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PREDICTIVE FACTORS FOR SELF-REPORTED OCCUPATIONAL INJURIES AT 3 MANUFACTURING PLANTS

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Abstract - The aim of the present study is to investigate the predictive validity of the Danish Safety Culture Questionnaire on retrospective and prospective self-reported occupational injuries in a sample of workers in the manufacturing industry. A total of 765 workers at 3 different manufacturing plants completed the questionnaire comprised of leadership, organizational and worker factors. The occurrence of self-reported injuries was reported twice: at the same time as the safety climate measures (retrospective) and secondly one year later (prospective). The strength of the association between the safety climate scores and the self-reported injuries was used as a measure of their predictive validity. 278 (36%) and 288 (41%) of the 765 participants reported experiencing at least one occupational injury during the previous and the preceding year respectively. Logistic regression showed that positive safety climate was associated with fewer injuries. The strongest association was found with the prospective self-reported injuries where all 6 safety climate dimensions reached significance whereas retrospectively, the associations were weaker and only significant for 2 of the safety climate dimensions.

INTRODUCTION

Causal theories of occupational accidents have changed a lot since the scientific study of safety emerged at the beginning of the last century. The primary focus at that time was technical measures to safeguard machinery. After the First World War attention was directed at the accident proneness of workers, leading to preventive strategies concerned with personnel selection, training and motivation (Hale & Hovden, 1998). In line with this early belief in the accident proneness of specific workers, some studies have found that individual characteristics such as personality traits correlate with occupational accidents (Clarke & Robertson, 2005; Frone, 1998; Hansen, 1989; Wallace & Vodanovich, 2003). However, the implementation of preventions strategies based on this assumption was the second least effective measure in a review of prevention programs (Guastello, 1993).

Since the mid-1980s there has been a greater focus on organizational factors as antecedents of accidents (Hofmann & Stetzer, 1996). Safety climate, safety culture and leadership are concepts that have increasingly been accredited a central role (Flin & Yule, 2004; Hale et al., 1998; Hofmann & Morgeson, 2004; Pidgeon, 1991; Zohar, 1980; Zohar, 2000; Zohar, 2002; Zohar & Luria, 2003). Unfortunately, because of the conceptual ambiguity that characterises the field surrounding safety climate and safety culture, it is difficult to draw any major conclusions on the success of this approach. Both safety climate and culture are poorly defined and no consensus exists on how to distinguish or operationalize them and their relationship with safety performance (Guldenmund, 2000; Mearns & Flin, 1999). However on a general level there is some supportive evidence for a relationship between safety climate measures and accidents (Clarke, 2000). Although a recent meta-analysis that distinguished between attitudinal, perceptual and mixed models of safety climate found no strong predictive relationship, it was found that the perceptual models of safety climate had most predictive utility (Clarke, in press).

These conceptual issues aside, many researchers have studied the relationship between organizational factors and injury outcomes. Hofmann & Stetzer (1996) showed that work pressure, with-in group communication and safety climate (management's commitment to safety and workers' involvement in safety activities) were associated with unsafe behaviour, and on a group-level marginally related to accidents within the previous 3 years. In a review of studies on the relationship between organizational and workplace factors and injury rates, Shannon, Mayr & Haines (1997) found that the seniority of the workforce, an active role of senior management in safety, and good relations between management and workers are among the factors consistently related to lower injury rates. They conclude that: "The synthesis of the results showed a number of organization variables consistently significantly related to injury rate. (…) Many can be seen as variables demonstrating management's positive attitude toward its workforce" (Shannon, Mayr, & Haines, 1997, p. 214-215). Oliver et al (2002) studied the influence of individual, work environmental and organizational variables on self-reported accidents within the previous two years. They found that key roles were played by participants' evaluations of organizational involvement in safety, social support, safe behaviour, and general health. Huang et al (in press) found that safety climate (management commitment to safety, return-to-work policies, post-injury administration and safety training) was a critical factor in predicting the history of self-reported injuries.

However, a limitation of most studies on predictors of occupational accidents (and all of those cited above) is the use of retrospective outcome data, which is collected at the same time as the predictor variables. Beside the obvious analytical problem of reverse temporality – i.e. not being able to interpret the causal relationship of the measured factors and accidents, this approach also posts a more general theoretical problem. The term safety climate is often used to describe the various factors studied, and although there is no consensus on a common definition of the term, it is generally understood to provide a "snapshot" of the current state of safety in an organization. It is not considered to be as temporally stable as, for instance, safety culture (Guldenmund, 2000; Mearns et al., 1999). So, as the safety climate in an organization is relatively changeable, it seems theoretically counterintuitive to try to document a relationship between the current safety climate and injuries that occurred up to 2 (Oliver, Cheyne, Tomás, & Cox, 2002), 3 (Hofmann et al., 1996) or even, in some instances, more than 10 years previously (Huang, Ho, Smith, & Chen, in press).

