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A test of Direct and Indirect Pathways Linking Safety Climate, Psychological Health, and Unsafe Behaviours

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Abstract

This study examined the relationship between workplace safety climate factors, individual psychological health factors, and self-reported errors and violation behaviours. The aim was to test hypotheses about different causal pathways for errors and procedural violations. A total of 308 aviation maintenance engineers completed a self-report questionnaire developed for this study. A structural model depicting workplace violations and psychological health acting as mediators between safety climate and errors was tested using structural equation modelling. The model fitted the data with safety climate accounting for 63% of the variance in violations and 52% of the variance in psychological health. Violations and psychological health combined to predict 58% of the variance in errors. The study demonstrates the importance of including both organizational and individual level variables to assess the safety status of an organization through the use of expanded safety climate surveys.

A test of Direct and Indirect Pathways Linking Safety Climate, Psychological Health, and Unsafe Behaviours

The concept of everyday cognitive failings was first introduced in the late 1800s by William James (1890) but sustained scientific interest in the concept had to await the advent of complex industrial technologies that stretched workers to their physical and mental limits. High-risk organizations such as offshore oil, nuclear power, chemical processing plants and aviation are unforgiving environments where errors can have devastating consequences. Growing concern about the cause of errors has led researchers to consider the impact of constructs such as safety climate, attitudes, social norms, stress, and cognition on safety behaviours such as errors and violations. However, much of this research is piecemeal. What is needed in the literature are studies that bring together these constructs in structural models that can be tested, thus providing empirical support for what are sometimes no more than descriptive models of error causation. The present study used structural equation modelling to test models of the direct and indirect effects of safety climate factors and individual psychological health on self-reported errors and violations in aviation maintenance. In the sections that follow, we trace the development of theory in this area of safety research before describing the development of a model that posits different causal pathways for errors and violations.

A group of researchers working mainly in the offshore oil industry (Fleming, Flin, Mearns, & Gordon, 1998; Mearns & Flin, 1999; Mearns, Flin, Gordon, & Fleming, 2001) modelled the accident causation process using Structural Equation Modelling (SEM). They hypothesised that people's perceptions of various organizational processes and practices – what is now called "safety climate" - influence the state of safety in the organization and that these perceptions can be captured using self-report questionnaires. Studies of safety climate by Flin and her colleagues shed some light on the potential contributors to accidents, with climate measures capturing up to 50% of the variance in safety outcomes.

These findings have been replicated in other industries and it is now accepted that safety climate measures can help to predict safety behaviours (Clark, 2006; Johnson, 2007). These findings appear to hold, whether the dependent variable is a self-reported measure of safety behaviour or actual measures of safety outcomes (e.g., Zohar, 2000; Cooper & Phillips, 2004; Johnson, 2007). Researchers in this area have therefore begun to pursue other lines of enquiry. One very active line of enquiry concerns the refinement of measurement instruments with which to capture the essential elements of safety climate and there are now many well-validated instruments from which to choose (e.g., Seo, Torabi, Blair, & Ellis, 2004; Silva, Lima, & Baptista, 2004; Evans, Glenda, & Creed, 2007).

A second line of enquiry aims to establish the mechanisms by which climate influences safety behaviours. Working within this tradition, Fogarty (2004) employed a safety climate approach to assist in the development of a model to explain morale, psychological health, turnover intentions, and error in the aviation maintenance environment. An instrument called the Maintenance Environment Survey (MES) was constructed and administered to 240 personnel responsible for maintenance of a large military helicopter fleet. The structural model predicted 45% of the variance in psychological health, 67% of the variance in morale, 27% of the variance in turnover intentions, and 44% of the variance in self-reported maintenance errors. In a follow-up study, Fogarty (2005) administered a revised version of the MES to 150 aviation maintenance personnel to test the fit of a model in which the effect of safety climate on errors was partially mediated by individual level factors, such as psychological strain. He found support for the model and argued that in the efforts to secure better safety outcomes, a dual focus should be maintained on organizational and individual level variables.

Within this same tradition, other researchers have taken a broader approach. Neal and Griffin (2006) used a longitudinal design to explore the role of safety motivation as a potential mediator of the safety climate-safety behaviour relationship. They reaffirmed the connection between climate and behaviour but warned that it takes time for positive changes in safety climate and safety motivation to manifest themselves in lower accident rates. Among the recommendations flowing from their study was that researchers not treat safety behaviour as a unidimensional construct. They identified safety compliance and safety participation as examples of distinct constructs that are usually not separated in studies of safety outcomes. The present study adopts that same view, arguing that errors and violations are distinct safety outcomes that need to be treated differently.

