The Complexity, Stability and Diagnostic Power of the Safety Climate Concept

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The Complexity, Stability and Diagnostic Power of the Safety Climate Concept

1. INTRODUCTION

It has been clear for several decades that the nature of accident and incident occurrence a complex, and not due to any single phenomenon. Indeed there is empirical evidence that accidents are multifaceted phenomena, resulting from the hazards present in the workplace, the work and organizational environment and the characteristics of the individuals involved (Iverson & Erwin, 1997; Oliver, Cheyne, Tomás & Cox, 2002; Zohar, 2000). Furthermore the hazards present may derive from characteristics of people and their social relationships, hardware (substances, machinery, equipment, the workplace, etc), and the interaction between these factors (Saarela, 1989). Thus, psychosocial (human) factors, organizational issues and their interaction with technical aspects are a primary concern in safety management and associated research.

In his report on the Piper Alpha disaster, Lord Cullen stressed the failures resulted from different psychosocial variables, like a lack of communication, lack of involvement in safety, and priority of production over safety (Cullen, 1990). An effective intervention to improve safety would, therefore, consider psychosocial and organizational issues as much as more technical issues. In order to develop good quality occupational safety practices, we must also influence the workers' actions and expectations (Margolis, 1973) and create a corporate atmosphere where safety is valued. It has been argued by various authors (see Cox & Flin, 1998 or Mearns, Flin, Gordon & Fleming, 1998 for examples) that an investigation into the prevailing safety perceptions, attitudes and beliefs, often characterised as safety climate, is a necessary prerequisite in the creation of such an atmosphere, and provides 'leading' indicators of the state of safety in an organization (Flin, Mearns, O'Connor & Bryden, 2000).

1.1 SAFETY CLIMATE

The concept of safety climate has developed since Zohar's (1980) definition of the term, based on that of organizational climate. Climate in organizations can be viewed as a collective subjective construct in which there are multiple subsystem climates that can be referenced to criteria such as structure, effectiveness, and safety, and can be analysed across levels over time (Falcione, Sussman & Herden., 1987). Climate has been held to be the individual descriptions of the social setting or context of which the person is part. Tagiuri (1968) defined climate as

> "the relatively enduring quality of the total (organizational) environment that (a) is experienced by the occupants, (b) influences further behaviour and (c) can be described in terms of the values of a particular set of characteristics (or attributes) of that environment". (pg 25)

Since its use by Argyris (1958) and Forehand and Gilmer (1964) to characterise employee perceptions of their organizations, climate has become a central concept of organizational research (Rousseau, 1988). Early approaches ranged from considering climate as an objective set of organizational conditions to the subjective interpretation of organizational characteristics. Litwin and Stringer (1968) focused their work on the consequences of organizational climate for individual motivation, thus supporting the general idea that climate encompasses both organizational conditions and individual reactions, or manifest and latent aspects. In this vein, Gujon (1973) compared organizational climate to the wind chill index, in that it involved the subjective perception of the joint effects of two objective characteristics, temperature and wind speed. This reasoning was used to argue that research on organizational climate would require the measurement of both objective organizational conditions and the individual perceptions of those conditions. The issue of whether climate is a shared perception, a shared set of conditions, or a combination of both has remained a topic of debate in the climate literature to this day (Denison, 1996).

In terms of definition, Moran and Volkwein (1992) have incorporated several previous definitions of organizational climate and proposed that it is:

> “a relatively enduring characteristic of an organization which distinguishes it from other organizations: and (a) embodies members collective perceptions about their organization with respect to such dimensions as autonomy, trust, cohesiveness, support, recognition, innovation, and fairness; (b) is produced by member interaction; (c) serves as a basis for interpreting the situation; (d) reflects the prevalent norms values and attitudes of the organization's culture; and (e) acts as a source of influence for shaping behavior.” (pg 20)

As stated already the concept of safety climate developed from the notion that an organizational climate for safety could be identified, although independent definitions of the safety climate concept have been offered. Niskanen (1994), for example, describes safety climate as:

> "…a set of attributes that can be perceived about particular work organisations…and which may be induced by the policies and practices that those organisations impose upon their workers and supervisors" (pg 241)

Examining definitions of climate allows us to identify a number of common attributes, which relate to the utility of the concept in the management of safety. In particular safety climate appears to refer to a set of attributes, characterised by shared perceptions and linked to behavioural outcomes. The importance of these common attributes of safety climate is the focus of this paper, and relate directly to the research questions posed here:

1. Climate in general, and safety climate in particular, is held to reflect perceptions of, and attitudes towards, the current state of particular facets of the organization and its management of safety (Flin et al, 2000). As defined above these attitudes and perceptions can relate to numerous dimensions (Moran & Volkwein, 1992), which in terms of safety might reflect policies, procedures and practices currently in use (Zohar, 2003). It has been argued that different facets of safety climate might be related to key features of the organization's culture for safety (Flin et al, 2000), and as such provide a proactive tool for the assessment of safety management practices (Cox & Flin, 1998). In terms of a management system, the multifaceted nature of safety climate will be useful in reflecting the different, but related, activities associated with safety management.

2. The second attribute of safety climate to emerge from its various definitions, relates to its collective nature. Climate refers to shared perceptions among members of an organization regarding its conditions (Reichers & Schneider, 1990). If individual perceptions and attitudes are to be aggregated to give some assessment of organizational conditions, then there must be some degree of homogeneity with the organization or sub-group (Zohar, 2003). If this is not the case then it could be arguable as to whether or not climate is being assessed, rather than issues on which there is no real consensus. In terms of utility, climate indicators that show a degree of agreement will help managers identify issues important to the whole workforce with some confidence.

3. The final feature of safety climate evident from the definitions is that it, in some way, influences behaviour. If safety climate is to be a truly useful concept is must reflect the current state of safety in a particular organisation and relate to other safety measures, for example, accidents or safe behaviours (Flin, et al, 2000; Zohar, 2003).

If this can be shown to be the case then, as Coyle et al. (1995) argue, measuring the potential precursors of accidents identified by safety climate provides a powerful proactive management tool, allowing the utilization of positive indicators of the state of safety performance, rather than focusing solely on a negative, lagging indicator such as accident rates.

1.2 Background

The purpose of this paper is to review and discuss empirical evidence on the three common elements found in most definitions and descriptions of safety climate, and research into the concept. In order to accomplish this, both evidence gathered by the authors in the last decade, as well as new analyses, are presented here. As an additional feature, the reader will find a comprehensive approach to recent multivariate statistical techniques and applications. Several methodological techniques are employed here, in particular, those from recent developments in structural equation modelling, and multilevel analyses, including some illustrative graphical displays, all useful in describing a complex phenomenon such as safety climate.

The structure of this paper is shown in figure 1 together with some specific hypotheses relating to the three broad research questions outlined above. These more detailed hypotheses are addressed in the series of studies described in the following sections.

2. Research Question 1: Is Safety Climate a Multi-factorial Construct?

Most theories on safety climate dimensions agree that there is not a unitary construct underlying the indicators used for measuring such a concept. Indeed, most empirical analyses of safety climate measures have searched for, and finally found, multiple dimensions underlying proposed measurement instruments. Given that safety climate has been defined as perceptions held by employees of all the aspect of their occupational safety environment, finding several dimensions grouping different aspects of this working safety environment is not surprising. In fact, safety climate is conceived as a multi-dimensional (multifactorial) construct, with different factors (dimensions) emerging according to the different aspects measured in a particular research (Flin, et al., 2000). According to this theoretical and empirical view, there are a number of hypotheses that can be tested relating when exploring whether safety climate is indeed a multi-factorial construct. The first is quite simply:

Hypothesis H1a. Safety climate indicators will be grouped into different factors. Consequently, safety climate is a multidimensional construct.

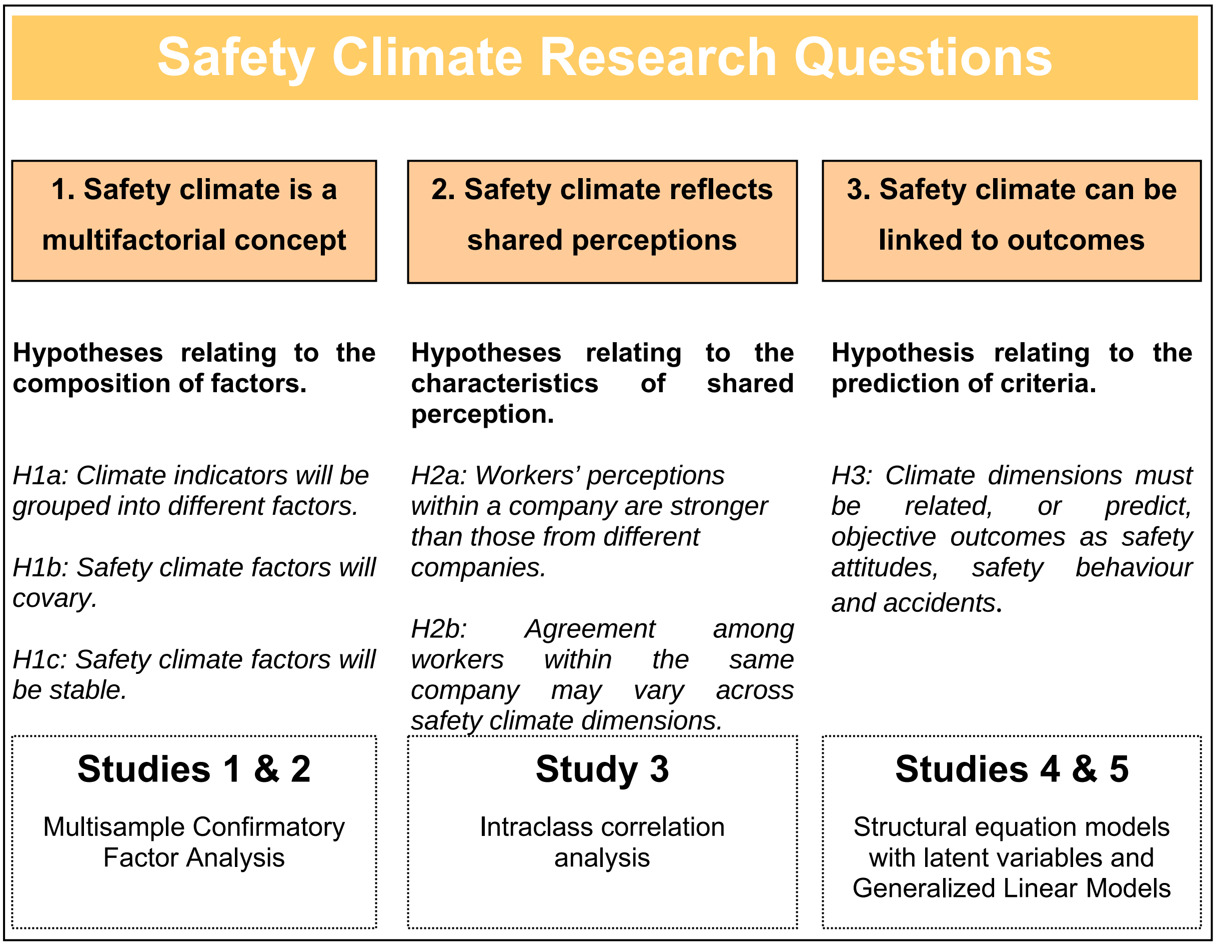

FIGURE 1: Summary of studies

Additionally, it is unlikely that an organization would attend only to particular aspects of safety management in the workplace. It is therefore likely that assessments of aspects of safety climate, if they are indicative of an overall concept, will be related, giving rise to correlated dimensions, and a second hypothesis:

Hypothesis H1b: Safety climate factors should covary.