The most valid way to identify predictors of occupational injuries is to measure hypothesised predictive factors *before* the injuries occur. Therefore a prospective design, where the factors under study are measured prior to injuries, is recommendable. Only a few such studies exist. In a prospective cohort study Swaen et al (2003; 2004) found that risk factors for being injured in an occupational accident included both individual factors (age, gender, educational level, fatigue, need for recovery, and smoking) and psychosocial work characteristics (high job demands, emotional demands, and conflicts with the supervisor and/or colleagues). In another study with a prospective design it was shown that a group level measure of safety climate (perception of supervisory safety practices) significantly predicted group level micro accident records in the following 5 months (Zohar, 2000).

Objective of the current study

The objective of the present study was to identify and compare the predictive utility of the 6 dimensions of safety climate on retrospective and prospective self-reported accidents.

The study reports on a cross-organisational survey that uses a longitudinal design which makes it possible to evaluate the predictive utility of both retrospective and prospective self-reported occupational injuries. The project, entitled "Safety Culture and Occupational Accidents", ran across two consecutive years with data collection occurring twice with a 1-year interval. Three industrial plants participated in the study. They were assessed on 6 different dimensions of safety climate. Data on self-reported injuries was collected retrospectively both for the year prior to the baseline measurement of safety climate and the following year.

MATERIAL AND METHODS

Design and study population

The project was a longitudinal study with data collection occurring twice exactly one year apart. The first round of measurements was performed in September 2003 (T0), while the second round was performed in September 2004 (T1). At both measurements a questionnaire on safety climate and accidents in the preceding 12 months was administered. The data presented here couples the safety climate scores from T0 retrospectively with self-reported accidents from T0 and prospectively with self-reported accidents from T1.

The study population was all production workers at 3 medium sized industrial manufacturing plants. Two of the plants (Plant A and B) were almost identical plants under the same corporation.

At baseline the number of workers at Plant A was 388, gradually decreasing to 341 at T1. At Plant B there was a workforce of 442 at baseline and 570 at T1. At plant C the number of workers was almost constant as there were 452 at T0 and 456 at T1. At each of the three plants there were 15-20 supervisors.

Questionnaire data

The newly developed Danish Safety Culture Questionnaire (Mikkelsen & Nielsen, under preparation) was used. DSCQ covers 6 dimensions of safety climate. Two leadership factors (Immediate supervisor general leadership and Immediate supervisor safety leadership), an organizational factor (Safety instruction) and 3 worker factors (Convenience violations, Safety oversights and Commitment to the workplace). *Immediate supervisor general leadership* is measured with 5 items covering general aspects of leadership. Four of the items are taken from the Multifactor Leadership Questionnaire form 5X (Avolio, Bass, & Jung, 1999). Sample item: My immediate supervisor uses methods of leadership that are satisfying. *Immediate supervisor safety leadership* is measured with 3 items covering the immediate supervisor's commitment to safety. Sample item: My immediate supervisor intervenes immediately if safety regulations are broken. *Safety instruction* is measured with 3 items covering the adequacy of safety training. Sample item: I have been shown how to perform my work safely at my current place of work. *Convenience violations* is measured with 3 items taken from the general unsafe behaviour factor from the Offshore Safety Questionnaire (Mearns, Whitaker, & Flin, 2003). Sample item: I ignore safety regulations to get the job done. *Safety oversights* is measured with 3 items covering reasons not to bring up safety issues with supervisors. Sample item: It is of no use to bring up safety issues. *Commitment to the workplace* was measured using 4 items from the Copenhagen Psychosocial Questionnaire (Kristensen, Hannerz, Høgh, & Borg, 2005). Sample item: Do you feel that your place of work is of great personal importance to you?

Questionnaires were administered at information meetings. At Plant A and B the workers had the opportunity to fill out the questionnaire at these meetings at both measurements. At Plant C the workers had to fill out the questionnaire during natural breaks throughout the workday at T0, while they were allowed to fill out the questionnaire at the information meetings at T1.

