and Mines, 2022), Spanish mining production in 2020 reached €3.061 billion and directly employed a total of 29,319 people across 2,655 mines.

Despite these low employment figures, the high accident rate in the mining sector in many countries has caused international concern. Although mining only employs 1% of all workers, it is responsible for about 8% of fatal occupational accidents (approximately 15,000 per year), which indicates that it has one of the highest accident rates among all sectors. The mining industry accounts for a substantial proportion of occupational accidents, particularly fatal accidents, which is why it is considered one of the most dangerous occupations in the world (Nowrouzi-Kia et al., 2018). In the United States, mining is a major economic force, but historically it has had one of the highest nonfatal accident rates of all industries (Shkembi, Smith, & Neitzel, 2022).

In the European Union (UE-28), according to 2019 data, 0.83% of nonfatal accidents take place in the mining industry, but the more relevant figure is the proportion that this 0.83% represents with respect to the total number of fatal accidents (EUROSTAT, 2022). In Spain, based on accident rate data for 2018 from the Ministry of Labour, Migration and Social Security, mining has an incidence rate (number of accidents leading to injury leave per 100,000 workers exposed to risk) of 13,150 compared to 2,826.86 for all sectors combined. The comparison is even more worrisome for fatal accidents, with an incidence rate of 40.09 in the mining sector versus 2.83 for all sectors; in other words, 14 times higher for mining

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(these calculations are our own based on accident rate statistics from the Ministry of Labour, Migration and Social Security).

As a sector of great global impact, there are several studies in the literature that analyze accident rates in the mining sector. These studies examine countries such as Spain (Sanmiquel, Rossell, & Vintró, 2015; Sanmiquel, Bascompta, Rossell, & Anticoi, 2021), Australia (Patterson & Shappell, 2010; Burgess-Limerick, 2011), Sweden (Lööw, & Nygren, 2019), Ghana (Amponsah-Tawiah, Ntow, & Mensah, 2016; Mensah, Siabi, Donkor, & Kurantin, 2022; Joe-Asare, Stemm, & Amegbey, 2023), Pakistan (Jiskani et al., 2019; Shah, Khayyam, & Mumtaz, 2021), China (Geng, & Saleh, 2015; Qiao, Li, & Liu, 2019; Li, Wang, & Chen, 2022), Turkey (Düzgün, & Leveson, 2018), and the United States (Groves, Kecojevic, & Komljenovic, 2007; Rahimi, Shekarian, & Roghanchi, 2022). Rahimi et al. (2022) carried out a retrospective study on the analysis of accidents in mines in the United States between 1983 and 2018 (95,812 accidents in 19,924 mines), using regression models to analyze the risk of suffering an accident as a function of several variables, such as type of mine, age and experience of the injured worker, days of injury leave, and part of the body injured.

When the occupational accident rates of Spanish mining are analyzed and compared against those in other countries, they prove to be much higher (Sanmiquel, Freijo, Edo, & Rossell, 2010). Studies have been carried out to investigate different factors and characteristics pertaining to these accidents in Spain, taking different approaches (Sanmiquel, Rossell, & Vintró, 2015) but ultimately aiming to establish improvement policies that minimize the risk index in the country's mining sector (Sanmiquel, Bascompta, Rossell, & Anticoi, 2021). According to these studies, all the accidents analyzed have involved an event or contributing factor that can clearly be avoided by implementing a rigorous and efficient preventive policy. Therefore, the rate of work-related victims in Spanish mining can be considerably reduced (Sanmiquel, Freijo, Edo, & Rossell, 2010). A systematic review of the literature has also revealed that the main cause of mining accidents are mechanical failures and, furthermore, that the impact of post-mining accidents has adverse environmental effects (Ismail, Ramli, & Aziz, 2021).

A detailed analysis of accidents, both fatal and nonfatal, requires the study of different variables' influence on the severity of injuries. There are several research studies in this vein (Karra, 2005; Ivaz, Stojanovic, Petrovic, & Stojkovic, 2020; Shahani, Sajid, Zheng, Brohi, & Mallah, 2021), and some of them bring detailed information about gender (Fontaneda, Camino-López, González, & Ritzel, 2019), age (Duplinsky, Nevrala, & Picalkova, 1982; Salminen, 2004; Margolis, 2010; Bravo et al., 2022), and worker experience (Margolis, 2010), among other factors. Ajith, Ghosh, and Janz (2022) conducted a literature review of over 3,000 articles and identified 24 that analyze the causes of mining accidents. These articles single out old age, inexperience, gender, and marital status as influencing variables, which are compounded by other factors such as alcohol and drug use, job dissatisfaction and stress, poor working conditions and an inadequate management model.

Mining also stands out for the diversity of tasks carried out by workers, many of them involving heavy machinery (Zujovic, Kecojevic, & Bougnovic, 2021). The work itself is very demanding in terms of physical exertion and strength, and there is a risk of falling rocks and being trapped underground. In addition, mining work is usually carried out in extreme environmental conditions and in damp, dusty environments (Sanmiquel et al., 2021). All this entails a wide variety of occupational risks to which workers are exposed and which frequently lead to occupational accidents. Some personal factors, such as physical and mental health, also play a fundamental role in occupational safety (Joaquim et al., 2018).

Given this frame of reference, we have selected a set of variables that influence the rate of mining accidents and, more specifically, the severity of these accidents. These variables have been categorized into five groups that are also used in this article: (a) personal; (b) business; (c) material; (d) temporal; and (e) geographic, following the categorization used in Camino-López, Ritzel, Fontaneda, and González (2008).

This paper aims to evaluate the relationship between these groups of variables and the severity of accidents to help identify appropriate prevention, control, and mitigation actions. We expect to gain deeper insight into the rate of accidents among workers in the mining sector, so that measures and strategies can be designed and prioritized to reduce this rate, whether quantitatively (number of accidents) or qualitatively (accident severity). The economic impact of accidents should also be borne in mind, and new knowledge about the accident rate should help to minimize costs associated with occupational health and safety (Bestratén & Baraza, 2015b).

The following sections cover the research's methodology, results, discussion, and conclusions. The conclusions describe proposals we believe could serve as a guide for companies and managers to devise health and safety policies in the mining sector.