Finally if these related factors are to be of use within organizations, it is important to ascertain how stable they are across different populations. In other words, to understand if these dimensions have certain degree of generalizability across positions within the same company, sites within the same company, and, to some degree, or even companies within the same sector. This gives rise to a final hypothesis relating to the multi-factorial nature of safety climate:

Hypothesis H1c: Safety climate dimensions should be relatively stable when the same indicators are used, at least in similar contexts.

The following two studies were designed to examine these three hypotheses and represent studies on the structure of safety climate and its stability across subpopulations.

2.1 STUDY ONE: THE FACTOR STRUCTURE OF SAFETY CLIMATE

This study[1] attempted to model the architecture of safety climate in a multinational manufacturing company by exploring the relationships between employee attitudes, appraisals of workplace hazards and evaluations of the physical work environment. In particular the study investigated a model that proposed five factors underlying the concept of safety climate. The proposed model was constructed based on the results of previous research (Cox, Tomás, Cheyne & Oliver, 1998; Tomás & Oliver, 1995), and theoretical considerations from the broader safety climate literature (Clarke, 2000; Flin et al, 2000). This proposed model, shown in figure 2, follows the broad hypothesis that safety climate is represented organizational variables (safety management and safety standards), evaluation and attitudes to group process variables (personal involvement and communication), and a more "personal" dimension of individual responsibility on safety issues.

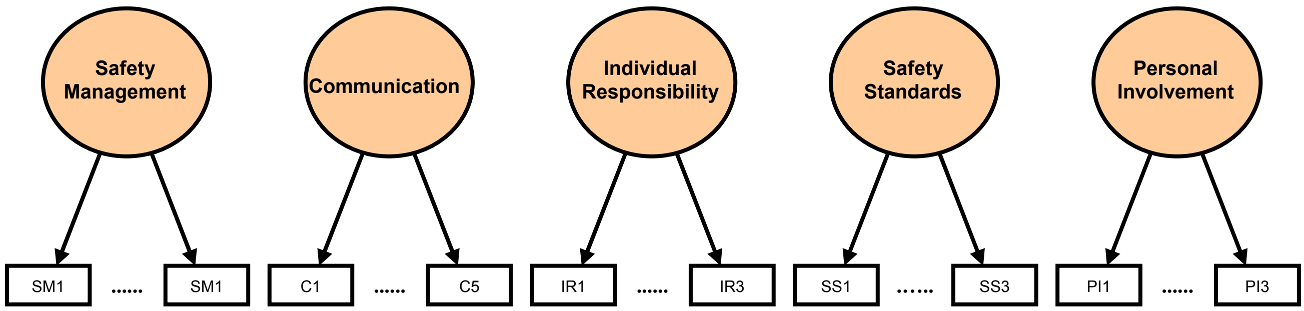

FIGURE 2: Hypothesised five factor model of safety climate

Sample

The research reported here is based on a questionnaire survey of the total population of employees in a manufacturing organization with factories in both the United Kingdom and France. A total of 915 valid questionnaires (63% response rate) were obtained from the survey: 6.4% were managers, 8% were line supervisors and 75.1% were regular employees

[1] This study is based on partial results reported by: Cheyne, A., Cox, S., Oliver, A., & Tomas, J. M. (1998). Modelling safety climate in the prediction of levels of activity. *Work & Stress*, 12, 255-271.

(this excludes 10.5% who did not provide this information). Respondents' work organization followed three patterns: 56% of them worked varying shifts; 44.6% worked only days; and 0.4% worked only nights. Four separate plants were involved in this study: plant 1 returned 145 valid questionnaires, plant two provided 128, plant 3 returned 83, and plant 4 provided 559 completed questionnaires.

Survey Instrument

The survey instrument was based on previous work in the area (Cox & Cox, 1991; Cox et al., 1998; Tomás & Oliver, 1995) which had focused on the measurement of employee attitudes to safety. It is included in Appendix 1 and comprised five sections.

a) *Section 1: Demographic Information,* including job type, department and shift pattern.

b) *Section 2: Physical Work Environment,* including four items from Tomás and Oliver (1995) on basic environmental work conditions: lighting levels, ventilation, working space, and humidity. Respondents indicated their agreement that these aspects of the working environment were satisfactory on a five point Likert-type scale (from 1 'strongly disagree' to 5 'strongly agree'). Cronbach's alpha measure of internal scale consistency for these four items was 0.67.

c) *Section 3: Hazards Checklist,* based on i) a checklist developed by Tomás and Oliver, (1995), ii) a hazard listing proposed by Cox (1992), and iii) additional hazards and amendments suggested by a group of safety practitioners from the organization under consideration. The final checklist included 24 common hazards and respondents were asked to rate the perceived frequency (on a scale of 0, where the hazard is never present, to 3, where the hazard is often present) and consequences (using a three point scale, 1 = slight, 2 = moderate and 3 = severe) of each of these hazards. The frequency and consequence ratings were multiplied together to give a score for each hazard, and these individual hazard scores were added together to give an overall hazard rating which could, therefore, vary between 0 and 216.

d) *Section 4: Attitudes to Safety.* The fourth section of the survey instrument contained 30 statements about safety issues at organizational, group and individual levels. These statements were based on a combination of those used by Cox and Cox (1991) and Tomás and Oliver (1995) with the addition of some statements to suit the study sector. Participants were asked to endorse these statements using a five point Likert-type scale as used in Section 2 of the questionnaire. The questionnaire was designed in consultation with the organization's representatives to capture attitudes to safety in five areas: Safety Management, Communication, Individual Responsibility, Safety Standards and Goals, and Personal Involvement. Cronbach's alpha measure of internal scale consistency for the Safety Management scale was 0.86, for the Communication scale was 0.75, for the Individual Responsibility scale was 0.47, the internal consistency measure of the Safety Standards and Goals scale was 0.68, and the scale relating to Personal Involvement Cronbach's alpha was 0.61. While 0.7 is generally accepted as the minimum desired value of the alpha coefficient (Litwin, 1995), indices with lower scores do not necessarily invalidate findings. The scale measuring Individual Responsibility is not reliable as defined by normal standards and cannot be considered on its own, however it can be included in a structural equation modelling using latent variables where this is accounted for (see later).

e) *Section 5: Safety Activities.* Section 5 presented a safety activities checklist and asked respondents to indicate the frequency (if appropriate) of their involvement in 16 different activities; for example, being involved in accident investigations, or taking part in job safety analyses. Respondents were asked to indicate if they had taken part in any of these activities in the last 12 months (where a score of 2 was assigned) or in the last 5 years (where a score of 1 was assigned). Separate activity scores were added to give an overall safety activity rating, varying between 0 and 32.

Statistical analyses

Structural equation modelling (SEM) was used to examine the factorial validity of the five factor model across the different plants. Structural equation modelling is a multivariate methodology that tests a hypothesised model in a simultaneous analysis of all the variables, to determine the extent to which it is consistent with the data. The existence of different groups (or plants) makes structural equation modelling especially appropriate in this case, since the a priori model can be easily tested across groups using multisample models. Multisample analysis is done by fitting an ordinary model in each sample or sub-sample, but in a single run simultaneously for all groups. This is done while taking into account that some parameters may be the same in each of the samples (for example, all factors loadings constrained to be equal). This type of analysis produces a single chi-square goodness of fit statistic, which evaluates the joint hypothesis that groups have equal parameters. Practically, multisample analysis involves the assessment of a baseline model where no constraints of invariance are imposed, and then a series of models where constraints are imposed on the equality of factor loadings and factor relationships between groups. Constrained models are then compared, through chi-square differences, with the baseline model to evaluate whether or not constraints have been properly imposed. The Lagrange Multiplier (LM) test in a multisample analysis indicates which of the constraints of equality should be released in order to improve model fit, and therefore give an indication of where loadings and/or relationships are not the same in each sample. A primary concern here is whether components of the measurement model are invariant across the four plants.

The structural equation models described in this study were estimated using maximum likelihood techniques within the EQS 5.1 program (Bentler, 1995). Although maximum likelihood is based on the assumption that variables are multivariate and normally distributed, there is growing evidence that it performs well under a variety of non-optimal conditions, including ordinal variables, and even for a very low number of categories (Chou & Bentler, 1995; Coenders, Satorra & Saris, 1997; Hoyle & Panter, 1995).

A critical issue in relation to any structural equation model is the assessment of the overall model fit. The most widely used index for the assessment of a specified model fit is the chi-square (χ^2) statistic, where a non-significant and small χ^2 value indicates that the observed data and not significantly different from the proposed model. A significant chi-square test would cast doubt on the model specification (Bollen & Long, 1993). This statistic, however, presents several problems, especially its dependence on sample size. As sample size increases nearly all models are evaluated as incorrect (Bentler & Bonnet, 1980). Hence other indices, based on different rationales which correct for this problem, have been developed. No single index seems sufficient for a correct assessment of fit (Hu & Bentler, 1995; Marsh, Balla & McDonald, 1988) and researchers are advised to use a variety of indices from different families (Marsh, Balla & Hau, 1996; Tanaka, 1993). Accordingly, one index from each main ‘family’ has been included in the evaluation of the models presented here. These include an absolute fit index, a type 2 incremental fit index, a type 3 incremental fit index and a measure of the error in the model.

Absolute fit indices directly assess how well a model reproduces the sample data. The goodness-of-fit index (GFI) performs better than any other absolute index (Hoyle & Panter, 1995; Marsh et al., 1988) and has been included in the results of this study. The GFI has only a small bias due to sample size compared with other absolute fit indices. Incremental fit indices measure the proportionate improvement in fit by comparing a target model with a restricted baseline model, usually a null model in which all the observed variables are independent. The Tucker-Lewis index, or non-normed fit index (NNFI), a type 2 incremental fit index, and the comparative fit index (CFI), a type 3 incremental fit index, have been included here. These two indices have been included following recommendations by Marsh et al. (1996). A value of 0.9 for all of these indices has been proposed as a minimum for model acceptance (Bentler & Bonnet, 1980).