Injury data

Self-reported injuries were collected via the questionnaires at both T0 and T1. Participants were asked how many times, if any, they had experienced 9 different types of injuries (8 specific types e.g. a cut or bruise, and "other") during the last 12 months. Participants were instructed to report any injury resulting in a work stoppage of any length, thus including both major and minor injuries. The total number of injuries per participant was calculated separately at T0 and T1 by summarizing across the 9 different types of injuries. On the basis of this the participants was coded separately at T0 and T1 as either having no injuries (if they had not reported any of the 9 different types of injuries) or at least one injury (if they had reported one or more injury).

Statistical analysis

All statistical analyses were performed using the Stata Statistical Package, Version 9.1 (702 University Drive East, College Station, Texas). The safety climate scale scores were generated as unstandardised sum mean scores, using the 'alpha, generate' command. This command does not employ casewise deletion. A score is created for every observation for which there is a response to at least one item. The sum score is divided by the number of items over which the sum is calculated. The odds ratio was uses as the measure of the strength of the association between the safety climate scores and the occurrence of injuries, using logistic regression. Change over time and differences between plant A, B and C in the injury incidence rate was analysed using the 'iri' command of the Epitab modulus

RESULTS

	Plant A	Plant B	Plant C
N	227	290	248
% Male	85.0	85.5	92.7
Age			
Mean	40.9	40.7	43.2
SD	9.6	8.6	10.2
Seniority Plant			
Mean	2.8	5.0	12.2
SD	1.0	3.2	10.0
Seniority Profession			
Mean	5.6	6.2	19.3
SD	7.4	5.7	11.5
% With at least 1 injury			
Retrospective (T0)	31.3	27.6	55.6
Prospective (T1)	29.5	33.1	59.7

Table 1. Participants' age, seniority and self-reported injuries

As table 1 shows, although the workforces at the 3 plants are similar in age and sex, there are clear distinctions between the 3 plants in terms of employee's seniority. The difference in plant seniority is explained by the fact that Plant C was much older than Plants A and B. Although Plant B had existed for more than 20 years, it had done so for only 10 years in its current form. Plant A was an offspring from Plant B, established app. 5 years prior to the study. The difference in profession seniority reflects the fact that Plant C was a traditional manufacturing plant with a long history of hiring and educating skilled craftsmen, whereas both Plants A and B was located in the outskirts of Denmark and therefore hired many unskilled people from different backgrounds (e.g. fishermen and farmers).

The rate of participation at Plant A at baseline was 93.8 % (n = 364) and 85.9 % at follow up (n=293). 326 workers were engaged at Plant A at both measurements and 69.6 % of these (n=227) answered the questionnaire at both times. The corresponding figures in company B were 87.8% (n = 388) at T0, 77.7 % (n=443) at T1 and 67.1 % at both measurements (n = 290 of 432). At Plant C 75.9 % (n =346) at T0, 76.1% (n = 344) at T1 and 65.2 % at both measurements (n= 248 of 379) participated. In total, 67.2 % of the workers engaged at the plants at both measurements (n = 765 of 1080) participated in the study. All questionnaire data reported here are from the workers who participated in both measurements.

		Plant A	Plant B	Plant C
General L	Mean	3.47	3.70	3.29
	SD	0.84	0.78	0.83
Safety L	Mean	3.43	3.69	3.03
	SD	0.85	0.78	0.75
Instruction	Mean	3.80	3.81	3.11
	SD	0.80	0.77	0.79
Convenience	Mean	3.15	3.30	3.26
	SD	0.92	0.86	0.88
Oversights	Mean	3.82	4.00	3.65
	SD	0.77	0.76	0.78
Commitment	Mean	3.25	3.61	3.36
	SD	0.79	0.74	0.76

Table 2: Mean sum scores and standard deviations of the 6 dimensions by plant

Safety climate mean sum scores

All items were scored on a one- to five-point Likert scale. A mean sum score for each of the 6 dimensions was calculated by dividing the sum scores by the number of items over which the sum was calculated. Before this was done, the scores of negatively phrased items were reversed. Thus, the scale of the mean sum score is the same as the scale of the individual items, with "1" indicating the worst possible and "5" indicating the best possible safety climate. This is true also for Convenience violations and Safety oversights, where a high score is associated with a low degree of violations and few oversights, and thus a good safety climate, and vice versa. The mean sum score and SD of each of the 6 dimensions by plant are given in table 2. Cronbach alpha coefficients ranged from 0.79 to 0.89 for the 6 factors. For further information on the development of the questionnaire and the specific items see Mikkelsen & Nielsen (under preparation).