The Current Study

Dekker (2003) noted that in modern usage error can mean three things: 1) error as the cause of failure (e.g., proficiency); 2) error as the failure itself (e.g., wrong decision); and 3) error as process, as an intentional departure from some kind of standard. Not distinguishing between these different possible definitions of error is a problem. To reduce this conceptual confusion, we propose that this third category of errors be labelled violations, a term already used by many researchers in this area. It is further proposed that errors and violations have different causes and that the distinction is therefore not simply a matter of nomenclature. In a broad sense, it has been said that errors tend to result from cognitive, social and organizational factors, and violations tend to result from attitudinal, social and organizational factors (e.g., Reason, 1995; Reason, 1997; Sutcliffe & Rugg, 1998). The proposition that errors and violations have different aetiologies is therefore not new, but it is often overlooked. Furthermore, the empirical evidence supporting this intuitive link is weak because most studies have focused on either errors (Fogarty, 2004, 2005) or violations (e.g., Lawton, Parker, Stradling, & Manstead, 1997; Mearns et al., 2001; Mearns, Whitaker & Flin, 2003). There is a need for studies that include both variables, linking them in a hypothetical nomological net that can be tested using SEM techniques.

The measurement part of the model comprised four elements: indicators for Safety Climate, Psychological Health, Violations, and Errors. The structural part of the model comprised the hypothesised linkages between these four dimensions. Figure 1 shows the full model.

Insert Figure 1 about here

In Figure 1, Safety Climate is represented by the reflective indicators Management Support, Commitment to Safety, Management's Awareness of Violations, Communication Effectiveness, Access to Resources, Training, and Workload. Fatigue, Strain and GHQ are reflective indicators of the underlying construct called Psychological Health. Error Causes, Error Types, and Mistakes are reflective indicators of the construct Errors. Violation Attitude and Violation Behaviour are reflective indicators of a construct called Violations. Because most of the scales used in the present study were adapted from those already reported and validated in the literature, they were expected to define their hypothesised underlying dimensions.

The first part of the structural model comprises the direct link between Safety Climate and Psychological Health and a further direct link to Errors, thus modelling the indirect linkage between Safety Climate and Errors noted by Fogarty (2004, 2005). The second element in the structural model comprises the direct link between Safety Climate and Violations and a further direct link to Errors. In support of the first of these links, Helmreich (2000) suggested that violations can stem from a culture of non-compliance, perceptions of invulnerability, or poor procedures. He also reported that over half the "errors" observed in a line audit safety operations (LOSA) exercise were due to violations and that those who violated procedures were more likely to commit other types of errors. Mearns et al. (2001) found pressure for production and work pressure explained 58% of the variance in a construct they labelled Safety Behaviours, with pressure for production being the main contributor. Scales measuring violations often appear in the literature as safety behavior scales, so this finding supports the direct link between Safety Climate and Violations. Other researchers have confirmed this link (e.g., Neal, Griffin, & Hart, 2000; Oliver, Cheyne, Tomás, & Cox, 2002; Rundmo, 2000; Rundmo et al., 1998). The final link, that between Violations and Errors, is strongly supported by the literature where various researchers have shown that procedural violations are the best predictors of accident involvement (Hofmann & Stetzer, 1996; Lawton, Parker, Stradling, & Manstead, 1997; Lawton & Parker, 1998; Meadows, Stradling, & Lawson, 1998; Mearns et al., 2001).

We labelled this Model 1, the fully mediated model. Two competing models were also tested. Reason (1997) proposed that unsafe acts are caused by workplace conditions (safety climate factors) such as inadequate tools and equipment, undue time pressure, insufficient training, under-staffing, poor supervisor-worker ratios, and unworkable procedures. Therefore Model 2 differed from Model 1 in that it included an additional pathway from Safety Climate to Errors. We called this the partially mediated mode.. Model 3 was also a minor variation of Model 1 with a pathway fitted between Psychological Health and Violations to test whether the previously-noted direct effects of health on errors (Fogarty, 2004, 2005) extends to other forms of safety behaviours.

Method

Participants

A total of 308 maintenance personnel from the Australian Defence Force (ADF) were involved in the study. Of the personnel who completed the survey, 33.7% (N = 105) were from the Army, 27.6% (N = 86) from the Navy, and 37.2% (N = 116) from the Air Force.