Finally, the Root Mean Square Error of Approximation (RMSEA), introduced by Steiger and Lind (1980) was also used as a fit index. This index is computed based on sample size and the noncentrality parameter and degrees of freedom for the target model (Browne & Cudeck, 1993; Steiger, 1990). MacCallum (1995) argues that the RMSEA is probably better than any other index where models are extremely parsimonious, because it measures the lack of fit per degree of freedom. A value of the RMSEA up to 0.05 would indicate a good model fit; a value of about 0.08 or less would indicate a reasonable error of approximation; and values greater than 0.1 indicate poor model fit (Browne & Cudeck, 1993).

Results

A multi-group factor analysis was conducted to consider the factorial validity of the safety attitude scales in each plant. A confirmatory model tests measurement assumptions, relating the indicators (observed variables) to the hypothetical latent variables (or factors). If such a measurement model does not obtain satisfactory fit, then there is no point in proceeding to test any other structural model containing these latent variables, until their proper measurement is achieved. In this particular study data were gathered from four different plants all belonging to the same parent organization. This makes differences in factorial structure across plants likely to occur, because of, for example, national and regional differences (one of the plants is situated in France). The stability of the dimensions must, therefore, also be established across plants. A fundamental concern in any multiple group comparison is ensuring construct compatibility, or measurement equivalence, when looking for between group differences (Little, 1997). If the structure is not stable across plants, mean and structural differences may be due to different factors arising for the different plants. In other words, mean differences and other parameter comparisons can be computed, only when the underlying structure has been clearly shown as general. Further comparisons are appropriate only when the architecture of safety attitudes is stable across plants. Therefore, the testing of the confirmatory factor structure proposed in figure 2 allow us a simultaneous test of the three hypothesis outlined before.

A sequence of models was used in order to test the factorial invariance across plants. As a first step, the five-factor model was separately tested for every group (plant), with no cross-group constraints. The five-factor model fitted the data well giving support to the idea that the responses to the 30 observed variables could be collapsed into five theoretical factors. As a more restrictive test for factor invariance, a multisample confirmatory factor analysis was employed, constraining all factor loadings to be the equal across groups. This model tests for equal weight of the indicators to define their factors across plants. The constrained multi-group analysis, however, resulted in a poor fitting solution (χ^2= 2968.6, d.f.= 1655, p<0.001, CFI= 0.82). Seven constraints among the 75 imposed were released, following LM test suggestion. This modified model resulted in a satisfactory fit to the data (χ^2= 2213.5, d.f.= 1648, p<0.001, CFI= 0.92). The better fitting model was achieved releasing just seven constraints involving factor loadings among two groups. It can be concluded after this analysis that the dimensionality (structure) of the safety climate scale, based on the attitude survey, seems rather stable across plants. Moreover, most of the factor loadings are almost the same across groups, indicating that factorial partial invariance has been achieved.

The five factor model was then tested for the overall sample to provide better estimates of factor loadings which in turn became reliability estimates of the observed variables and provided a further indication of factors' internal consistency (Bollen, 1989). This measurement model showed a better model fit (χ^2= 1209.747, d.f.= 395, p<0.001, CFI= 0.886, GFI= 0.905, RMSEA = 0.051) and was used as the basis for the description of attitudes to safety in this study. Factor loadings for each item on the appropriate factor are shown in table 1.

TABLE 1: Standardised factor loadings for the five factor model

Item Description	Safety Managemt.	Comm.	Individual Respons.	Safety Standards	Personal Involvement
Safety has a high priority	0.709				
Safety specific jobs always get done	0.555				
Management listens to safety concerns	0.536				
Company tries to prevent accidents	0.636				
Workers who act unsafely are disciplined	0.509				
Training has not been adequate	0.446				
Safety performance has improved here	0.328				
Safety training has a high priority	0.734				
Process of continual improvement	0.661				
Management takes the lead on safety	0.475				
Lessons from accidents are used	0.507				
We have defined safety objectives	0.482				
Line supervisors actively support safety	0.660				
Only interested in safety after an accident	0.614				
Safety issues are included in meetings		0.633			
I have been shown how to work safely		0.545			
Good communications about safety issues		0.816			
Relevant safety issues are communicated		0.642			
Informed of the outcome of safety meetings		0.487			
I look out for others' safety			0.400		
I can influence performance			0.513		
Safe working is a condition of employment			0.519		
Unsafe behaviours are tolerated				0.666	
Necessary to take shortcuts				0.587	
Accidents are tolerated as part of job				0.684	
Everyone plays an active role					0.495
People here want to achieve high levels					0.559
Only a few people are involved in safety					0.462
My colleagues and I help each other					0.510
We always report accidents/incidents					0.455

The loadings shown in table 1 were all large and statistically significant (p<0.001), indicating satisfactory reliabilities of the items. Moreover, on examination of the factor loadings, it can be concluded that the five latent variables (or factors) presented very similar reliabilities, hence the internal consistency of the factors seems adequate, although, as indicated by the estimation of Cronbach's alpha, the individual responsibility factor did have less consistent indicators (lower loadings).

Finally, table 2 shows the correlations among the five safety climate factors. All of the correlations were positive, statistically significant (p< 0.01) and large. Safety management is the factor with the highest intercorrelations, while individual responsibility was correlated to a lesser extent with the other factors. These correlations give support to the idea of a multifactorial orthogonal construct, with highly related concepts.

TABLE 2: Correlations among the five factors

	Safety Management	Communication	Individual Responsibility	Safety Standards
Communication	0.881			
Individual Responsibility	0.774	0.725		
Safety Standards	0.814	0.611	0.629	
Personal Involvement	0.869	0.718	0.749	0.745

2.2 STUDY TWO: THE STABILITY OF THE FACTOR STRUCTURE

Within the safety culture and climate arena, several studies have been devoted to the existence of different subcultures within organizations (for example, Alexander, Cox & Cheyne, 1995; Cox et al, 1998; Harvey, Bolam & Gregory, 1999). Subcultures or subclimates within an organization have been found both in terms of interpretations, that is the intensity of attitudes and perceptions held by different subgroups to the same aspects of safety, and in terms of the structure of attitudes and climate arising from the analysis of underlying dimensions. This latter difference infers that interpretations of basic constructs are different across different groups, a finding that could be considered in conflict with the notion of a shared organizational safety culture. Many organizational subgroups could be examined for such differences, but a 'natural' division of workers is that of employment level. Indeed, some authors have argued that organizational hierarchy gives rise to subcultures (Trice & Beyer, 1993). Organizational hierarchy provides a further opportunity for examining the factor structure described in the first study. Specifically, do different employment groups within the same organization exhibit different climate structures? In other words, is the five factor model of safety climate stable across employment levels? The broad hypotheses tested in this particular study are the same as those tested in study one, but applied to different employment levels.

Sample

This study is based on a questionnaire survey of 12 UK manufacturing sites belonging to two large multinational companies. Four of the sites were thoses described in the previous study. The sites were all involved in very similar production processes and were equipped with comparable plant and machinery. A total of 1187 valid questionnaires (53% response rate) were obtained from this survey. 4% were managers, 11% were line supervisors and 85% were regular employees, reflecting the actual proportions in the organizations (4%, 12% and 84%)[2].

Survey Instrument

The same survey instrument as described in study 1 was used in this research. The internal consistency of each of the scales in each of the employment sub-samples, as measured by Cronbach's alpha, is shown in table 3. As in study 1 the alpha value for the scale relating to Individual Responsibility is the most problematic, suggesting that it may not be reliable. This should be borne in mind when dealing with the scale's results.

TABLE 3: Alpha coefficients for the three samples involved in the study

Scale	Employees	Supervisors	Managers
Safety Management	.86	.83	.85
Communication	.76	.64	.77
Individual Responsibility	.49	.62	.59
Safety Standards	.64	.64	.67
Personal Involvement	.66	.63	.58

Statistical analyses

Multisample structural equation modeling (SEM) techniques were used to explore the structure of safety climate indicators and the stability of that structure across employment level subsamples.

Results

Structural equation modelling was used to examine the factorial validity of the five-factor model described in study 1 and its equality across the different employment groups. In effect this is an examination of whether the items comprising the measuring instrument operate equivalently across different populations and whether the factorial structure of the instrument

[2] This study is based on partial results reported in: Cheyne, A., Tomas, J. M., Cox, S., & Oliver, A. (2003). Perceptions of safety climate at different employment levels. *Work & Stress*, 17, 21-37.

is equivalent across those populations (Byrne, 1994). A sequence of nested confirmatory multi-group models, employing maximum likelihood estimation, was used here in order to test the factorial invariance between the three groups, in the attitude and work environment items. As a first step, the overall measurement model (including the 30 attitude statements and 4 work environment items) was estimated in all three sub-samples without constraining the factor loadings to equality. Goodness-of-fit indices for this multigroup model (and subsequent models) are shown in table 4.

TABLE 4: Goodness-of-fit indices for employment level measurement models

Model	χ^2	d.f.	Prob.	CFI	GFI	NNFI	RMSEA	χ^2 difference
1	3311.51	1536	<0.001	0.854	0.869	0.841	0.031	-
2	3386.48	1592	<0.001	0.853	0.867	0.844	0.031	74.97
3	3344.14	1046	<0.001	0.855	0.869	0.845	0.031	32.64

Although Model 1 has a statistically significant χ^2 statistic, the model fit can be considered sufficient given that the comparative fit index (CFI), the goodness of fit index (GFI) and the non-normed fit index (NNFI) are close to 0.9 (the acceptable value (as described by Bentler and Bonnet, 1980)); and that it is extremely parsimonious (1536 degrees of freedom). Model 1 shows that the basic structure of the model fits the data in all three samples and sets a baseline model against which to test for cross-group equalities. A second model (Model 2) proposed equal factor loadings across the three groups, testing for measurement equivalence across samples. The χ^2 difference between Models 1 and 2 is 74.97 and the difference in degrees of freedom is 56, indicating that the test is significant. In terms of practical fit indices (the CFI, GFI and NNFI), however, differences between the models are small, giving support to the possibility of measurement equivalence across the three sub-samples.

