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Safety climate in defence explosive ordnance: Survey development and model testing

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ABSTRACT

Safety climate surveys are tools for monitoring safety standards, and versions of these instruments have now been developed in many high-risk industries. The explosive ordnance (EO) industry has been slow to embrace this technology, yet there is a demonstrable need for these tools. This study describes the development and validation of the EO Safety Survey (EOSS). A total of 272 EO workers from the Australian Defence Force (ADF) completed the survey. In phase one of the study, exploratory structural equation modelling (ESEM) techniques were used to test the dimensionality of scores derived from the generated safety climate and behaviour items. In phase two, an *a priori* structural model linking safety climate, psychological strain, compliance behaviour, willingness to report, and errors was tested. Results showed that reasonably well-defined safety climate and safety behaviour constructs were found to underlie the survey items. In addition, support was found for a model that connects safety climate with errors via a psychological health pathway and via a safety behaviours pathway. To be effective, safety interventions should address both paths. The model also showed safety climate having a direct effect on compliance and both a direct and an indirect, via compliance, effect on willingness to report. The study thus introduces a new climate measure for use in an EO environment and clarifies the pathways linking safety climate with reporting behaviours and errors.

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1. Introduction

1.1. Background

On 12 October, 1654, approximately 40 tonnes of gunpowder exploded, destroying much of the city of Delft in the Netherlands. Over a hundred people were killed and thousands wounded. On 6 December 1917, the SS *Mont Blanc*, a ship carrying 2653 tons of explosives, collided with the SS *Imo* in Halifax Harbour, Nova Scotia. *Mont-Blanc* caught fire, drifted into town and eventually exploded. More than 2000 people were killed and much of Halifax was destroyed. The explosive ordnance (EO) incidents described in these opening lines are among the most catastrophic of their kind. They seem reassuringly remote and one wonders whether such things could still happen.

The answer is an unequivocal "Yes". Zahaczewsky (2015) estimated that worldwide between 1995 and May 2010, nearly 218 incidents involved ammunition dumps, resulting in over 4700 fatalities. He went on to list other, more recent, EO disasters. Interspersed among these major events were many smaller EO incidents where mishaps occurred for individuals engaged in handling weapons, munitions, or ordnance. Clearly, there is nothing remote about EO safety issues and these ongoing incidents emphasise the need for research into their causes.

The current study developed from a review of policies and procedures for the management of explosive ordnance within the Australian Defence Force (ADF). While there had been no recent major EO incidents, even small safety EO incidents can have defence implications. As well as the potential for physical harm and distress to individuals, such events can trigger suspensions of equipment use, reviews of training, and lengthy investigations. The conduct of operations can also be affected. The aim of the study was to measure selected human factors that might contribute to EO incidents, and to model their associations with safety behaviours. We describe the development of an EO safety survey where the selection of scales was informed by a theoretical model of accident causation (Fogarty and Buikstra, 2008) and items were generated following a study of the EO environment and interviews with EO personnel. A second aim of the study was to test an extended

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version of the model upon which the survey was based, thereby serving as a test of the validity of scores generated by the measure. Specifically, we were interested in the links between safety climate, psychological strain, compliance, errors, and incident reporting.

1.2. Conceptual model linking safety climate to safety performance

The model that provided the theoretical framework for instrument development is depicted in Fig. 1. The four main constructs captured by the model are safety climate, psychological strain, compliance, and errors. We introduce each of these constructs before discussing their interrelations. We then describe the extensions to this model in the current study.

Safety climate is the most important component in the model. Safety climate refers to the individual's perceptions of the organisational policies, procedures, and rewards relevant to safety in the organisation (Guldenmund, 2000; Griffin and Neal, 2000; Schneider et al., 2013). This definition distinguishes it from safety culture, which is usually regarded as a stable, deep-seated aspect of an organisation that expresses itself through climate (Guldenmund, 2000, p.221). Safety climate scales have been widely used for over three decades across diverse industries. They are easily administered, the resulting data are quantitative, benchmarks can be established, and feedback can be provided to management and the workforce. It is also generally accepted that safety climate measures can predict safety behaviours (Johnson, 2007; Nahrgang et al., 2011; Neal and Griffin, 2004; Zohar, 2010).