The Survey Instrument

The Australian Defence Force (ADF) Flying Safety in Maintenance Climate Survey was developed for the present study in conjunction with subject matter experts from the ADF. The survey was divided into eight sections: (a) Background Information, (b) Flying Safety, (c) Workplace Flying Safety, (d) Working Procedures and Practices, (e) Reporting Procedures and Practices, (f) Training and Resources, (g) Other Issues and (h) General Health. Some sections of the survey were of interest to the Directorate of Flying Safety but not to the authors. The subscales described below are those relevant to the current study.

There were seven subscales in the Safety Climate section of the survey: 1) management support (Mgntsup) where three items measured how often management listened to safety concerns from subordinates such as supervisors and tradesmen (e.g., Managers listen to concerns from tradesmen/supervisors and react appropriately); 2) safety commitment (Safecomm) where four items assessed how committed the organization, management, and colleagues were to safety (e.g., The ADF is committed to flying safety); 3) management's awareness of conditions affecting safety (Mgntawar) where three items assessed management's awareness of workplace pressure and resulting shortcuts (e.g., Managers are aware that the pressure placed on supervisors makes it necessary to take shortcuts/risks to achieve the task); 4) communication effectiveness (Commeff) where three items measured the extent to which management was successful in communicating safety issues to subordinates (e.g., Management communicates issues effectively to tradespersons); 5) access to resources (Resacc) where four items assessed the availability of various resources such as personal protective equipment, manuals, equipment, and tools (e.g., I have access to all the tools that I need for my work); 6) training standards (Train) where seven items were used to assess the adequacy of training, including on-the-job training, trade skills, systems knowledge and formal training (e.g., The trade skills of junior personnel are adequate); 7) Workload (Workload), which was assessed using five items that rated the complexity of task performance (e.g., I undertake tasks concurrently to get the job done).

The Safety Climate items mostly employed 5-point ratings that ranged from 1 (strongly disagree) to 5 (strongly agree). Resources, Workload, and Management Support were rated on a

5-point scale that ranged from 1 (always) to 5 (never). Scores were recoded so that higher scores indicating a higher level of resources, workload and management support.

After the climate section, three subscales were used to measure the latent construct Psychological Health. The first of these was an abbreviated version of the strain scale used in Fogarty (2004, 2005). It comprised five items (e.g., How often do you feel stressed at work because of the job itself?). Four items were included to measure fatigue (e.g., How often do you feel fatigued at work because of the working hours?). Response options for both the strain and fatigue subscales ranged from 1 (never) to 5 (always). The third subscale was the 12-item version of the General Health Questionnaire (GHQ: Goldberg and Williams, 1988). The GHQ explores several aspects of psychological health and has been used as a measure of job-related strain (Parkes, 1992; Payne, Wall, Borrill, & Carter, 1999). Participants were required to respond to a number of statements regarding the state of their psychological health: anxiety and insomnia (e.g., Lost much sleep over worry?); social dysfunction (e.g., Have you felt that you are playing a useful part in things?); and severe depression (e.g., Been thinking of yourself as a worthless person?). Scores on this variable were recoded so that higher scores indicated better psychological health.

The next section of the survey instrument used two subscales to measure procedural violations. In the first of these (Violbeh), comprising five items, respondents indicated how frequently they engaged in unsafe behaviours (e.g., I will temporarily disconnect or remove a part to make a job easier, but not document the disconnection/removal). Possible responses ranged from 1 (always) to 5 (never). The second subscale (Violatt), comprising four items, tapped willingness to violate rules and procedures (e.g., I am prepared to take risks, other than those inherent in my job, to get a task done). Violatt employed a 5-point Likert scale that ranged from 1 (strongly disagree) to 5 (strongly agree). For both of these subscales, scores were recoded so that higher scores denoted a higher occurrence of violations or a greater willingness to engage in procedural violations.

In the final section of the survey, items from the Maintenance Environment Scale (MES: Fogarty, 2004) and the 48-item aircraft maintenance checklist developed by Hobbs and Williamson (2000) were used to form three marker variables for the latent construct, Errors. The first subscale (Errtype, 10 items), asked respondents to indicate how often they made different types of errors (e.g., I have missed out steps in maintenance tasks). In the second subscale (Errcaus, 10 items), respondents were required to indicate how often they had made errors because of different background factors (e.g., I make errors because of lack of concentration). In the third subscale (Mistakes, 4 items), respondents indicated how often they made mistakes due to training deficiencies (e.g., I make mistakes because my systems knowledge is lacking). Ratings for all subscales were made on a 5-point scale ranging from 1 (always) to 5 (never). Scores were recoded so that higher scores represented the occurrence of more errors and mistakes.