The third model (Model 3) used the results of the Lagrange Multiplier (LM) test to examine for cross sample constraints that were not correctly imposed in Model 2. Only a few relationships differ between the three samples. The only constrains that were indicated as incorrect by the LM test were six of the 36 factor loadings, including the strength of the relationship between indicators 14, 23 and 26 and the safety management factor, indicator 10 and the communications factor, indicator 25 and the individual responsibility factor, and indicator 28 with the involvement factor. The χ^2 difference in fit between Model 3 and the baseline model (Model 1) is not significant, suggesting that Model 3 is as good a representation of the data as Model 1, while allowing most factor loadings to be constrained to equality. Table 5 presents the multisample measurement model described by Model 3, with both the unstandardised and standardised values, given that standardised coefficients may differ due to differences in variable standard deviations across the samples, even though the strength of the relations are the same (Bollen, 1989). Apart from the six unconstrained indicators, all the other paths were constrained to equality and these constrains were tenable.

TABLE 5: Factor loadings for the employment level measurement model

	Unstandardised			Standardised		
Item	**E**	**S**	**M**	**E**	**S**	**M**
Safety management						
1. Health and safety have a very high priority here	1.00	-	-	.695	.677	.650
2. Safety specific jobs always get done	.955	-	-	.601	.409	.556
3. Management listens to my safety concerns	.783	-	-	.571	.469	.524
6. The company makes an effort to prevent accidents happening	.780	-	-	.645	.643	.672
9. Management are prepared to discipline workers who act unsafely	.810	-	-	.582	.466	.532
14. The safety training I receive is not detailed enough for my job	.666	.530	.375*	.462	.290	.273
17. Levels of safety performance have improved over the last two years	.530	-	-	.352	.351	.285
20. Safety training has a high priority here	.979	-	-	.721	.680	.705
22. There is a process of continual safety improvement in the company	.730	-	-	.691	.593	.688
23. Management takes the lead on safety issues	.697	.921	1.02	.477	.534	.691
24. What is learnt from accidents is used to improve safety training	.678	-	-	.560	.487	.555
26. On my site we have defined safety improvement objectives	.575	.881	.367	.487	.555	.334
27. Supervisors actively support safety	.886	-	-	.657	.624	.584
30. The company is only interested in safety after an accident occurs	1.01	-	-	.609	.541	.721
Communication						
7. Safety issues are included in communications meetings	1.00	-	-	.608	.504	.621
8. I have been shown how to do my job safely	1.04	-	-	.582	.452	.527
10. There are good communications here about safety issues	1.61	1.45	1.34	.843	.704	.809
12. Relevant health and safety issues are communicated	1.03	-	-	.672	.466	.766
15. I am informed of the outcomes of health and safety meetings	1.04	-	-	.483	.351	.482
Individual Responsibility						
5. I look out for the safety of my colleagues	1.00	-	-	.452	.571	.588
18. I can influence health and safety performance here	1.36	-	-	.468	.699	.631
25. Safe working is a condition of my employment here	1.23	1.07	.786	.530	.555	.506
Safety Standards						
4. As long as there are no accidents unsafe behaviour is tolerated	1.00	-	-	.650	.688	.671
11. It is sometimes necessary to take unsafe shortcuts to get work done	.789	-	-	.524	.520	.534
21. Minor/trivial accidents are tolerated as part of the job	.830	-	-	.634	.638	.631
Personal Involvement						
13. Everyone plays an active role in safety issues	1.00	-	-	.562	.540	.431
16. Everyone wants to achieve the highest levels of safety performance	.862	-	-	.596	.628	.558
19. Only a few people are involved in health and safety activities	.891	-	-	.470	.388	.398
28. My colleagues and I help each other work safely	.579	.716	.775	.519	.588	.576
29. Accidents and incidents are always reported	.781	-	-	.448	.376	.405
Work Environment						
31. The light levels in my workplace are adequate	1.00	-	-	.331	.382	.385
32. The ventilation in my workplace is adequate	2.86	-	-	.780	.803	.856
33. Space allocated for doing tasks in my workplace is adequate	1.14	-	-	.326	.345	.365
34. The humidity levels in my workplace are adequate	2.59	-	-	.769	.803	.811

E = Employees, **S**= Supervisors, **M** = Managers;
All factor loadings are statistically significant at $p < 0.01$, except * which are significant at $p < 0.05$

Among the indicators that were different across the samples, three of them belong to the safety management factor. This factor may then be considered stable in spite of these cross group inequalities because of the large number (eleven) of other, equally constrained, indicators available. The strength and sense of all relationships are similar, as shown in table 5. For example, variable 25 is a reliable indicator in the employee sample, with unstandardised value of 1.23 (standardised value of 0.530), as it is in the supervisor sample (unstandardised loading of 1.07, and standardised value of 0.555), and in the managers' sample (unstandardised loading of 0.786, and standardised value of 0.506). As in this example, no other difference across samples makes an important difference in the interpretability of the substantive model; all indicators, even those that are not equal across samples, are reliable and significant. Only the loadings for item 14 (The safety training I receive is not detailed enough for my job) showed a marked difference between samples, with the loading in the manager sample only significant at the 0.05 level.

2.3 Safety Climate as a Multi-dimentional Concept

Overall results in studies 1 and 2 have found solid evidence for a multifactorial definition of safety climate. The five-factor model has been established trough confirmatory factor analysis, a powerful tool for testing theoretical hypothesis. Thus, support has been found from both studies for the first hypothesis named H1a. At the same time, the confirmatory factor analyses have found strong relationships among the factors, supporting second hypothesis H1b. More importantly, the five factor model has been found stable enough to be used as a "general purpose" safety climate questionnaire across different plants in one company and across hierarchical levels in different companies. This stability was established through multi-sample confirmatory factor analyses, again a very exigent and powerful statistical tool. Therefore, third hypothesis H1c has also found empirical support across different sub-samples.

3. Research Question 2: Does Safety Climate Reflect a Shared Concept?

Social research is often focused on problems concerned with the relationship between individual and society. The fact that individuals interact with their social contexts suggests that their views may be associated to some degree with group or social beliefs and norms. Any attempt to examine such interactions needs to consider simultaneously two levels of analysis, the individual and the group (social context). The definitions of safety climate described earlier suggest that it is a shared construct within the workers' social context (Zohar, 1980). The research described at this point aims to explore potential shared conceptions of safety climate within organizations. The basic assumption is that those working for the same company must agree to a certain extent in their perceptions of safety issues. If this is not the case, conceptualizations of safety climate as a shared phenomenon, reflecting a common atmosphere or culture for safety, would be replaced by a collection of individual evaluations of safety issues connected to personal variables. Additionally the notion of basic agreement within companies may be accompanied by subsidiary hypotheses relating to the differential degree of agreement according to the level of safety issues covered in every factor. That is, more "organizational factors" such as safety norms, values, and more "external factors", such as supervisory behaviour, or perceptions of co-workers behaviour should have more in common, and should, therefore, produce greater agreement than perceptions on personal behaviours, such as measures of individual responsibility for safety issues. On the other hand, it should be borne in mind that the possibilities of several safety climates within the same company are possible as discussed in relation to study 2, thus agreement may be far from perfect. This study, therefore tries to test two related hypotheses:

> *Hypothesis H2a: Workers within a company are more alike (their scores covary) in their perceptions of safety climate than workers in different companies.*
>
> *Hypothesis H2b: The level of agreement among workers within the same company may vary across different safety climate dimensions. Dimensions relating to organizational issues would have larger levels of agreement than those relating to individual or group issues.*

3.1. STUDY THREE: AGREEMENT AMONG CO-WORKERS

The research design is a two stage survey design (illustrated in figure 3), in which companies were randomly selected. Within those companies another random sampling of employees was conducted. All of the organizations were based in the Valencian region of Spain. Workers were interviewed while they were undergoing annual medical tests at the Valencian Health and Safety Executive. The response rate was close to 95%.

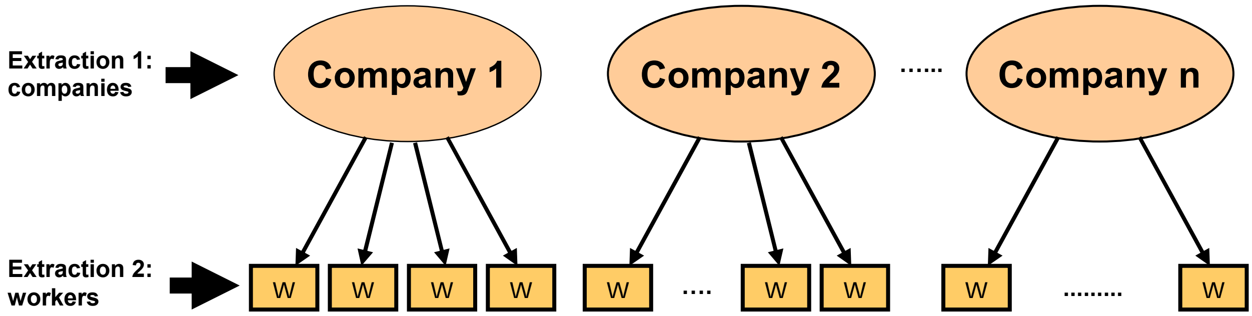

FIGURE 3: Two stage random sampling

Sample

The final sample consisted of 37 companies, comprising 297 workers. Invalid questionnaires were deleted and companies in which data from only one or two workers remained were also deleted from the total sample. Small companies were more likely to be dropped during this process, potentially biasing the sample towards "bigger" companies. No doubt, the representativeness of the sample in the population was diminished by the procedure. However, the main objective of this research is to test for the existence of agreement among workers in the same companies, therefore the representativeness of the sample in terms of company size is not a major concern. It is much more important to be sure that there are enough data points per company in order to get reliable estimates of inter-workers agreement. The mean number of workers per company was 10.61 (ranging from 3 to 28).

Most of the companies had less than 21 workers (49.9%), and 41.5% had between 21 and 100 workers. A variety of industrial sectors were represented, including: chemical (4.1%), metal industries (36.2%), commerce and tourism (3.1%), educational and health services (12.2%), administration or banks (10.3%), construction (6.7%), manufacturing industries (27.2%). 73.8% of the workers were male, with a 26.2% of women. Participants' ages had a mean of approximately 39 years and a standard deviation of 11.75. Most respondents (80%) were general employees, 10.4% were supervisors, and 9.5% were managers.

Survey instrument

The survey instrument used was the same as that described in study 1 with the following additions and changes:

a) Additional information on individual accident rates over a two-year period was collected. This information included four indicators of accident involvement: near-misses, minor (non-severe) accidents, accidents resulting in up to three days-off work and, severe accidents resulting in three or more days-off work. These items were included as an objective outcome measure and took the place of the safety activity checklist in the previous studies.

b) As a result of piloting in this sample, the workplace hazards checklist contained a further seven hazards taking the total to 31 in total.

c) Again after piloting, only 27 of the safety climate items described in study 1 were included in this questionnaire.