Equivalent research has studied other productive sectors such as construction (Camino-López et al., 2008; López-Arquillos, Rubio, & Gibb, 2012), agriculture (Baraza, & Cugueró-Escofet, 2021), and metalworking (Fuentes-Bargues, Sánchez-Lite, González-Gaya, Rosales-Prieto, & Reniers, 2022).

The aim of the research presented in this paper is to gain newfound insight into the probable causes of mining accidents in Spain, expanding and updating our knowledge on the matter to identify suitable mitigating actions.

2. Methodology

In Spain, occupational accidents are defined as all injuries that employees suffer as a result of their work. Since 2003, the National Institute of Occupational Safety and Health, a part of Spain's Ministry of Labour, Migration and Social Security, has used online forms to gather information about all accidents that result in one or more working days lost. A detailed and specific report form is filled in for each accident and stored separately.

This accident report contains a lot of information about the company (size, activity) and the injured worker (sex, age, length of service, nationality). It also includes data on the part of the body injured, the deviation that caused the accident, the day of the week the accident occurred on and work days lost.

For this specific study, the Ministry of Labour, Migration and Social Security provided anonymized data on all occupational accidents in the Spanish mining industry according to the definition set by the Statistical Classification of Economic Activities in the European Community (NACE) (EUROSTAT, 2008). During the period studied (2013 to 2018), this classification has remained unchanged. The health authorities in Spain must determine the seriousness of each occupational accident and include this as an additional data point. Thus, each accident is classified into one of three levels of severity: light accident, serious accident, or fatal accident.

The design of this study is based on previous accident analysis research carried out for the construction sector by Camino-López et al. (2008) and López-Arquillos et al. (2012). For our study, we have adapted their methodology to the mining sector, selecting the most relevant variables, classifying them into groups, and then analyzing the relationship between these variables and accident severity.

2.1. Accident data

For this study, we include all accidents taking place in Spain between 2013 and 2018 that involved at least one working day lost. A representative time period has been chosen in order to perform a meaningful statistical analysis (15,032 accidents). Subsequent years have not been included to avoid distorting the data with the effect of the COVID-19 pandemic. Likewise, previous years have been excluded, as they could present different behaviors associated with changes in the preventive culture, awareness, and regulations (Bestratén, & Baraza, 2015a). The data are taken from the accident reports that Spanish companies are obliged to file with the Ministry of Labour, Migration and Social Security.

Of the 3,420,087 accidents reported in Spain during the sample period, 15,032 occurred in the mining sector (the NACE codes included are 051, 052, 071, 072, 081, 089, 091 and 099; see Table 1). Of the total number of accidents analyzed for the mining sector between 2013 and 2018 (15,032), 14,816 (98.56%) were classified as light accidents and 168 (1.12%) as serious. An accident at work is light when the injury caused to the worker is not classified as serious and does not imply any disability; or if it does, it lasts less than 30 days. A total of 45 fatal accidents (0.1%) were also reported.

2.2. Variables analyzed

The variables considered are classified into five groups as follows: (a) personal; (b) business; (c) material; (d) temporal; and (e) geographic, following the categorization used in Camino-López et al. (2008). The selected variables are grouped into these categories as shown in Table 2.

Personal variables include characteristics of the injured employee: age, gender, nationality, and length of service. Business variables include type of activity according to NACE, size of the company and accident location. The temporal variables refer to the day of the week the accident occurred on and the duration of the resulting injury leave (used as a measure of the accident's severity). Material variables include aspects specifically about the accident: how it happened (causes) and the type of injury suffered (consequences). The geographical variable used in this study describes the geographical area where the accident occurred using the regions into which Spain is divided.

2.3. Statistical analysis

The statistical package used for this analysis was Stata 16/MP. We studied the relationship between severity and the rest of the variables using contingency tables, where we calculated the chi-square statistic (χ^2) to test the hypothesis of independence between them (Camino-López et al., 2008; López-Arquillos et al., 2012). This statistic shows the possible influence of the different values of the variables on severity.

Table 1
Miner activities.

Activity	NACE Code
Anthracite and coal mining / Anthracite and coal extraction	051
Lignite mining / Lignite extraction	052
Iron ore mining / Iron ore extraction	071
Non-ferrous metallic ore extraction / Non-ferrous metallic ore mining	072
Stone, sand and clay extraction	081
Other extractive industries not elsewhere included	089
Oil and natural gas extraction support activities	091
Other extractive industry support activities	099

Table 2
Summary of variables.

(a) Personal	Gender
	Age
	Nationality
	Length of service
(b) Business	Activity (NACE code)
	Company size
	Accident location
(c) Material	Deviation
	Injury
(d) Temporal	Days of injury leave
	Day of the week
(e) Geographic	Region of Spain

To understand which cells of the contingency table are relevant, we used corrected standardized residuals by comparing expected and observed frequencies. Corrected standardized residuals (*csr*) are marked with an asterisk (*) when their absolute value is less than 1.96, meaning a significance of 95% is not achieved and, therefore, we cannot reject the independence hypothesis (i.e., the variables may be independent). For absolute *csr* values greater than 1.96, we can reject an aleatory influence between the variables and severity and thus reject the independence hypothesis (i.e., the variables are dependent). We report all results with this asterisk (*) in each table throughout the paper, the variable values included.

Accident rates are ratios obtained by dividing the number of accidents in a category by the total number of accidents. Several ratios are calculated in this way. The total accident rate (TAR) is obtained by dividing the total number of accidents in a specified category by the total number of accidents analyzed. The light accident rate (LAR) is obtained by dividing the number of light accidents in a category by the total number of light accidents. The serious accident rate (SAR) is calculated by dividing the number of serious accidents in a category by the total number of serious accidents. Finally, the fatal accident rate (FAR) is the result of dividing the number of fatal accidents in a category by the total number of fatal accidents.

Given the nature of the available data, we are able to study and compare groups of accidents in the mining sector that have already occurred. However, the rates obtained are not based on the association between accidents and workers at risk, since data on workers at risk for each category are not available. Our data allow us to compare different severities correctly by determining the probability that an accident in a specific category will be light, serious or fatal.