For all subscales, the dependent variable was the mean response for the subscale, that is, the total score divided by the number of items.

Procedure

The survey was administered to participant groups by serving members of the ADF Directorate of Flying Safety. Maintenance workers, maintenance officers, and personnel indirectly related to maintenance work were asked to participate in this study. The surveys were completed in group sessions lasting from 30 to 45 minutes and were then mailed to the university research team.

Statistical Analyses

The competing structural equation models were proposed and tested using the AMOS 4.0 (Arbuckle, 1999) program. Model fit was assessed using Chi Square (χ^2), the Chi Square to degrees of freedom ratio (χ^2/df), the Tucker-Lewis Index (TLI), the comparative fit index (CFI), and the root-mean-square error of approximation (RMSEA).

Results

A small number of missing values were replaced using the expectation-maximisation (EM) algorithm (Roth, 1994) in SPSS version 10.0. Following data screening, descriptive statistics were compiled to ascertain the spread of scores on the indicator variables. The means and standard deviations show a reasonable spread of scores. Additional normality checks (not reported) showed positive skewness on safety commitment (Safecomm), access to resources (Resacc), and the two measures of violation behaviours. GHQ scores were negatively skewed. These outcomes were not surprising and the degree of skewness was not judged to be problematic for the multivariate analyses to follow. With the exception of the training subscale, the internal consistency reliability estimates (Cronbach's alpha) for all variables were above .70, and most were above .80.

The main aim of the study was to test the conceptual model shown in Figure 1 and to compare fit indices with those obtained for two competing models. These fit indices for these three models are summarised in Table 1.

Insert Table 1 about here

The fit indices for all three models were indistinguishable in terms of their fit to the data and were either on the borderline or within commonly recommended cut-off values for these fit indices. Model 1, the fully mediated model, gave a slightly more parsimonious account of the data, however, so we selected it as our preferred model. The full measurement and structural model, with parameter estimates, is shown in Figure 2.

Insert Figure 2 about here

All pathways shown in the model were significant. The model accounted for 51% of the variance in Psychological Health, 61% of the variance in Violations, and 58% of the variance in Errors. As well as the direct effects, there was a significant indirect effect of Safety Climate on Errors ($b = .65$, $p < .01$).

Discussion

The aim of this study was to validate and extend existing models of organizational and individual factors in the prediction of unsafe acts. The study brought together the key outcome variables of errors and violations and related these to organizational and individual factors in a model which described the direct and indirect effects of safety climate and individual psychological health on self-reported errors and violations. The outcomes support the claims of other researchers that safety climate directly influences violations (e.g., Oliver et al., 2002; Rundmo, 2000; Rundmo et al., 1998), and that individual health directly influences the frequency of errors (Fogarty, 2004, 2005). Specifically, a large amount of the variance in violations (63%) can be explained by the safety climate of the organization and a large amount of the variance in errors (58%) can be explained by the combined effects of safety climate and psychological health. This study has supported the proposition that errors and violations have different psychological antecedents.

These findings are important to safety practitioners, particularly in the aviation industry. Hudson (2007) has written a very useful road map for implementing a safety culture in an organization. Towards the end of the paper, he warns academics against the dangers of continuing to refine measurement instruments instead of looking at how the instruments are used and what he calls coming “down from the trees” (p. 719) and engaging with industry. At the same time, he emphasises the importance to industry of having well-founded empirically justified theories. We would like to think that our focus in this study on breaking down safety problem behaviours into two easily-recognised components and showing that they have different aetiologies places us near to the bottom of the tree. A one-size-fits-all approach to safety behaviours might well prove effective but it will be highly inefficient. Attempts to reduce intentional and unintentional unsafe acts should be aimed at both individual and organizational levels, with an understanding of the different origins of errors and violations.

Whilst these findings replicate earlier research on errors and break new ground by considering errors and violations together, we should point out that the methodological shortcomings in this study. Firstly, using cross-sectional methodology is an evidently weak approach to causality (MacCallum & Austin, 2000). The use of self-report measures for all variables is also problematic in that there is the possibility of method variance as the source of commonality among the variables. One global concern of studies that involve structural equation modelling is that conclusions are likely to be limited to the particular sample. In this study, a restricted sample was used, that is, military aviation maintenance, and results should be treated cautiously when generalising beyond this population as the military population may not be representative of the maintenance population in general.