Analyses

Covariation or agreement among the scores of participants may be studied through a number of statistical techniques, such as the kappa and alpha coefficients, generalizability theory, latent class models, etc. The *intraclass correlation coefficient* (ICC) is probably the most adequate statistic to estimate agreement among subjects with quantitative data. The ICC is a population estimate of the variance explained by the grouping structure, that is, by the fact that several workers from each company have been selected. It has been extensively used to test for statistical independence in survey research. The ICC has been estimated through the application of a null model within the context of multilevel modelling techniques or, in other words, a random effects ANOVA model has been estimated with safety dimensions or variables as dependent variables and company as a random effect independent variable (Hox, 1995; Snijders & Bosker, 1999).

In order to test for the intraclass correlations it is important to have a sampling design with at least two stages, and to assume that there is an infinite (or extremely large) population in every stage, from where data are random sampled. If these assumptions hold, as is the case here, a relevant statistical model to estimate the amount of ICC is the random effects ANOVA model, or Eisenhart's type II model. The structural model states that Y_{ij}, the observed score of participant (worker) *i* from company *j,* depends on

$$Y_{ij} = \mu + U_j + R_{ij} ,$$

Where μ is the overall population mean, U_j is the specific effect of company *j,* and R_{ij} is the residual effect (error) for worker *i* within company *j.* The variability of the different companies, that is the variability of U_j is the *population between group variance* (τ^2), and measures how different companies in the dependent variable, whereas variability of different workers within the same company, that is the variability of R_{ij} is the *population within group variance* (σ^2), and measures the variability of workers scores to their company means. The total variance of Y_{ij} is the sum of these two variances,

$$\text{Var}(Y_{ij}) = \tau^2 + \sigma^2$$

If scores heavily depend on which company the worker belong to, the between group variance (τ^2) would be large compared to within group variance (σ^2). However, if scores do not heavily depend on companies but on workers' job and personal characteristics, τ^2 will be small compared to σ^2. The intraclass correlation coefficient (ICC) can be defined as

$$\text{ICC} = \tau^2 / \text{Var}(Y_{ij}) = \tau^2 / (\tau^2 + \sigma^2) .$$

This is the proportion of variance that is accounted for by the company level of analysis. It varies between 0 and 1, with 0 indicating that all the variance in the scores is accounted for by the workers' job and personal characteristics, and 1 indicating that all the variance in the scores is accounted for by the company each worker belong to. For intermediate values, it is needed to state a null hypothesis of zero to test if we can consider that the estimate of the ICC in the sample may be considered statistically significant. Searle, Casella, and McCulloh (1992) offer more information on estimating the ICC under various research designs.

Results

This study has used a two-stage sampling design in which there are two levels of analysis: the worker and the company. It can be assumed that some variation on the safety scores depend on worker's personal and job characteristics but also that some of the variation among these scores may be explained by being in a particular company with particular conditions, or in a particular corporate atmosphere for safety. If the workers within the same company did not share the same vision, their scores on the variables are independent and, as a consequence, the ICC should be zero or statistically non significant. On the other hand, if workers share their vision on safety issues to some extent, then ICC correlation should be statistically different from zero, because at least part of the variance in safety climate may be explained by belonging to a particular group or organization. Estimates of the ICC correlation for each of the safety variables in the five factor model of safety climate, as well as those for work environment and work hazards, have been calculated in order to test for the shared nature of these dimensions.

As an example, the estimates for the population between group variance and within group variance estimates for the safety management dimension were, respectively, $\tau^2 = 0.15$ and $\sigma^2 = 0.37$, thus giving an estimate for the ICC of

$$\text{ICC} = \tau^2 / \text{Var}(Y_{ij}) = \tau^2 / (\tau^2 + \sigma^2) = 0.15 / (0.15 + 0.37) = 0.15 / 0.467 = 0.32$$

An ICC of 0.32 is statistically significant ($p < 0.01$) and shows that about a 32% of the variance in the safety management scores is due to company. There is still room for individual (worker) differences, but not a negligible amount of the variance is shared as hypothetised in H4. As a way to better understand the meaning of a significant intraclass correlation a catterpillar plot with the means of safety management for each of the 37 companies is presented in Figure 4). The dashed lines represent the overall mean across companies and participants, and the figure shows how companies differ from this overall mean. In other words, there is some variability between companies. The ICC's and their hypothesis tests statistically test if these differences among companies' means are greater than expected by chance.

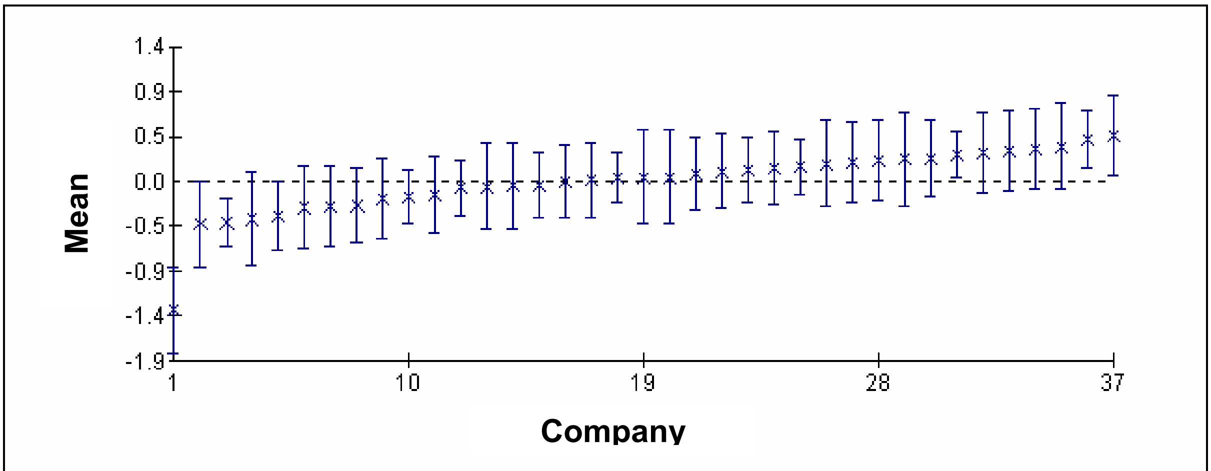

FIGURE 4: Caterpillar plot showing means for safety management in each company, with 95% confidence intervals

Table 6 shows the estimates for the ICC's of each safety climate dimension plus work environment and work hazards. Not all dimensions of safety climate present significant intraclass correlations. In particular safety standards, individual responsibility, and personal involvement did not seem to be shared among the workers within a company. However, safety management, communication and work environment and hazards present significant and strong intraclass correlations, suggesting that these dimensions represent shared perceptions.

TABLE 6: Intraclass correlation coefficients for the five safety climate dimensions and work environment and hazards

Dimension/variable	ICC	p
Safety Management	0.32	<0.01
Communication	0.25	<0.01
Individual Responsibility	0.06	>0.05
Safety Standards	0.04	>0.05
Personal Involvement	0.07	>0.05
Work Environment	0.18	<0.01
Workplace Hazards	0.21	<0.01

3.2 CLIMATE AS A SHARED CONSTRUCT

The results of Study 3 partially support hypothesis H2a, given that four of the seven dimensions exhibit significant intraclass correlation coefficients, suggesting that workers agree more on these within companies. The same results allow examination of the proposition that there might be differential covariation across dimensions (hypothesis 2b). H2b states that the level of agreement should be larger for "organizational" dimensions than for more "individual variables". In the light of the table 6 results there is some support for this hypothesis as well. ICC's for the organizational dimensions safety management, communication, work environment and work hazards are large (and statistically significant) compared to the personal variables individual responsibility and personal involvement, as expected in the hypothesis. However, the ICC for safety standards does not support this hypothesis, perhaps suggesting that this variable capture individual standards of behaviour.

4. RESEARCH QUESTION 3: CAN SAFETY CLIMATE BE LINKED TO BEHAVIOURS?

Safety climate dimensions, as described earlier, are perceptions held by employees on different aspects of health and safety at work, relating both to personal and organizational issues. These perceptions help or allow the workers to understand and react to the work environment, in particular to behave safely, analyse the risk, and avoid accidents, in short how to make sense of their environment (Cox & Flin, 1998). Although perceptions may be objectively wrong or at least distort the reality, they should be related, in some sense, to objective safety measures. Attitude data, in the form of climate surveys has been exploited to determine the relationships between underlying factors and their effects on broader outcome measures, including accident rates, safe behaviours or general assessments of the organization. Zohar's (1980) study found some relationship between his safety climate measure and safety performance. In a similar vein, several researchers have examined the relationship between climate variables and accident outcomes. For example, Hofman and Stetzer (1996) found their measure of safety climate, derived from that proposed by Dedobbeleer and Béland (1991), was related to accident rates. Given these findings we can propose a final hypothesis:

> *Hypothesis H3: Safety climate dimensions reflect perceptions, but they are related or may predict other safety outcomes.*

The final two studies discussed here were designed to explore the potential links between safety climate and behaviours and accidents (study 4) and the potential relationship between the five factor model described in other studies and accidents (study 5).

4.1. STUDY FOUR: PREDICTION OF ACCIDENT RATES

This study is a survey design of Spanish workers. It aimed to test, through structural equation modelling, the direct and indirect effects of safety climate dimensions on three health and safety outcomes: safe behaviour, general health, and accident rates. Specifically, the a priori model (shown in figure 5) proposes that:

(1) perceptions of organizational involvement (including social support and indicators of safety culture and climate discussed in studies 1-3) should be related to general health (Tomás & Oliver, 1995) and individual safe behaviour (Dwyer & Raftery, 1991), and should be related (negatively) to occupational accidents (Iverson & Erwin, 1997);

(2) evaluations of the physical working environment should be related to accidents and individual level variables for example general health and safe behaviour (Cheyne et al, 1998; Tomás & Oliver, 1995); and

(3) individual level variables, for example general health and safe behaviour, should be related to occupational accidents (Baker & Marshall, 1987).

Sample

Data were gathered through random sampling from the population of workers in the province of Valencia, Spain. Workers were interviewed using a questionnaire while they were undergoing annual medical tests at the Valencian Health and Safety Executive. Medical staff at the agency were responsible for all tests, interviews and survey administration. The present study is based on data from 525 completed surveys, representing around 95% of those attending the medical tests[*]. Ages ranged from 16 to 64 years, with an average of 37

[*] Although the sampling procedure was similar, participants in this study did not take part in study 3.

and a standard deviation of 10.84. 84.2% of the sample was male. Most participants (79.5%) were regular full-time employees, 15.6% were supervisors and 5.9% were managers or senior managers. They worked in a variety of industrial sectors and these included: chemical (11%); construction (4%); metal fabrication (33.9%); other manufacturing industries (16.8%); administration or banks (5%); commerce and tourism (2.7%); education and health services (1.7%); and other services (14.9%).