3. Results and discussion

Accidents in the mining sector account for 0.43% of the total number of accidents occurring in Spain between 2013 and 2018. The values are lower than those in other sectors, such as manufacturing, construction, and agriculture. However, they are relevant, especially considering the total number of workers in this sector. The values for the mining sector are also relevant in terms of fatal accidents, which represent 1.15% of all fatal accidents taking place during this period.

With respect to incidence rates, it is important to show the information in the form of total (AR_{total}) and fatal (AR_{fatal}) accident rates. These accident rates are calculated as follows:

$$AR_{total} = \frac{number\ of\ accidents\ with\ sick\ leave \times 10^5}{average\ number\ of\ exposed\ workers} \quad (1)$$

$$AR_{fatal} = \frac{number\ of\ fatal\ accidents \times 10^5}{average\ number\ of\ exposed\ workers} \quad (2)$$

where "average number of exposed workers" refers to the number of workers who work on average over the course of a year and who are therefore likely to suffer an accident.

Table 3 shows the total accident rate, AR_{total}, and the fatal accident rate, AR_{fatal}, for the whole set of accidents in Spain from 2013 to 2018, and separately for the mining sector.

The TAR for the mining sector is 5.38 times higher than the TAR for all sectors in the period between 2013 and 2018. Looking specifically at fatal accidents, the comparison is even worse: the FAR is 14.17 times higher than the average FAR for all sectors. Although the mining sector employs few workers compared to other sectors (the average number of workers for the 2013–2018 period is 18,708), these figures show that its accident rates are proportionally much higher than expected. Hence the importance of studying mining from the point of view of accident frequency and, critically, accident severity (comparing light, serious and fatal accidents).

With respect to the mining sector's fatal accident rate for 2013 (FAR 68.90), it should be noted that a major accident befell the Pozo Emilio del Valle mine in Pola de Gordón (León), accounting for 6 out of the 14 deaths reported that year. The accident occurred when 11 men working in a coal mine at a depth of 694 meters were surprised by a sudden escape of firedamp gas that displaced oxygen and caused the immediate suffocation of five miners and the posterior death of a sixth. The other affected workers were hospitalized (Tobella, Fernández, & Hierro, 2013). This information has been taken into consideration in the analysis of the various variables considered in this paper.

The intention of this paper is ultimately to obtain information about the "how," "who," "when," "where," and "with" of serious or fatal accidents.

3.1. Personal variables

During the period between 2013 and 2018, 97.18% of the total 15,032 accidents happened to men (14,608), while only 2.82% happened to women (424). This result is directly related to male dominance in the sector.

Very few women work in the mining sector (Abrahamsson et al., 2014), and mining in Spain has been a man's job (Sanz, & López, 2017). Statistics on the Spanish mining sector show that, in 2018, 92.36% of the workers were men, and this percentage is even higher when considering production alone, reaching 97.36% (Directorate General for Energy Policy and Mines, 2020). Equivalent data are seen in other countries such as Sweden (Abrahamsson et al., 2014), India (Lahiri-Dutt, 2012) and Australia (Eveline, & Booth, 2002).

The prominence of men in the sector is conditioned by the type of work, which involves many tasks requiring a great deal of effort being carried out under unfavorable conditions. This acts as an entry barrier for women, on top of certain prevalent traditional and cultural aspects inherent to the sector (Jenkins, 2014). Additional social reasons further increase this male dominance (Sanz, & López, 2017).

As for accidents among women, which account for 2.82% of the total (424), these are confined mainly to administrative jobs. Statistical data from 2018 show that in Spain, 5.73% of women assigned to the mining sector carried out their work in offices (Directorate General for Energy Policy and Mines, 2020). This is also observed in the severity of the accidents they suffer. In the period under study, women only accounted for five serious accidents and one fatality, compared to the respective figures for men, 163 and 44. Thus, the values pertaining to women are insignificant in the mining sector (Directorate General for Energy Policy and Mines, 2020).

Age has an important effect on the severity of accidents, especially in an increasingly aging society. The studies reveal contradicting results, as several show a relationship between serious injuries and older workers, whereas others do not show a direct relationship between these two variables (Bravo et al., 2022). This situation can be linked to the loss of certain capacities that are used to avoid accidents, such as hearing and eyesight, together with an increase in confidence that can dissuade workers from following certain preventive measures against risks (Blanch, Torrelles, Aluja, & Salinas, 2009; Bande & López-Moruelo, 2015).

Table 4 shows the influence of the worker's age on severity. The results highlight maximum severity in the age range between 30 and 49 years, which represents 74.54% of all accidents. The severity of the accidents in this age group shows a SAR of 64.29% and a FAR of 62.22%. This information is in line with the characteristics of miners, who are concentrated in this age range. Regarding fatal accidents in this age range, the Pola de Gordón mining accident that took the life of six workers (five between 40 and 49 years old and one between 30 and 39) should be noted as an exception. This information does not affect our results analysis.

There are two characteristics that explain the higher accident rate in the 30–49-year age range. First, it is a declining sector for deep mines (especially coal mines) (Directorate General for Energy Policy and Mines, 2020), which means few new young workers. Second, this first reason is enhanced by other social aspects, such as mine closures and the danger inherent in the sector.

Moreover, the sector has a special regime that involves an earlier retirement age. This must be considered as a result of the working conditions and the presence of silicosis as an associated occupational disease (Menédez, Cavalin, García, & Gherasim, 2021).

The figures for workers aged 50 to 59 are also noteworthy, with 2,017 accidents (13.42% of the total). These workers suffer proportionally more serious accidents (22.62% of the total) and fatal accidents (31.11% of the total). This suggests an influence of age on accident rate, which lines up with findings in other studies (Bravo et al., 2022).

Table 3
Accidents in mining compared to all sectors, Spain (2013–2018).

All sectors	2013	2014	2015	2016	2017	2018	TOTAL
Total number of workers	23,190,000	22,955,000	22,922,000	22,823,000	22,742,000	22,807,000	137,439,000
Total number of accidents	489,329	514,274	554,630	593,099	624,033	644,722	3,420,087
Total number of fatal accidents	558	580	629	693	699	729	3,888
Total Accident Rate (TAR)	2,110.09	2,240.36	2,419.64	2,598.69	2,743.97	2,826.86	2,488.44
Fatal Accident Rate (FAR)	2.41	2.53	2.74	3.04	3.07	3.20	2.83
Mining	2013	2014	2015	2016	2017	2018	TOTAL
Total number of workers	20,320	19,409	17,688	19,276	18,759	16,798	112,250
Total number of accidents	2,642	2,930	2,851	2,406	1,994	2,209	15,032
Total number of fatal accidents	14	6	8	4	5	8	45
Total Accident Rate (TAR)	13,001.97	15,096.09	16,118.27	12,481.84	10,629.56	13,150.38	13,391.54
Fatal Accident Rate (FAR)	68.90	30.91	45.23	20.75	26.65	47.62	40.09

Table 4
Total mining accidents comparing age and severity, Spain (2013–2018).