Safety climate measures such as the ones used in these studies are very useful but they should be standardised so that the items and scales are basically the same across administrations, thus permitting the establishment of benchmarks on the various scales (Flin et al., 2000). The focus of the research up to this point has been the identification of key safety outcomes and defining the network of relationships among these variables and background climate variables. A further aim has to be the linking of self-report measures with actual performance outcomes, rather than simply using self-report as the basis of measurement operations. The low base rates of incidents and errors suggests that this research will involve higher level modeling, but it is our expectation that the models developed to this point will prove useful in explaining safety data, whatever form it takes.

In conclusion, the safety literature tends to be dominated by discussions of error taxonomies and descriptive models of accident causation, such as the Reason (1997) model. We see these contributions as valuable but we also believe that they must be supported by empirical research. Structural equation modelling is a technique that can be used to test assumptions embedded in popular descriptions of accident causation. This study has developed and validated a model that encompasses a number of organizational, social and individual factors that predict a significant proportion of the variance in self-reported errors and violations. In ongoing studies, we are seeking to extend the model presented here to include incident reporting, another key psychological variable in the quest to achieve safer and more productive working environments. Safety will continue to be critical as complex high-risk industries, such as aviation, become more technologically-driven and complicated. Consequently, organizations will need to maintain a heightened awareness of safety, risk, and security.

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Table 1

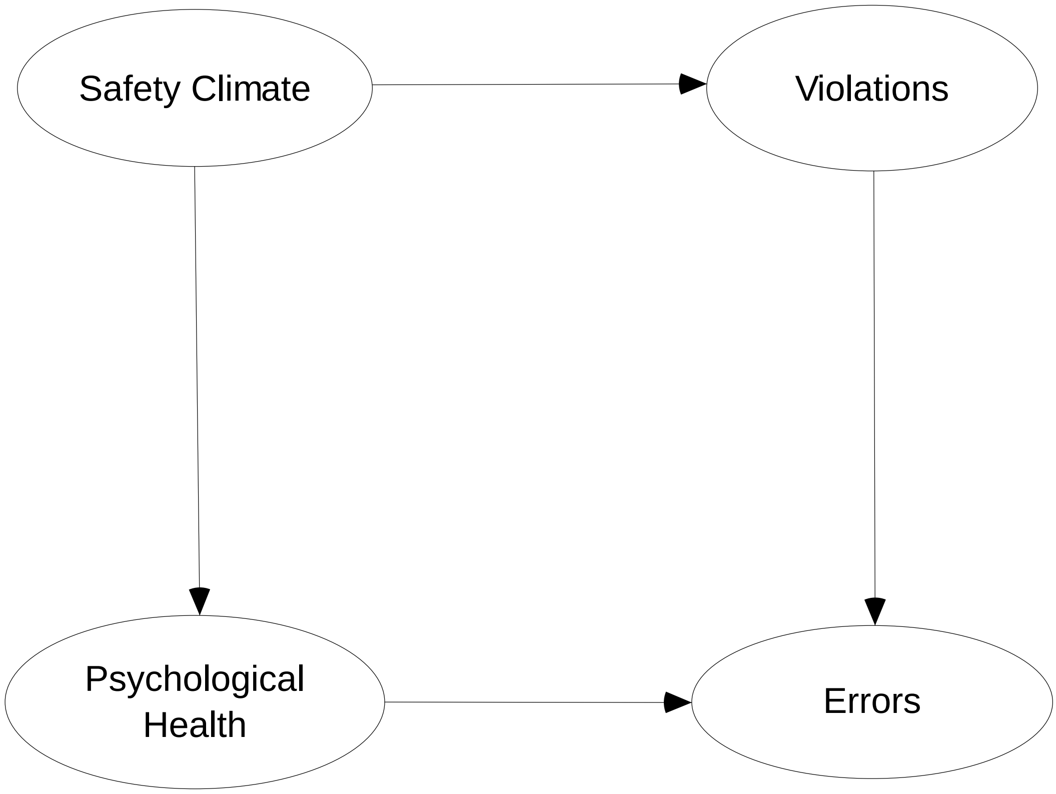
Summary of Fit Statistics for Different Models