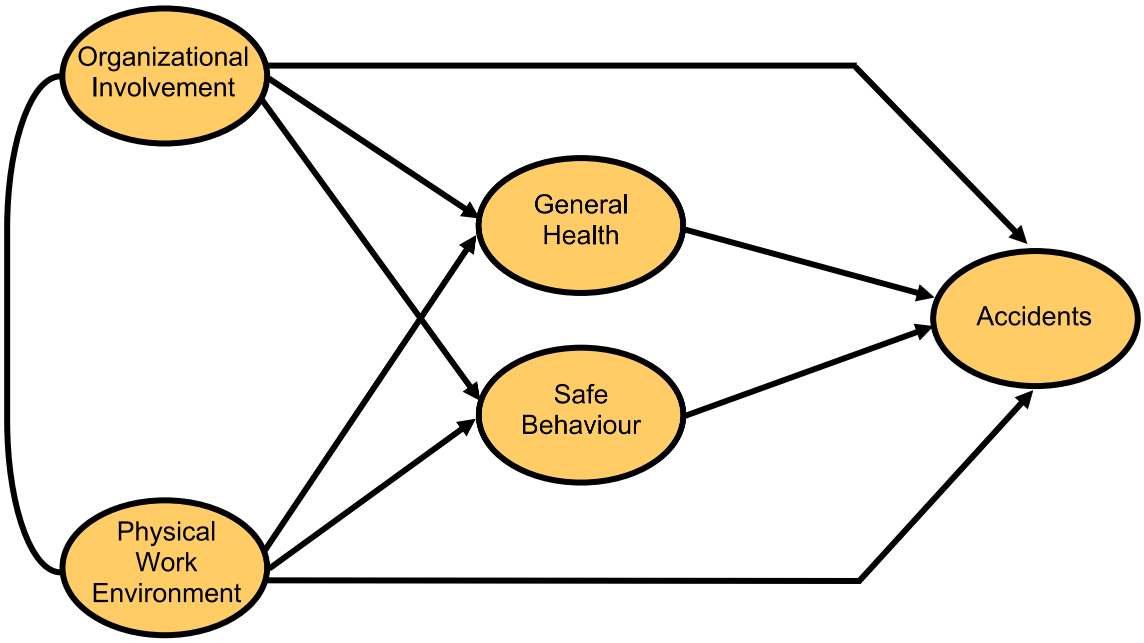

FIGURE 5: A priori model predicting safe behaviours, general health and accidents

Survey instrument

The survey instrument included safety culture/climate measures developed by Tomás and Oliver, 1995, and those developed in studies 1-3, as well as measures of general health states (Cox, Thirlway, Cox & Gotts, 1983; Goldberg, 1972). In addition to collecting demographic information the questionnaire comprised of the following five sections.

a) The accident involvement items described in study 3.

b) Organizational involvement in safety, containing questions relating to perceptions of safety climate. 15 items made up the organizational involvement factor, arranged into indicators of safety management and policy, supervisors' safety support and behaviour, and co-workers' safety support and behaviour. These items are based on those used by Tomas and Oliver (1995) and in studies 1-3. The safety management and policy sub-scale had a Cronbach's alpha measure of internal consistency of 0.78, the supervisors' safety support had an alpha of 0.76, and the co-workers' safety support had an alpha of 0.78.

c) Quality of working conditions described in the previous studies and included environmental variables, such as light, humidity and noise levels, work-overload and 'routinization'. Finally this section included the inventory of hazards, listing 21 common hazards, included in the other studies described in this paper.

d) Section 5 of the survey instrument comprised measures of participants general health. The 12 item General Health Questionnaire GHQ-12 (Goldberg, 1972) showed a reliability alpha of 0.76. A nine item anxiety checklist (alpha = 0.83), based on Cox et al. (1983), was also administered to participants as an indicator of general health.

e) The final section (Section 6) contained four items on individual safety-related behaviours. These presented participants with items relating to: (i) their use of safety equipment; (ii) the taking of shortcuts; (iii) following safety rules; and (iv) the incompatibility of working safely and quickly. These items had a Cronbach's alpha measure of internal consistency of 0.60. Respondents indicated their agreement with these items using the same 5-point Likert-type described previously.

Analyses

Structural equation modelling, using latent variables, was employed to test the relationships among the components. Each latent variable, or factor, comprises several indicators or measures, as described in the previous section[3]. The overall fit of the resultant models was assessed using the same indices employed in studies 1 and 2.

Results

The model in Figure 5 was estimated and tested. This model posited both direct and indirect effects of the organizational and physical work environment factors on accidents, and thus, both the general health and the safe behaviour factors mediate the effects of the other factors on accidents. Overall fit results shown that the model is a reasonable representation of the observed data. The chi square was statistically significant (χ^2_{126} = 264.03, $p< 0.001$), but all the other indices assessed the model as adequate (CFI= 0.921, GFI= 0.911, AGFI= 0.89, and RMSEA= 0.06). The model fit may be considered quite good, specially taking model parsimony into account.

[3] This study is partially based on results presented in Oliver, A., Cheyne, A., Tomás, J.M., & Cox, S. (2002). The effects of organizational and individual factors on occupational accidents. *Journal of Occupational and Organizational Psychology, 75,* 473-488.

Close scrutiny of the analytical fit, the estimates for the free parameters in the model, is also required. These analytical results have two separate components: the factor loadings, which link the observed variables to the hypothesised constructs or factors, as detailed in studies 1 and 2, and the structural relationships among these constructs, as proposed in figure 5. Theoretical constructs are not observable, thus before the model can be tested empirically, a set of indicators must be defined for each factor. There must be reliable correspondence between the indicators and constructs. The factor loadings relating to each observed variable with its construct gave an indication of their reliabilities. That is, the measurement part of the models offered data on construct validity and indicators' reliabilities. Standardised factor loadings relating each observed variable to their constructs are shown in Table 7.

TABLE 7: Standardised loadings for all observed variables

	Latent variables (factors)				
Observed variables	*Organizational involvement*	*Physical work environment*	*Safe behaviour*	*General health*	*Accidents*
Supervisor's response	0.822				
Co-worker's response	0.792				
Safety management	0.821				
Environmental Conditions		0.783			
Noise		0.651			
Workload		0.787			
Hazards		0.335			
Taking Shortcuts			0.250		
Following Rules			0.825		
Using Safety Equipment			0.709		
Safely vs Speed			0.325		
Anxiety checklist				0.709	
GHQ anxiety				0.797	
GHQ depression				0.644	
Near misses					0.703
Minor accidents					0.700
Up to three days off					0.540
Severe accidents					0.478
Correlation between organizational involvement and physical work environment = –0.645					

Note: All loadings p< 0.01

All loadings relating indicators to organizational involvement and the physical work environment were statistically significant ($p < 0.001$). In the case of organizational involvement, the three indicators seem highly reliable, strongly related and central to the definition of the construct. Although less solid, the physical work environment factor can also be sustained by the results. It must be considered that it is not necessary that more hazardous companies (or jobs) also have higher ergonomic stressors (problems with light, pace of work, noise, overload etc.). Thus there is no strong theoretical reason to expect stronger relationships between the environmental indicators and the physical work environment factor than those found in the study. The moderate relation of hazards to the factor may also be “study dependent” because more working environment indicators were considered in the model, compared with the previous studies. These first two factors were highly related, but can still be considered separate, in line with results by Tomás and Oliver (1995). In terms of the other latent variables, the indicators of general health were all extremely reliable in measuring the construct. On the other hand, the first indicator of the safe behaviour factor cannot be considered consistent enough to adequately represent the construct. This indicator deals with unsafe shortcuts in the manufacturing process and may, in part, be inconsistent with its factor because it is not only an indicator of personal behaviour but also this behaviour that may be organizationally sanctioned. Despite the low loading, it was decided to keep it in the model due to its theoretical importance. Finally, the four indicators of accidents were highly reliable. The variable asking about number of severe accidents was not as strongly related to the latent variable as the other indicators, but still is highly reliable. This result can also be due to the smaller variance and extreme non-normality of this variable.

The main aim of the study was to assess the relationships between organizational and social, work environment and individual variables and occupational accidents. The theoretical framework, proposed in figure 5, is illustrated again in figure 6 this time including the relationships from the study data.

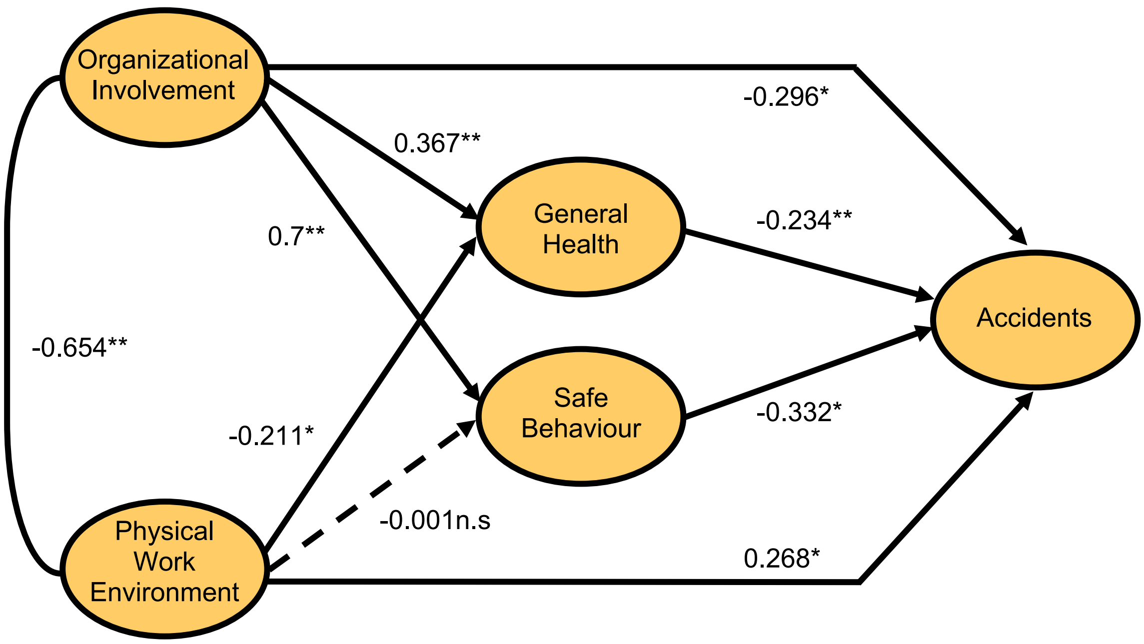

FIGURE 6: Estimates of the structural part of the model

The direct effects on accidents were all statistically significant, as shown in Figure 6. Employees perceived that occupational accidents were decreased when individuals were exhibiting safe behaviours and in good general health, the organization was more involved in safety management, and the physical work environment was less hazardous. As well as the direct effects, there were a significant indirect effect of organizational involvement on accidents (β= 0.311, p< 0.01). The proposed indirect effect of physical work environment was not statistically significant (β= 0.05, p> 0.05). All the proposed effects accounted for 50% of the variance of safety behaviour, 28.1% of general health and 20.15% of accidents.