Chi-Sqd =	52.10		df =	24	Sig =	0.001		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
Age	N =	15,032	N =	14,816	N =	168	N =	45
(years)	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
<16	1	0.01	1	0.01*	0	0.00*	0	0.00*
16–19	30	0.20	29	0.20	1	0.60	0	0.00
20–24	315	2.10	313	2.11	2	1.19	0	0.00
25–29	1,216	8.09	1,201	8.11	12	7.14	3	6.67
30–39	5,547	36.90	5,494	37.08	47	27.98	6	13.33
40–49	5,658	37.64	5,574	37.62	61	36.31	22	48.89
50–59	2,017	13.42	1,963	13.25	38	22.62	14	31.11
60–64	246	1.64	239	1.61	7	4.17	0	0.00
65–70	0	0.00	0	0.00	0	0.00	0	0.00
>70	2	0.01	2	0.01*	0	0.00*	0	0.00

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

Of the total accidents in the mining sector in the period between 2013 and 2018 (see Table 5), 94.12% (14,148 accidents) involved workers of Spanish nationality. The remaining 884 accidents (5.88%) therefore happened to workers from other countries. This value stands below the average for all economic sectors, where accidents suffered by foreign workers account for around 10% of all accidents (National Statistics Institute, 2016).

Continuing with nationality, the severity level of accidents suffered by foreign workers in the mining sector presents a SAR of 9.94% and a FAR of 2.22%, which indicates that they proportionally suffer a greater number of serious accidents than Spanish workers, but this is reversed when it comes to fatal accidents. The effect of the accident that occurred in 2013 in Pola de Gordón, with six deceased miners, all of them of Spanish nationality, must be taken into consideration in this regard.

A parallel analysis of other sectors with a greater presence of foreign workers, such as agriculture (Baraza, & Cugueró-Escofet, 2022), allows us to conclude that the low accident rate and the severity of the accidents is associated with the low presence of foreign labor in the sector.

Tenure or work experience is the set of skills and knowledge acquired by a worker in a certain job or during a specific period of time. Lack of experience is one of the most cited causes associated with significant accident rates in different sectors (Bande & López-Moruelo, 2015; Cattledge, Hendricks, & Stanevich, 1996).

Table 6 shows the effect of workers' experience on the severity of the accidents under study. It is important to note that these data refer to the period of time the person has been employed at a particular company, rather than their experience in the industry as a whole.

Table 6 shows that more than half of all mining accidents (58.18%) happen to workers with between 5 and 30 years' experience. The figure is the same for light accidents (58.31%) and slightly lower for serious accidents (47.62%) and fatal accidents (55.56%). These results show us again that the mining sector has a highly consolidated workforce with employees possessing a huge amount of cumulative knowledge.

In the specific case of mining, there is a direct relationship between workers' age and work experience (Margolis, 2010). In this regard, it should be noted that although age can increase accidents and their severity, as indicated above, experience can help to reduce them and lower their severity, as workers with greater experience show greater concern for the risks involved in their work (Bande & López-Moruelo, 2015). Therefore, situations with opposite effects can occur.

Finally, it should be noted that work experience is one of the aspects that characterizes the mining sector and sets it apart from other, more precarious sectors that bring in younger workers and have higher turnover rates (so less work experience), as is currently the case in construction (Camino-López et al., 2008) and agriculture (Baraza, & Cugueró-Escofet, 2021).

3.2. Business variables

An organization's activity is a relevant aspect when studying occupational accidents. We classify economic activities following the Statistical Classification of Economic Activities in the European Community (NACE) (EUROSTAT, 2008).

Table 7 shows that accidents are concentrated in activities 051 (anthracite and coal mining), 081 (stone, sand and clay extraction) and 089 (other extractive industries), which account for 47.68%, 30.69%, and 12.71% of all mining accidents, respectively. Together, they represent 91.09% of all accidents. The last group, 089, includes mineral extraction for chemicals and fertilizers, peat extraction, and salt extraction.

It is important to highlight the existence of two clearly different mining sectors with differing activities (what we might call subsectors), which require a separate analysis: surface mines, or outdoor mining (code 081), and underground mines (code 051). These subsectors vary insofar as the type of mining work is clearly

Table 5
Total mining accidents comparing nationality and severity, Spain (2013–2018).

Chi-Sqd =	6.76		df =	3	Sig =	0.001		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
	N =	15,032	N =	14,816	N =	168	N =	45
Nationality	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
Spain	14,148	94.12	13,950	94.15	154	90.06	0	97.78
Foreign countries	884	5.88	29	5.85	17	9.94	0	2.22

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

Table 6
Total mining accidents comparing length of service and severity, Spain (2013–2018).

Chi-Sqd =	39.79		df =	21	Sig =	0.008		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
	N =	15,032	N =	14,816	N =	168	N =	45
Length of service	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
<1 month	449	2.99	440	2.97	7	4.17	2	4.44*
1–3 months	926	6.16	908	6.13	14	8.33	4	8.89
4–12 months	1,518	10.10	1,482	10.00	33	19.64	3	6.67
1–2 years	1,338	8.90	1,317	8.89	16	9.52	5	11.11
3–4 years	1,933	12.86	1,908	12.88	18	10.71	5	11.11
5–10 years	4,619	30.73	4,572	30.86	37	22.02	9	20.00
11–30 years	4,126	27.45	4,067	27.45	43	25.60	16	35.56
> 30 years	126	0.84	122	0.82	3	1.79	1	2.22*

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

Table 7
Total mining accidents comparing activity (NACE code) and severity, Spain (2013–2018).