Plant	Injuries T0	Injuries T1	Person Time	IRR(T0/T1)	p-value
A	71	67	227	1.06	0.73
B	80	96	290	0.83	0.22
C	138	148	248	0.93	0.56
Total	289	311	765	0.92	0.37

Table 3: Number of injuries at T0 and T1 by plant and the incidence rate ratio between T0 and T1.

Injury Outcome

The distribution of reported injuries per subject was similar at T0 and at T1. At T0, 476 (62.2%) reported no injuries and 289 (37.8%) reported at least one injury. Less than 10% reported more than 4 injuries. Similarly at T1, 454 (59.4 %) reported no injuries, 311 (40.7%) reported at least one injury, and less than 10% reported more than 4 injuries. The absolute number of subjects reporting at least one injury, by plant and by time period, is given in table 3. Although Plant A improved and Plant B worsened somewhat during the one year follow-up, no significant change in the incidence rate occurred from T0 to T1. The injury rates were similar at plants A and B, whereas the injury rate at plant C was about twice the rate at plant A and B, at both T0 and T1 ($p<0.001$).

Association between safety climate dimensions and injuries

The association between each of the 6 dimensions of safety climate and the occurrence of self-reported injuries, both retrospectively (T0) and prospectively (T1), were estimated using logistic regression on individual data records. The effect was first estimated separately for each plant, and a log likelihood ratio test of the separate effects against the combined effect for all plants together was then used to see if the plant specific effects of the safety climate dimensions differed significantly (i.e. test of effect modification). For all dimensions and for both T0 and T1, the test was insignificant, indicating no effect modification by plant. Therefore, only the combined effect is of interest. In all logistic regression models, the estimated effect of the safety climate dimensions is controlled for 'plant' using indicator variables, and for 'age' using a linear effect of 10 year age groups.

		OR(A)*	OR(B)*	OR(C)*	p(LR)#	OR§	p(OR)§
General L	T0	1.057	0.796	1.019	0.430	0.953	0.613
	T1	1.007	0.633	0.790	0.149	0.788	**0.012**
Safety L	T0	0.840	0.695	0.945	0.435	0.818	**0.040**
	T1	0.782	0.729	0.771	0.951	0.759	**0.005**
Instruction	T0	0.849	0.708	1.120	0.143	0.884	0.209
	T1	0.764	0.793	0.765	0.984	0.775	**0.009**
Convenience	T0	0.975	0.724	0.654	0.167	0.769	**0.003**
	T1	0.820	0.665	0.723	0.636	0.729	**0.000**
Oversights	T0	0.860	0.816	1.003	0.666	0.894	0.261
	T1	0.997	0.665	0.654	0.179	0.742	**0.003**
Commitment	T0	0.668	0.761	1.139	0.080	0.845	0.099
	T1	0.857	0.710	0.630	0.484	0.722	**0.001**

* Company specific odds ratios
# p-value of the likelihood ratio test of effect modification.
§ Odds ration and p-value of the combined effect.
Significant p-values in bold

Table 4: Logistic regression of the effect of the safety climate dimensions on injury reporting at T0 and T1, plant specific effects, the combined effect, and test for effect modification, controlled for plant and age.

For all dimensions of safety climate, the odds ratio of the association between the safety climate dimensions and the occurrence of reported injuries were lower than 1.00, indicating that a good safety climate is associated with fewer reported injuries (see table 4). The strength of the association between the safety dimensions and the occurrence of reported injuries was stronger prospectively than retrospectively, that is, the odds ratio is farther away from the null-value of 1. Furthermore, all the prospective associations were significant, whereas only Immediate supervisor safety leadership and Convenience violations were significant retrospectively (see table 4).

DISCUSSION

The main strength of the current study is the use of a longitudinal design that makes it possible to evaluate the predictive value of the safety climate factors on both retrospective and prospective self-reported injuries. The main finding is that the safety climate factors showed a stronger relationship with prospective self-reported injuries than retrospective self-reported injuries. Although this is what is expected from a theoretical point of view, as safety climate (and safety culture) in general is understood as an antecedent of occupational accidents (Griffin & Neal, 2000; Neal, Griffin, & Hart, 2000; Neal & Griffin, 2004; Zohar, 2000), this is an important result as it sheds some light on the causal relation between safety climate and accidents.