The results of this study provide some evidence that climate can be significantly related to outcome measures such as accident involvement. On that basis it is appropriate to examine whether or not the five factor model discussed in studies 1-3 can be related to similar outcome measures.

4.2. Study Five: Predicting Accidents Using the Five Factor Model

The study is once again focused on a survey of Spanish workers. Like the previous study, it aims to test through structural equation modelling direct and indirect effects of safety climate dimensions on accident rates. It shares the main hypotheses with study four. Given that study 4 found relationships between accidents and safety climate dimensions, this study explores the potential links between the stable five factor model of safety climate developed in studies 1 and 2, and accident involvement. Relationships between each of the five factors, and work environment and workplace hazards, and accidents will be explored. Additionally an a priori model proposing a specific pattern of relationships, based on those shown in relation to safety activities (Cheyne, et al., 1998) is shown in figure 7.

Sample

The research was based on a questionnaire survey of a population of workers in Valencia, Spain[#]. Workers were surveyed while they were undergoing annual medical tests at the Valencian Health and Safety Executive. The data include 544 valid questionnaires, with a response rate of 90%. Participants' ages ranged from 16 to 65 years (mean= 37.56, S.D.= 10.94) and 76.8% were male. Most respondents (80%) were general employees, 10.4% were supervisors, and 9.5% were managers or senior managers. A variety of industrial sectors were represented, including: chemical (4.1%), metal industries (36.2%), commerce and tourism (3.1%), educational and health services (12.2%), administration or banks (10.13%), construction industry (6.7%), other manufacturing industries (4.3%), and other service industries (22.9%).

[#] This study was carried out at a different time form study 4, similarities between sample characteristics are due to the fact that we sampled from the same working population.

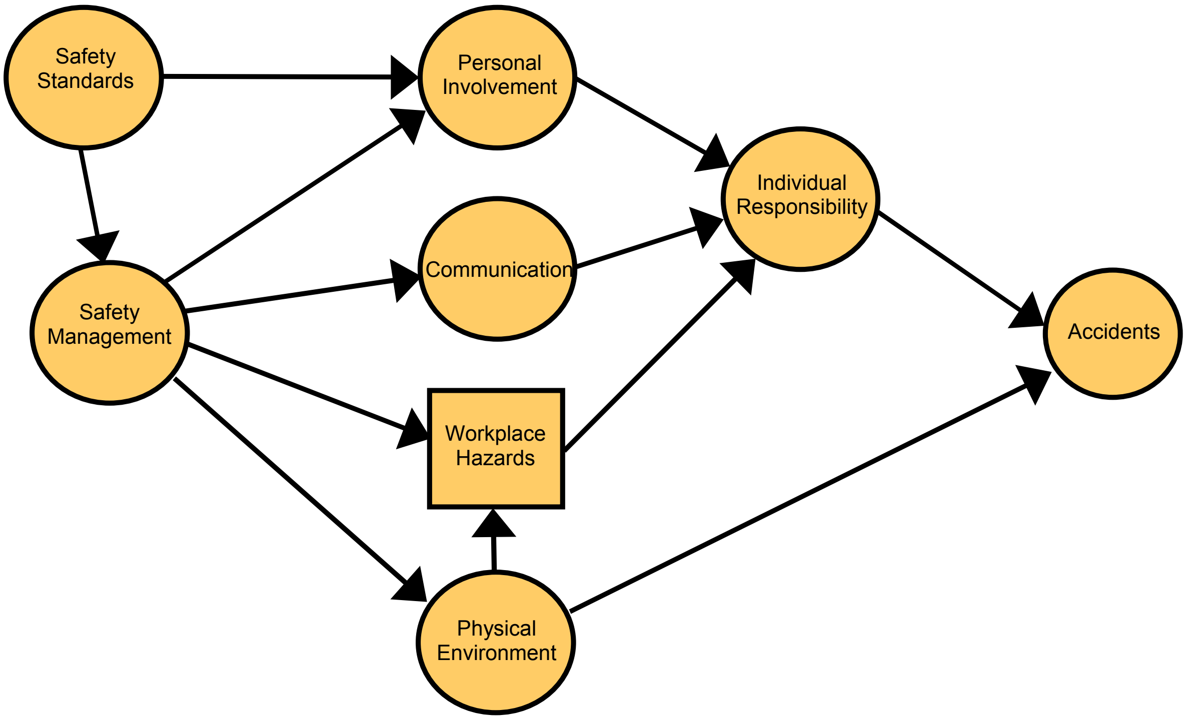

FIGURE 7: Hypothesised structural model relating safety climate, hazards, work environment and accidents

Survey Instrument

The survey instrument employed in this study is the same as that described in study 3.

Analyses

Of the several statistical techniques were used to test for the relationships between safety climate dimensions and accident rates, two were employed in this study. Firstly, in order to predict separately each accident indicator, generalized linear models with observed variables were used. From the available generalized models, multiple linear regression, with and without non-linear transformations of the dataset, and Poisson regression, with and without correction for overdispersion, were employed. The second type of model used was structural equation modelling with latent variables. It was utilised to establish a latent factor of overall accidents with four observed indicators. A brief explanation of these models and the programs used for their estimation is presented below.

Generalized linear models with observed variables. Accident rates are counts, from a scale of measurement perspective, they are quantitative discrete variables, and normally present highly positively skewed distributions. These considerations, taken together, make the selection of statistical technique difficult. Most resarchers apply standard linear regression techniques in order to predict accidents. This practice may be inadequate because, with accident data, distributional assumptions are not met, specially normality and homogeneity of variance, and this may also lead to out of range predictions. As a consequence the regression estimates may be biased, unefficient and inconsistent (Long, 1997). A possible remedy for this situation is to transform the accident data, usually with square root or logarithms (Judd & McClelland, 1989), in order to meet assumptions. The main problems with this practice is that it is sometimes difficult to find a transformation that simultaneously corrects for all distributional problems, and also that interpretations of coefficients is more difficult (McCullagh & Nelder, 1989).

An alternative to linear multiple regression is Poisson regression, in which the model assumes that the dependent variable (criteria) consist of discrete counts, and assumes independence and equal probability across time of event occurrence. A Poisson regression model is an exponential type of model in which the expected value for the dependent variable depends on the predictors according to a structural model (Gill, 2001):

$$E(y_i \mid x_i) = \mu_i = \exp(\sum_j \beta_j x_{ij})$$

An assumption of the Poisson regression model is equal-dispersion, that is equal mean and variance of the conditional distributions. However, this assumption is rarely tenable (Long, 1997), with the norm being overdispersion. If our data have overdispersion standard error of the estimates will be underestimated, and probability values affected. A possible solution for this problem is to correct the standard errors through an estimate of the amount of overdispersion within the data set.

Structural equation modelling with latent variables. Structural equation models with latent variables were used to explore the overall pattern of interrelationships between the variables of interest in the different sections of the survey, and specifically to explain accident rates. The structural models described in this study were estimated using maximum likelihood techniques, the standard method of estimation. More detailed explanations of structural models and their fit indices were presented in study 1.

Results

Generalised linear models. The five factors of safety climate, work hazards and work environment were used as predictors of accident involvement in the generalised linear models. There are four dependent variables, the four indicators of accident occurrence. Therefore, there are four models (multiple regression, multiple regression with transformed dependent variables, Poisson regression, and corrected Poisson regression) for each dependent variable, a total of 16 linear models. Percentages of variance explained by the set of predictors may be calculated across the models, but they are not comparable, thus they will not be presented here. The b-estimates have different interpretations across models and are also difficult to compare. However, coefficients signs and the statistical significance of predictors in the equations may well be compared across models. Information on the estimates and their significance for the linear and non linear models is presented in table 8[4].

TABLE 8: Regression coefficients and their statistical significance for the three linear models

	Near Miss			Minor Accidents			< 3 Days off Work			Serious Accidents		
Predictors	*MR*	*MRT*	*CPR*	*MR*	*MRT*	*CPR*	*MR*	*MRT*	*CPR*	*MR*	*MRT*	*CPR*
Safety management	-.07	.03	-.08	.24	.18	.33	.26**	.18**	1.46**	.33**	.21**	1.32**
Communication	-.09	-.11	-.10	-.13	-.10	-.17	-.11#	-.08#	-.05	-.24**	-.12*	-.86**
Individual responsibility	.14	.08	.16	.20	.05	.23	.03	.02	.03	.09	.06	.20
Safety standards	-.16	-.08	-.21	-.23*	-.07	-.29*	-.09*	-.08**	-.57**	-.11*	-.08*	-.44*
Personal involvement	.01	.02	.00	-.19	-.03	-.23	-.11#	-.07	-.63#	-.05	-.04	-.14
Work environment	-.21	-.12*	-.27#	-.05	-.03	-.05	-.05	-.04	-.26	-.12*	-.08*	-.42*
Work hazards	.01**	.005**	.01**	.01**	.005**	-.01**	.00	.00	.00	.00	.00	.00

Note ** p <0.01, * p<0.05, # 0.05>p<0.01

As it may be seen in table 8 results are very similar across linear and non-linear models. The only significant predictor of near misses was work hazards, and this results was the same across all statistical models considered (p< 0.01). Work hazards and safety standards and goals are significant predictors of minor accidents, and this result is consistent across models, with the exception of a non significant coefficient for safety standards when the square root of minor accidents is used as the dependent variable. With respect to accidents resulting in up to three days off work, the three models showed the same pattern of results, with safety management and safety standards as significant predictors. Finally serious accidents are significantly predicted by safety management, communication, safety standards, and work environment, in all statistical models.