Chi-Sqd =	149.52		df =	21	Sig =	0.000		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
Activity	N =	15,032	N =	14,816	N =	168	N =	45
(NACE code)	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
Anthracite and coal mining (051)	7,168	47.68	7,126	48.10	31	18.13	11	24.44
Lignite mining (052)	271	1.80	268	1.81	3	1.75	0	0.00
Iron ore mining (071)	56	0.37	55	0.37	1	0.58	0	0.00
Non-ferrous metallic ore mining (072)	851	5.66	829	5.60	18	10.53	4	8.89
Stone, sand and clay extraction (081)	4,614	30.69	4,493	30.33	98	57.31	23	51.11
Other extractive industries (089)	1,910	12.71	1,889	12.75	14	8.19	7	15.56
Oil and natural gas extraction support activities (091)	52	0.35	50	0.34	2	1.17	0	0.00
Other extractive industry support activities (099)	110	0.73	106	0.72	4	2.34	0	0.00

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

different, as are the accidents that occur in the respective mines (Sanmiquel, Freijo, Edo, & Rossell, 2010).

Outdoor mining is done when commercially useful deposits are near the surface. Mechanical means (heavy and large machinery) or explosives are used to remove the land that covers or surrounds the geological formation containing the deposit or material bank.

Between 2013 and 2018, a total of 4,614 accidents were reported for this type of mine (30.69% of the total). This proportion remains the same for light accidents (LAR 30.33%) but increases considerably for serious accidents (SAR 57.31%) and fatal accidents (FAR 51.11%). If we remove the accident in Pozo Emilio that claimed six lives in 2013, the FAR would be 43.59%, which is still higher than expected. This is due to the type of activity, which involves the use of heavy machinery and explosive material.

Underground mining takes place below the surface, through underground work. In comparative terms, the machinery used in underground mining is much smaller than the machinery used in open pits. This is because of the limited space in the galleries and the other mining work going on. Underground mining accounts for 47.68% of the total accidents under study (7,168), a proportion that remains the same for light accidents (LAR 48.10%), but substantially drops for serious accidents (SAR 18.13%) and fatal accidents (FAR 24.44%). We must highlight, once again, the change in results caused by the Pola de Gordón accident, which occurred in an underground mine and killed six miners.

The mining sector is run by a few very large companies that control most of the mining operation. According to 2018 data, employment in the mining sector according to company size (number of employees) is distributed as follows: there were 2,098 companies with between 1 and 9 workers (76.82%), 432 companies with between 10 and 19 workers (14.35%), 140 with between 20 and 49 workers (5.13%), 38 with between 50 and 99 workers (1.38%), 16 with between 100 and 499 workers (0.59%), and 7 companies with 500 workers or more (0.26%) (Directorate General for Energy Policy and Mines, 2020).

Company size is a highly relevant variable, if not the most relevant variable, in determining the risk prevention model to apply. It can influence the accident rate of a company, as well as the severity of the accidents that occur (Page, 2009). Table 8 shows the severity of accidents depending on company size.

Companies with more than 500 workers account for most of the accidents (TAR 30.00%; 4,509 accidents), but these accidents show much lower severity, with a SAR of 6.55% and a FAR of 6.67%. The opposite can be said for smaller companies with less than 25 workers, as they bear 25.77% of the accident rate (3,874 accidents) but have a much higher proportion of serious accidents (SAR 47.96%) and fatal accidents (FAR 51.11 %). However, these data are only for the accidents that took place and do not account for the number of people employed in these companies, so the results can be misleading depending on the conclusions to be drawn.

In the mortality figures studied, there is a significant trend towards higher mortality in smaller companies. This suggests that larger mines are safer than smaller mines (Page, 2009). This may be due to labor authority pressure (which is higher for larger companies) and all the security measures implemented by the employer.

It has been shown that larger companies generally display better safety levels than smaller ones (Salminen, Saari, Saarela, & Räsänen, 1993; Fabiano, Curro, & Pastorini, 2004). This is not exclusive to the mining sector, occurring in other sectors such as construction (Camino-López et al., 2008; López-Arquillos et al., 2012) and metalworking (Fuentes-Bargués et al., 2022) as well.

It is worth noting that not all mining accidents occur at one's usual worksite. Accidents sometimes occur when workers are moving between sites or between different areas of their usual

Table 8
Total mining accidents comparing company size and severity, Spain (2013–2018).

Chi-Sqd =	124.86		df =	21	Sig =	0.000		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
Company size	N =	15,032	N =	14,816	N =	168	N =	45
(workers)	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
<5	894	5.95	863	5.82	25	14.62	6	13.33
5–10	1,042	6.93	1,013	6.84	20	11.70	9	20.00
11–25	1,938	12.89	1,893	12.78	37	21.64	8	17.78
26–50	1,835	12.21	1,790	12.08	37	21.64	8	17.78
51–100	1,802	11.99	1,785	12.05	15	9.36*	1	2.22
101–250	1,295	8.61	1,284	8.67	9	5.26	2	4.44
251–500	1,717	11.42	1,693	11.43	16	9.36	8	17.78
> 500	4,509	30.00	4,495	30.34	11	6.43	3	6.67

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

work location. Table 9 includes the severity of accidents in the mining sector based on the location of the accident.

Indeed, Table 9 confirms that not all mining accidents occur at one's usual worksite, but most of them do (93.55%). However, accidents sometimes happen when workers are travelling between sites or between different areas within their usual work location, and this percentage increases for higher severity accidents.

Considering the above results, a high percentage of the accidents analyzed occurred at the person's usual worksite (TAR 93.55%), but the serious and fatal accidents rates are considerably lower (SAR 76.19% and FAR 75.56%). Accidents at non-usual worksites account for 2.79% of all accidents, although their severity is much greater (SAR 11.90% and FAR 13.33%).

It is important to note that high FARs in the mining sector, especially at one's usual worksite, are related to the mining equipment used, especially conveyors, haul trucks, and dumpers. Deaths tend to occur during maintenance and repair activities (Duarte, Marques, & Santos, 2021). This analysis underlines the importance of implementing preventive action plans that maximize safety when using mining machinery (Mitchell, 1989; Angeles & Kumral, 2020).