We found that positive safety climate, measured by the Danish Safety Culture Questionnaire, was associated with fewer self-reported injuries. This association was found to be stronger and statistically more significant with prospectively reported injuries than with retrospectively reported injuries. Taking into consideration that the safety climate and the retrospective injuries were measured simultaneously by the same questionnaire, whereas the prospective injuries were measured one year later, the stronger prospective rather than retrospective association is even more noteworthy. Further, since it is known that recall becomes weaker as the recall time-interval increases, the true value of safety climate in predicting injuries may be even stronger than the association estimated in this study. The fact that safety climate did predict injury risk in the following year suggests that our measure of safety climate does not merely reflect a momentary picture, but rather is a measure of a somewhat stable construct. The fact that the nature of the association between the safety climate factors and both the retrospective and prospective outcome measure was the same, adds to the credibility and validity of studies that have only used retrospective outcome measures. The difficulty of reverse temporality might not be as problematic if the measures used are somewhat stable across time. The measurement invariance of the 6 safety climate factors used in this study has previous been established using a multi-sample confirmative factor analysis (Mikkelsen et al., under preparation).

Two factors showed a significant relationship with both retrospective and prospective self-reported injuries. The factor showing the strongest relationship with both types of self-reported injuries was Convenience violations. This is in line with the source of this factor, where Mearns et al (2003) found that the original scale was consistently related to retrospective accidents. That Convenience violations shows a stronger relation with the outcome measures than Immediate supervisor safety leadership is not surprising as it is expected to occur closer to accidents in the causal chain. However the fact that these factors showed a significant relationship with both outcome measures might be an indication of their importance, which is in line with previous research (Flin, Mearns, O'Connor, & Bryden, 2000; Flin, 2003)

An obvious weakness of the study is that the outcome measures are self-reported injuries in the last 12 months. A 12-month reference period is frequently used in injury surveys to obtain an adequate number of injuries for analysis. However, a shorter recall period is desirable to provide more accurate estimates (Landon & Hendricks, 1995). Studies have shown that injuries are under-reported by up to 43 percent due to recall bias when using a 12-months reference period, and a recall period between 2 weeks and a maximum of 3 months, depending on the severity of the injury, is recommend to minimize underreporting (Harel et al., 1994; Landon et al., 1995). With the 12 months follow-up period used in this study there is also the risk that significant changes in the safety climate factors occur during those 12 months, changes that influence accidents reported at T1. However, in the current study, the 12 month follow-up period was considered the best compromise between obtaining an adequate number of injuries and still having relatively precise measures of the safety climate factors.

Another weakness is the fact that the study is based solely on self-reported data. This may create problems with information bias, and the potential for common method bias exists when both independent and dependent variables are measured by the same informant. This might hold true for the retrospective self-reported injuries as these are collected at the same time as the safety climate measures. However, when looking at the prospective self-reported injuries this is somewhat compensated for as the independent and dependent variables are collected at two different points in time 1 year apart (T0 and T1). Even so, it would further strengthen the conclusions if it was possible to use a more objective outcome measure, such as accidents reported to the plants or government authorities, although those types of measures are also biased by underreporting.

One further point that needs consideration is the level of the measures used. The analysis associates the different factors of safety climate with self-reported injuries at an individual level. However, the concept of safety climate implies a group-level way of thinking (Zohar, 2000), where there is some shared way to perceive, understand or interpret organizational events either at the organizational level or in sub-units. The most correct way to analyse data would then be to aggregate safety climate scores at an organizational or group level and investigate the predictive power of these on group-level self-reported injures. Of course, the appropriateness of using group-level analyses depends on the specific items in the safety climate measures (i.e. do they pertain to a group norm or individual preferences). The current measure of safety climate represents a mixture of group and individual level items as the Leadership, Safety instructions and Safety oversights factors relate to group-level perceptions, while the Convenience violations and Commitment to workplace factors relate to the individual level. Consequently, it would be advisable to perform group-level analyses for at least some of the factors. But to do this one needs to be able to identify the correct group to analyze upon. The correct group might not necessarily match the organizational sub-units as these might not correspond to actual social units, and the level of interaction between members of sub-units might differ markedly between units depending on the work tasks performed. Although data on each worker’s placement in organizational sub-units was gathered in the present study, it was decided (on the basis of the above mentioned reasons) that these did not reflect the correct social units, and that there was no meaningful way to identify these with the data available. So although desirable it was not feasible to perform group-level analyses with the current data.

CONCLUSION

The present study has shown that a measure of 6 different safety climate factors was associated with retrospectively and prospectively self-reported injuries. The strongest association was found with the prospective self-reported injuries where all 6 safety climate dimensions reached significance whereas retrospectively, the associations were weaker and only significant for 2 of the safety climate dimensions.

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