In his review of 30 years of safety climate research, Zohar (2010) encouraged the development of industry-specific scales to identify new, context-dependent targets of climate perceptions. A search of the literature revealed a small number of instruments developed for the related petro-chemical domain (e.g., Nielsen et al., 2013) but few, if any, safety climate instruments developed within a military EO context. Using the model shown in Fig. 1 as a conceptual framework, the authors commenced development of an EO safety survey.

Background research started with a qualitative analysis of existing safety/performance data, including an EO incident database. This phase was followed by a series of focus groups at multiple levels in the organisation, aiming to delve into issues and concerns affecting safety performance. Another source of items was the existing literature on core safety climate dimensions. Although a small number of core safety dimensions are recognised, safety climate measures vary widely in the number and nature of their scales (Flin et al., 2000; Morrow et al., 2010; Neal and Griffin, 2004; O'Connor et al., 2011), leaving open the question of which ones to include in this study. A final source of items was the experience of the authors in survey design and administration in both the military and civilian sectors.

The three other elements in the model were psychological strain and the two safety behaviours, namely safety compliance and self-reported errors. Psychological strain was defined by measures of fatigue and psychological distress. It is an individual differences variable that falls outside the safety climate domain but was included because of its known links with safety performance (Clarke, 2010; Fogarty, 2005; Fogarty and Buikstra, 2008). Safety compliance and errors, are both forms of safety performance, which can be distinguished from safety outcomes such as accidents (Christian et al., 2009) and can be investigated using self-report measures.

The essential features of the Fogarty and Buikstra model were that safety climate predicted safety compliance and psychological strain, both of which had a direct influence on errors. Another feature of the model was the lack of a direct link between safety climate and errors. Instead, the link between safety climate and errors was mediated by safety compliance through one pathway and psychological strain through another pathway. The violations pathway is self-evident in that failure to follow procedures is known to be associated with errors and accidents. Furthermore, violations are more likely to occur when safety climate is poor (Probst, 2015; Reason, 1997). The psychological strain pathway is not as well established in the literature. Fatigue and stress are associated with organisational factors such as poor workload planning, lack of resources, and poor supervision (Clarke, 2010; Fogarty, 2005; Oliver et al., 2002). Fatigue and stress, in turn, are associated with errors and accidents (Clarke, 2010; Fogarty, 2005).

1.3. Extensions to the model

The Fogarty and Buikstra (2008) model was extended in the present study in two ways. First, a distinction was made between safety compliance behaviours exhibited by the respondent and behaviours exhibited by others in the workplace. The distinction was made because of referent shift research indicating the different outcomes obtained when the subject of an item stem is "I" versus "they" (Chan, 1998). The location of the variable in the structural model, however, remained unchanged: it retained its status as a mediator between safety climate and errors (see Fig. 1). A second change involved the addition of a scale to measure

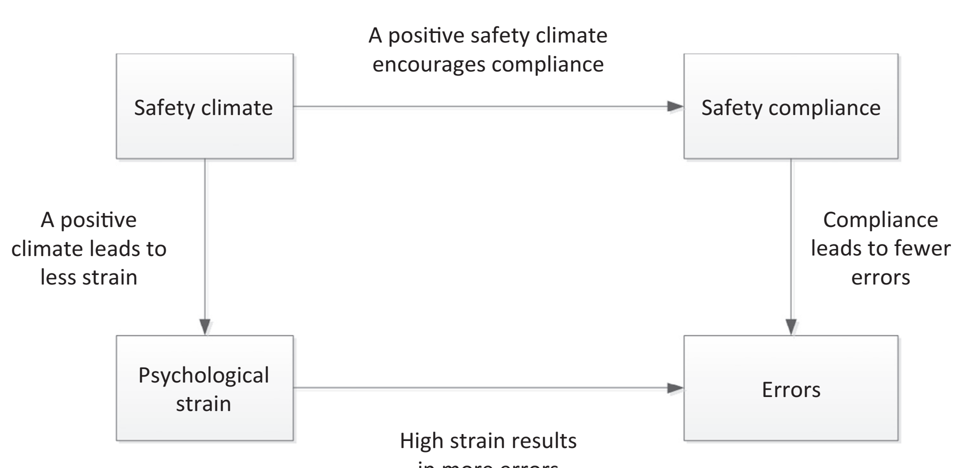

Fig. 1. Conceptual model underlying instrument construction (Fogarty and Buikstra, 2008).

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