As mentioned above, accidents occurring between one's home and work or between two worksites account for a relevant part of the accident and accident severity rates. These are usually road accidents (with the worker's own vehicle), which are outside the company's scope of action, even though they are legally computed as occupational accidents. In this case, it is important to consider safety and prevention criteria such as those included in the ISO 39001 standard (Sánchez-Toledo & Baraza, 2015).

3.3. Material variables

Accident deviation has been frequently studied in the literature (Sanmiquel et al., 2015; Melchior & Ruviaro, 2019). Table 10 presents the aggregate deviations data for all mining accidents occurring in Spain between 2013 and 2018. The deviations classification follows the European Statistics on Accidents at Work (ESAW) methodology (EUROSTAT, 2013).

Regarding mining accidents and the deviations causing them, six deaths were associated with category 020 ("Deviation due to overflow, tipping, leakage, spillage, emanation") and, more specifically, with category 023 ("In gaseous state, overflow, overturn"). This data corresponds specifically to the Pola de Gordón accident in 2013, which we have already discussed. This type of accident is common in underground mines, especially in the coal sector (Yin et al., 2017). Causes include poor ventilation and failures to detect harmful substances in the air.

Once again, we will consider this accident as an exceptional event. Thus, the main types of accidents correspond to categories 040 ("Total or partial loss of control of work equipment or unspecified materials"), accounting for 18.97% of total accidents (2,851) and 26.67% of fatal accidents (12); 060 ("Body movement without added physical effort"), which accounts for 21.67% of total accidents (3,257) and 6.67% of fatal accidents (3); and finally, 070 ("Body movement because of or with unspecified physical effort"), with the highest number of accidents (4,084; 27.1%), although none of them fatal. Categories 060 and 070 correspond mainly to musculoskeletal disorders, aspects to be analyzed from an ergonomic perspective (Alcaide & Dalmau, 2018).

Mechanical issues have been considered the cause of a significant number of accidents (Ismail et al., 2021). In this regard, category 040 stands out for its significant number of accidents and for their seriousness. These results match those of other studies in which it was determined that machinery, especially heavy machinery, is involved in a very significant number of mining accidents and impacts on their severity (Rufft, Coleman, & Martini, 2011). The type of machinery involved are conveyors, bolting machines, milling machines and transport equipment, such as lorries or loaders. The most common activities associated with these accidents are the operation of the machine and its maintenance or repair.

Table 9
Total mining accidents comparing accident location and severity, Spain (2013–2018).

Chi-Sqd =	169.63		df =	9	Sig =	0.000		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
	N =	15,032	N =	14,816	N =	168	N =	45
Accident location	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
Usual worksite	14.062	93.55	93.81	128	76.19	34	34	75.56
On the way from one worksite to another	196	1.30	1.24	10	5.95	3	3	6.67
Going to the worksite or back home	354	2.35	2.31	10	5.95	2	2	4.44
Non-usual worksite	420	2.79	2.65	20	11.90	6	6	13.33

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

Table 10
Total mining accidents comparing deviation and severity, Spain (2013–2018).

Chi-Sqd =	977		df =	141	Sig =	0.000		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
	N =	15,032	N =	14,816	N =	168	N =	45
Deviation (code)	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
Deviation due to electrical problem, explosion, fire (010)	90	0.60	87	0.59	2	1.19	1	2.22
Deviation due to overflow, tipping, leakage, spillage, emanation (020)	441	2.93	430	2.90	5	2.38	6	13.33
Breaking, bursting, sliding, falling, collapsing of material agents (030)	2,180	14.50	2,124	14.34	42	25.00	14	31.11
Total or partial loss of control of work equipment or unspecified materials (040)	2,851	18.97	2,796	18.87	43	25.03	12	26.67
Worker falls, slips or trips, unspecified (050)	1,884	12.53	1,843	12.44	38	22.62	3	6.67*
Body movement without added physical effort (060)	3,257	21.67	3,234	21.83	20	11.31*	3	6.67*
Body movement because of or with unspecified physical effort (070)	4,084	27.17	4,072	27.48	9	5.36*	0	0.00
Surprise, fear, violence, aggression, threat, presence (080)	48	0.32	44	0.30	4	2.38	0	0.00
Other deviation (099)	98	0.65	86	0.58	6	3.57	6	13.33
No information (000)	102	0.68	100	0.67	2	1.19	0	0.00

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

We must therefore stress the importance of having operational and preventive maintenance procedures in place for machinery, as well as implementing additional safety measures (Rufft et al., 2011).

Despite not appearing as an important type of accident, category 010 (“Deviation due to electrical problem, explosion, fire”) is in fact relevant, given the consequences an accident of this type can have. Zhu et al. (2019), after analyzing 782 mine explosion accidents in China, found that about 55% of gas explosions occurred in coal mines with low methane gas emission rates. The same authors found that dust explosions in coal mines caused approximately 59% of fires and explosions, claiming more than 100 victims.

Table 11 shows the aggregate data for accidents and their severity by injury type for the period between 2013 and 2018 in Spain’s mining sector. Injuries are categorized according to ESAW (EUROSTAT, 2013).

Categories 010 (“Superficial wounds and injuries”) (TAR 36.70%); 020 (“Bone crushing”) (TAR 7.45%), and 030 (“Dislocations, sprains and strains) (48.45%) add up to 92.60% of the occupational accidents on record. These values match those of other productive sectors (Camino-López et al., 2008; López-Arquillos et al., 2012; Baraza & Cugueró-Escofet, 2021; Fuentes-Bargues et al., 2022). Similarly, focusing on the part of the body injured, Rahimi et al. (2022) indicate that injuries to the upper part of the body are the most important in terms of increasing severity.

If we analyze the mining accidents classified as serious, the three abovementioned types of injury (010, 020 and 030) add up to 55.95% of the total accidents, not including any fatal accidents for the period between 2013 and 2018. Moreover, 60.00% of serious accidents are the result of multiple injuries (code 120). This indicates that most serious and fatal accidents occur due to concussions and internal injuries, heart attacks, strokes, and other non-traumatic conditions. Here we have not considered the six deaths due to suffocation in the Pola de Gordón accident in 2013. We must also point out that accidents caused by non-traumatic diseases (myocardial infarction, cerebral hemorrhage, etc.) are considered work accidents in Spain unless there is evidence to the contrary.