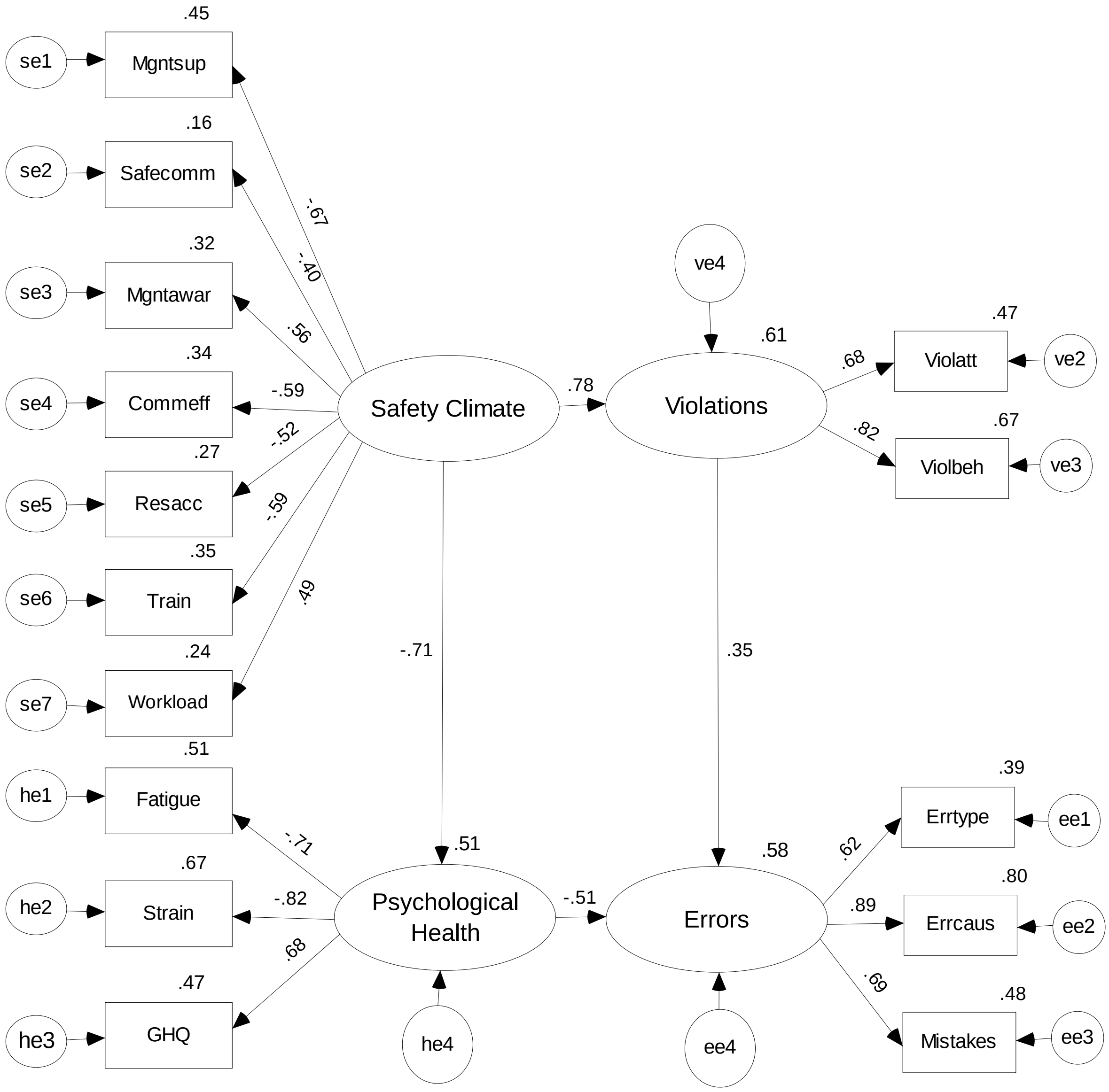
Model	χ^2	df	p	χ^2/df	TLI	CFI	RMSEA
1	182.66	86	< .01	2.12	.92	.94	.06
2	182.62	85	< .01	2.15	.92	.94	.06
3	180.89	85	< .01	2.13	.92	.94	.06

Figure Captions

Figure 1. Conceptual model representing relations among Safety Climate, Psychological Health, Violations, and Errors (Indicator variables not shown)

Figure 2. Empirical model representing relations among Safety Climate, Psychological Health, Violations, and Errors


Safety Climate
Violations
Psychological Health
Errors



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