Structural Modelling with latent variables. Finally, a structural equation model with latent variables was used in order to study the link between safety climate and the different accident rates. The final model, based on a very few modifications of hypothetised model (shown in figure 7) resulted in a good model fit, after a few minor statistic and theoretically driven modifications. The chi-square is statistically significant (χ^2= 1293.559, d.f.= 586; p<0.001), but the CFI and the GFI were 0.87 and 0.81, respectively, indicating only an acceptable model fit, and finally, the RMSEA shown an excellent fit (0.063). The standardized relationships between the variables (latent and observed) in the model are

[4] The estimates and the statistical significance of the Poisson regression without the corrections are not presented in table 8, because estimates are the same as those for the corrected Poisson regressions and standard errors are not correct due to the presence of overdispersion.

shown in figure 8. The measurement part of the model (explored in detail in studies 1 and 2) has not been included for clarity, but all factor loadings were statistically significant ($p<0.01$), in the theoretical direction and large, indicating that all indicators were highly reliable in the measurement of latent factors, including the different accident indicators. In terms of accident prediction, the main predictor was safety standard and goals, an organizational variable. Work-place hazards also had an important effect on accidents. Overall, the amount of variance of accidents explained for by both predictors was a 25%, which may be considered a large effect on accidents in this context.

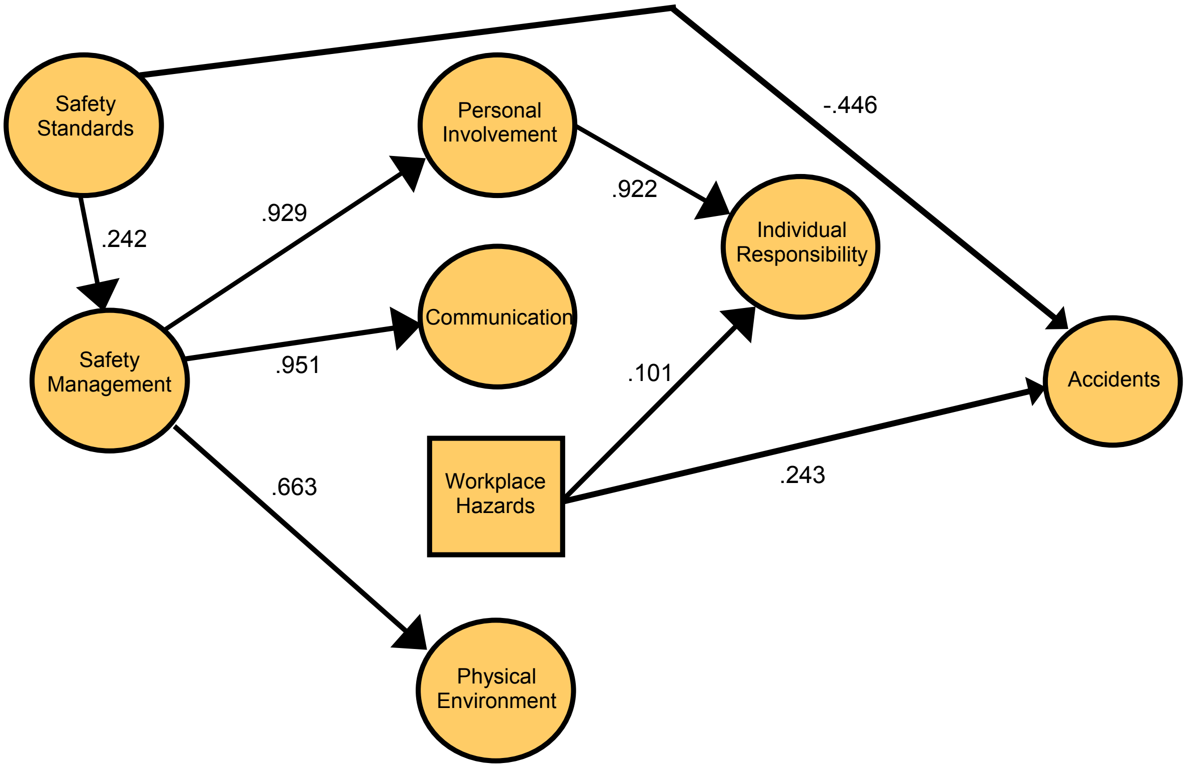

FIGURE 8: Final model explaining accidents

4.3 THE RELATIONSHIP BETWEEN CLIMATE AND ACCIDENTS

A primary aim of studies 4 and 5 was to investigate relationships between elements of safety climate and accident rates. Study 4 provided evidence that climate could be linked both directly and indirectly with accidents. The explicative model constructed in study 5, including safety climate, accident involvement and working environment variables, illustrated relationships with the five factor model described in studies 1-3 and accidents in a sample of Spanish workers. Both studies supported hypothesis H3, that safety climate is related to behavioural outcomes. The level of prediction of accidents within the model in study 5 was relatively good. Of the safety climate dimensions, safety standards and goals is highly related to accidents, suggesting that perceptions and attitudes measured by this aspect of climate might give an insight into accident involvement. The model also confirmed the relationship between work-place hazards and accidents as an outcome index. The explicative model suggests that, while respondents in this study do not perceive a relationship between management issues and the hazards that they face, they do recognize that these both have an influence on the occurrence of accidents, and much more so than their own personal responsibility. Moreover, the relationships between accidents and these factors were shown consistently by both methodological approaches taken in study 5; structural equation modelling and regression analysis.

5. Conclusions and Discussion

The robustness of the five factor structure of safety attitudes, as well as the variable strengh of the relationships amongst the components in different settings gives an indication of its potential within health and safety management systems. The five factors lend weight to the assertation that climate is a multi-dimensional concept and they which relate broadly to the 'core' dimensions identified in reviews of the area (Clarke, 2000; Flin, et al., 2000). The second study presented above suggests that there were some minor differences in the way the three hierarchical groups defined the attitude factors, and provides some evidence that managers, supervisors and employees conceptualise climate differently depending on their place in the organisation. The majority of items in the five factor model were, however, equal, suggesting cross-group equality in the measurement models and not the type of factor structure differences reported in the nuclear sector by Harvey et al. (1999), or the transport sector by Niskanen (1994). So, while some differences do exist, a general overall pattern still holds, and climate, as conceptualised by the five factor model, will still be a meaningful concept to all employees, no matter what their level in the organisation.

The five dimensions described in the first two studies reflect attitudes to safety. Study 3 examined which of these dimensions were shared within organisations, and could perhaps be said to truly reflect a safety climate (Zohar, 1980). The resulting intraclass correlation coefficients suggest that there is a level of agreement on, or sharing of, attitudes and perceptions within companies on certain of the attitude measures. Perhaps not surprisingly the levels of agreement are lower (and non significant) for those variables that refer directly to personal factors such as responsibility and involvement. The one exception to this is the dimension relating to safety standards and goals. In this sample of Spanish workers these standards could reflect expected behaviour at the sub-organisational level, or it could be that there are no clearly understood norms of behaviour relating to the items in this dimension within the organisations involved in the study.

The latter two studies provide some insights into the practical implications of attending to climate and attitudes, particularly when these can be related to accidents. Study 4 clearly presents a model predicting accidents as final outcome of a process where safety climate, characterised as shared perceptions, is involved. Study 5 explores this further by looking for links between the five factor model and accident outcomes. One explanation for the pattern of results found in study 5 could be that those surveyed are displaying a somewhat skeptical attitude to their own involvement in the accident process, where they do not feel that they personally can prevent accidents from occurring, and that these are more directly related to their environment or the organization's safety management. This might be particularly true of accidents with up to three days away from work and severe accidents where the regression analysis also showed a relationship between these and the safety management and communication dimensions. These findings might suggest that workers hold a kind of fatalistic attitude that has been represented in previous studies describing the nature of safety climate (Cox & Cox, 1991; Williamson et al., 1997), where it was characterized more directly by items focusing on individuals' lack of control over being safe. The results from this study may be more indicative of externally focused attributions relating to accidents and incidents, centring on the organization or the hazard environment as the basic cause of accidents. This possibility would certainly support Brown and Holmes' (1996) conclusions that perhaps those individuals who have experienced trauma in the workplace blame their managers.

Furthermore, the results suggest that the final structural model also generalizes, not only across different groups in organisations (as seen in study 2), but also across cultures. The similarities between the structures found in UK samples and the Spanish sample described in this study allow a core general model to be derived. In effect the safety climate dimensions are stable for this sample of the Spanish population, providing some empirical support for the generalization of the five factors model of safety climate across cultures. This finding is in line with those described by Janssens et al. (1995), where similar structures were observed in different national operations of a multinational company, although in this case the organizations involved are not related. The broad hypothesis presented by Cheyne et al (1998), that organizational variables (safety management and safety standards and goals) influence environmental (physical work environment and workplace hazards appraisal) and group process (communication and personal involvement) variables which, in turn, influence individual precursors to behaviour (individual responsibility and level of safety activity), was supported in part by the Spanish data. In the Spanish sample, most of the relationships hold up and the main effects are of about the same strength as in previous British samples. Differences are mainly in terms of a few relationships, and not in the direction but in the intensity of those relationships. Specifically there are no relationships between work-place hazards and the physical work environment and between safety management and work-place hazards. This suggests that those in the Spanish sample perceive the hazards they face in their work-place as more distinct from the organization and its management, than do those in previous studies, although they still feel that these affect the responsibility that they must take for their own safety.

There are practical implications based on this model explaining the relationships between climate and accidents. The fact that those involved here take a more skeptical view of their own role might direct managers to emphasize the responsibility of everyone for safe working. Such a strategy of attitude change would reflect safety behaviour modification interventions and could involve the rewarding of expressions of personal responsibility (Cox & Cox, 1991). The exact role played by personal skepticism and individual responsibility is, however, only alluded to in the model presented here, future development of the model could focus on enhancing the individual responsibility dimension and examining how it might further explain accident occurrence. When the results of study 3 are also considered, we could suggest that attempts to influence climate, and by extension accident involvement, are easiest at the level of the working environment and the safety management system.

In general the findings on the structure of, and relationships within, safety climate also have implications for the formulation of policy within multi-national organizations (Janssens et al., 1995), where different operating cultures exist. These results may represent an important consideration for supranational bodies and/or multinational organizations seeking to harmonize working practices, legislation and regulation, or organisations merging two distinct operating cultures. Examination of this, and similar, models would suggest that practices appropriate in one location may have little effect in another. In this case, it has been suggested (Sesé, et al., 2002) that accident prevention in Spain is still focused on risks, and not on the interaction of human, environmental and organizational factors, a state reflected by the model described here.

Finally, the assessment of safety culture and climate, when found to be related to objective outcomes, might provide an additional benchmark between these differing operating cultures. Employing culture and climate measures would move away from, what was until recently, traditional reliance on one particular variable in the analysis of accident occurrence. The increasing practice of assessing organizational safety climate markers also has the additional benefit of utilizing positive indicators of the state of safety performance, rather than focusing solely on a negative, lagging indicator such as accident rates, and may provide the proactive management tool described by Coyle et al. (1995).

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