3.4. Temporal variables

Table 12 shows work days lost due to accidents, broken down by accident severity. Lost workdays are also a measure used to determine the severity of an accident, as seen in several studies (Fontaneda et al., 2019; Baraza & Cugueró-Escofet, 2022).

Data on the number of days lost per accident with respect to accident severity show that most accidents lead to an injury leave of up to three months, basically for light accidents (LAR 88.68%). For injury leaves up to one month, the LAR is 63.61%. We should point out that light accidents sometimes last several days because

Table 11
Total mining accidents comparing injury and severity, Spain (2013–2018).

Chi-Sqd =	3,400		df =	42	Sig =	0.000		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
	N =	15,032	N =	14,816	N =	168	N =	45
Injury (code)	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
Superficial wounds and injuries (010)	5,517	36.70	5,502	37.14	15	8.77	0	0.00
Bone crushing (020)	1,120	7.45	1,046	7.06	74	43.27	0	0.00
Dislocations, sprains and strains (030)	7,283	48.45	7,278	49.12	5	2.92	0	0.00
Amputations (040)	68	0.45	53	0.36	15	8.77	0	0.00
Concussions and internal lesions (050)	454	3.02	428	2.89	20	11.70	6	13.33
Burns, scalds and frostbite (060)	179	1.19	174	1.17	5	2.92	0	0.00
Poisonings and infections (070)	6	0.04	6	0.04	0	0.00*	0	0.00*
Drowning and asphyxiation (080)	22	0.15	15	0.10	1	0.58	6	13.33
Effects of noise, vibration and pressure (090)	17	0.11	17	0.11	0	0.00*	0	0.00*
Extreme temperature effects (100)	10	0.07	10	0.07	0	0.00*	0	0.00*
Psychic trauma, traumatic shock (110)	25	0.17	25	0.17	0	0.00	0	0.00
Multiple injuries (120)	189	1.26	139	0.94	23	13.45	27	60.00
Heart attacks, strokes and other non-traumatic injuries (130)	52	0.35	31	0.21	15	8.77	6	13.33
Other injuries (999)	70	0.47	69	0.47	1	0.58	0	0.00*
Unknown injury (000)	23	0.15	23	0.16	0	0.00	0	0.00

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

Table 12
Total mining accidents comparing days of injury leave and severity, Spain (2013–2018).

Chi-Sqd =	9,000.00		df =	21	Sig =	0.000		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
	N =	15,032	N =	14,816	N =	168	N =	45
Injury leave	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
1 day	24	0.16	0	0.00	0	0.00*	24	53.33
2–7 days	2,673	17.78	2,649	17.88	4	2.38	19	42.22
8–15 days	3,578	23.80	3,574	24.12	2	1.19	2	4.44
16–30 days	3,207	21.33	3,201	21.61	6	3.57	0	0.00
1–3 months	3,738	24.87	3,714	25.07	24	14.29	0	0.00
4–6 months	1,534	10.20	1,440	9.72	93	55.36	0	0.00
7–12 months	187	1.24	155	1.05	31	18.45	0	0.00*
> 1 year	94	0.63	83	0.56	11	6.55	0	0.00*

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

their actual recovery time is longer than initially expected (López-Arquillos et al., 2012).

The most serious accidents are concentrated in periods of absence between one month and one year, with the SAR at 88.10%. If we consider only the interval of absence from four to 12 months, the SAR is 69.65%; and if we reduce the interval to four to six months, the SAR is 55.36%. This means that more than half of all serious mining accidents lead to the injured miner being absent for between four and six months. If we consider all the accidents with an absence of more than one month, the SAR reaches 93.45%, meaning that 93.45% of the serious accidents that occur in the mining sector entail a period of injury leave of more than one month.

Most fatal accidents involve an absence of one day (FAR of 53.33%) or an absence between one and seven days (FAR of 42.22%). In the database used for the study, cases of instant death or death during accident are recorded as having one day of absence. This justifies these high figures for one-day injury leaves. In the remaining cases, the difference between the day of the accident and the day of death is recorded. The data presented do not include relapses from previous accidents which require a new period of injury leave.

Table 13 presents the accident severity rate data according to the day of the week. Monday is shown to have more total accidents (TAR 24.16%).

According to Elfering, Gerhardt, Pereira, Schenker, and Kottwitz (2020), Monday is the day of the week with the highest accident rate. This is the so-called "Monday effect," a consequence largely due to notifying weekend accidents on Monday because of the worker's social benefits with the insurance company (Camino-López et al., 2008). This effect has a direct impact on the number of light accidents reported on Saturday (TAR 2.80%) and Sunday (TAR 1.36%), compared to other days, such as Tuesday, Wednesday or Thursday, where the number of total accidents remains more or less constant. In any case, the fact that Monday is the day on which the most accidents are recorded in the mining sector (TAR 24.16%) is not something exclusive to this sector, as this is seen in most economic sectors (Camino-López et al., 2008; López-Arquillos et al., 2012; Baraza & Cugueró-Escofet, 2021; Fuentes-Bargues et al., 2022). The number of accidents is lower on Fridays, because many mining centers work half days.

3.5. Geographic variable

According to data from the Ministry for the Ecological Transition and the Demographic Challenge, the regions of Spain that employ the highest number of workers in the mining sector are Andalusia, Asturias, Castilla y León, Catalonia, and Galicia. These regions account for 68.42% of all mining jobs in Spain (Directorate General for Energy Policy and Mines, 2020). Andalusia stands out for metal mining and rock extraction; Galicia for the extraction of ornamental rocks, especially slate; Asturias and Castilla y León have a large proportion of coal mines, a dangerous and declining subsector; and Catalonia is mainly characterized by potash mining, which is also in decline.

Table 14 displays information on the accident severity rates in the different regions of Spain. The region of Castilla y León stands out for the total number of deaths (15); this is related to the Pola de Gordón accident mentioned previously, which led to six deaths.

Asturias stands out in the total accident rate, as it represents 44.00% of the total accidents and 44.43% of light accidents. These proportions decrease significantly when it comes to serious accidents (SAR 15.79%) and fatal accidents (FAR 6.67%). This contrasts with employment numbers, as Asturias is not the region with the highest number of jobs in the mining sector. Asturian mining is fundamentally coal-based, and coal is a raw material in disuse, associated with a reduction in direct labour and an increase in accidents (Knights, & Scanlan, 2019).

Table 13
Total mining accidents comparing day of the week and severity, Spain (2013–2018).

Chi-Sqd =	21.64		df =	18	Sig =	0.248		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
Day of	N =	15,032	N =	14,816	N =	168	N =	45
the week	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
Monday	3,631	24.16	3,587	24.21	34	19.88	10	22.22
Tuesday	3,049	20.28	3,003	20.27	35	20.47	11	24.44
Wednesday	2,880	19.16	2,838	19.15	32	18.71	10	22.22
Thursday	2,673	17.78	2,635	17.78	26	15.20	11	24.44
Friday	2,176	14.48	2,137	14.42	36	21.05	1	2.22
Saturday	421	2.80	414	2.79	5	2.92	2	4.44
Sunday	205	1.36	202	1.36	3	1.75	0	0.00*

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

Table 14
Total mining accidents comparing region of Spain and severity, Spain (2013–2018).

Chi-Sqd =	21.64		df =	18	Sig =	0.248		
	Total accidents		Light accidents		Serious accidents		Fatal accidents	
Region of	N =	15,032	N =	14,816	N =	168	N =	45
Spain	Number	TAR%	Number	LAR%	Number	SAR%	Number	FAR%
Andalusia	1,070	7.12	1,034	6.98	28	16.37	6	13.33
Aragón	534	3.55	524	3.54	9	5.26	1	2.22
Asturias	6,614	44.00	6,583	44.43	27	15.79	3	6.67
Cantabria	120	0.80	118	0.80	2	1.17	0	0.00*
Castilla La Mancha	411	2.73	404	2.73	5	2.92	2	4.44
Castilla y León	1,748	11.63	1,712	11.56	21	12.28	15	33.33
Catalonia	1,618	10.76	1,599	10.79	15	8.77	4	8.89
Ceuta	3	0.02	3	0.02	0	0.00	0	0.00
Madrid	202	1.34	198	1.34	4	2.34	0	0.00
Valencia	438	2.91	423	2.86	14	8.19	1	2.22
Extremadura	515	3.43	501	3.38	13	7.60	1	2.22
Galicia	921	6.13	893	6.03	23	13.45	5	11.11
Balearic Islands	235	1.56	230	1.55	4	2.34	1	2.22
La Rioja	36	0.24	36	0.24	0	0.00	0	0.00
Navarre	100	0.67	100	0.67	0	0.00	0	0.00*
Basque Country	160	1.06	156	1.05	1	0.58	3	6.67
Murcia	310	2.06	302	2.04	5	2.92	3	6.67

(*) *Corrected Standardized Residuals < 1.96 in absolute value.*

In the opposite situation we find the region of Andalusia. Despite Andalusia being the region with the highest number of jobs in the mining sector (Directorate General for Energy Policy and Mines, 2020), it only registers 7.12% of the accidents studied, but accounts for 16.37% of the serious accidents and 13.33% of the fatal accidents. In this case, we find mostly open-pit mines. This leads us to believe that region plays a determining role in the rate of accidents due to the type of mine located there, which is a key factor in accident rate analysis, and not so much because of other geographical conditions (Sanmiquel et al., 2015).

4. Conclusions

Many of the sub-activities carried out in the mining sector are in decline. This is due to sustainability issues linked to the industries in operation. The aging workforce and the absence of younger people training to enter the sector also have an impact in this regard. Mining is concentrated in several regions in Spain, mainly focusing on the sub-activities mentioned above.

By analyzing data on the severity of accidents against several variables, we are able to shed some light on the most relevant ones, which can be helpful in arranging measures to potentially diminish accident numbers and severity.

Regarding company size, smaller companies tend to account for more serious accidents. Therefore, labor authorities should look after employees working for smaller firms, rather than focusing on larger ones alone.

As for workers' age, it is clear that the sector is aging, which comes with additional problems, as the skills necessary to avoid accidents can diminish with age. This explains the prevalence of accidents among older workers, even though they tend to be more experienced. The more serious accidents also occur among middle-aged workers more often than among their younger counterparts. This is because the sector is in decline, bringing in few younger employees.

In the mining sector, there is a direct relationship between age and accumulated work experience, making it a highly consolidated industry in terms of its workforce. Most accidents befall workers with between 5 and 30 years' experience. While age can potentially increase the number and severity of accidents, experience in this sector has the opposite effect, reducing the accident rate and lowering severity, as workers with greater experience show greater concern for the risks involved in their work. In this sector, work experience counteracts the tendency for there to be more, and more serious, accidents with age.

4.1. Implications for the industry and government

A first look at mining accidents in Spain could be misleading, as the low number of people employed may hide the sector's high accident rate. For this reason, although raw material mining is in decline, it must not be forgotten by the authorities. This is the only way to ensure the safety and health of miners who continue to be employed in this sector. The labor administration must be especially sensitive to this sector. Specific action plans and increased inspections at mining facilities are measures that could reduce the high accident rate found.

Identifying the most important variables present in mining accidents was the first step to reduce accidents in the sector. The conclusions of this article can be used to study prevention measures and implement them in situations where the most serious accidents are shown to occur.

4.2. Limitations

This paper analyzed the occupational accident and accident severity rates in Spain's mining sector between 2013 and 2018. The conclusions drawn here could therefore differ from those in other European Union countries and the rest of the world.

We have only considered accidents leading to at least one day of injury leave. Naturally, therefore, this study does not analyze incidents or near misses (accidents without personal injury). In addition to this, the Ministry of Labour, Migration and Social Security's work accident registry system only contains accidents that have been reported. The implication is that some accidents may not have been reported and have therefore not been considered in this study.

Similarly, we analyzed the seriousness of the accidents once they had already occurred. In other words, we have not analyzed the probability of accidents actually occurring. The nature of the data used in this research has allowed us to study and compare groups of accidents that have taken place in the mining sector, in

order to show the probability that an accident in this area will be light, serious or, in the worst case, fatal.

4.3. Future research

Future research will need to perform a detailed study of some of the variables, in order to gain more precise insight into their influence on the severity of accidents in the mining sector.

Given the different activities and related occupational risks of several subsectors of underground and outdoor mining, further studies differentiating between the two would be interesting and worthwhile, both to shed greater light on the issue and to develop prevention measures accordingly.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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