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Development and validation of an Integrated Organizational Safety Climate Questionnaire with multilevel confirmatory factor analysis

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Abstract Meta-analytic and traditional reviews on safety climate reveal theoretical and methodological safety climate issues still open. The main aim of this study is to propose a questionnaire which combines recent and different approaches to safety climate, trying to give a contribute about these issues. The present research led to the development of a new questionnaire to measure safety climate, suitable for blue-collar workers, and to the evaluation of its psychometric properties, and usefulness to measure safety climate in the industrial sector. Multilevel confirmatory factor analysis (MCFA) was used to properly evaluate the factor structure underlying the safety climate questionnaire composed of three scales: organizational safety climate scale, supervisor's safety climate scale and co-workers' safety climate scale. The clear distinction, made with the use of three different scales, among safety agents (organization, supervisor, co-workers), allows the assessment of workers' perceptions focused on each level, and allows to deeply explore, for instance, lateral relationships of supervisor's safety climate and co-workers' safety climate, analysing the interactions between the roles of these two safety agents. A two-level design was used, considering the individual level and the work-group level. Data collection involved 1,617 blue-collars from eight Italian manufacturing companies. The MCFA results demonstrated the importance to use proper analysis to study the factor structure of a multilevel construct as safety climate, and confirmed the theoretical structure of safety climate purposed from Griffin and colleagues, using not only psychological climate (i.e., the individual level), but also the group level safety climate.

Keywords Multilevel confirmatory factor analysis · Safety climate scale · Metal-mechanic blue-collars · Safety agents · Co-workers · Safety performance

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1 Introduction

Safety climate and culture research developed successfully since the inquiry into Chernobyl disaster that identified inadequate safety culture as a major underlying factor for the accident (IAEA 1986). However, the most important seminal paper on this topic was proposed by Zohar in 1980, some years before the disaster. In this paper Zohar offered a great contribution on the definition and operationalization of safety climate, showing how this construct is related to the general safety level in the organizations and, in particular, how "management commitment to safety is a major factor affecting the success of safety programs in industry" (1980, p. 101).

The ensuing success of this approach to safety is indicated by later studies, which show how safety climate is a robust predictor of safety subjective outcomes, such as safety behaviour, and of objective outcomes, such as accidents and injuries (Christian et al. 2009). From the nineties the literature about safety climate increased markedly, and a large number of scales have been created (Glendon 2008). Nevertheless meta-analytic studies and safety climate reviews on safety climate reveal that some issues are still open from a theoretical and methodological point of view (Guldenmund 2000; Clarke 2006; Glendon 2008; Christian et al. 2009). From a theoretical point of view, for example there is still ambiguity about safety climate themes and dimensions (Zohar 2010).

From a methodological point of view there is confusion about the levels of analysis, because many measuring instruments in safety climate research use items referring at the same time to organizational, group and individual levels. Zohar (2010, p. 1521) suggests that "given the target of climate perceptions can relate to organization or group levels of analysis (i.e. senior management commitments and policies vs. supervisory or co-worker practices), it follows that climate measurement should be based on level-adjusted subscales offering separate measures for climates associated with respective organizational levels. [...] the practice of mixing items associated with divergent levels of analysis must be discontinued in order to avoid level discrepancy errors in safety climate measurement."

Furthermore, very often authors didn't considered safety climate multilevel structure and the importance to test for example within-unit homogeneity of perceptions (e.g. adopting r_{wg} or AD criteria) or between-unit variability relating to relevant units of analysis. If the data collected are multilevel in nature they should be analysed accordingly. Shannon and Norman (2009, p. 329), referring to factor analysis of safety climate surveys, argued: "It appears that most, if not all, determinations to date of the factor structure are incorrect, since they have treated the data from individual survey respondents as completely independent" and emphasised the importance that a proper analysis requires adjustment to incorporate the multilevel nature of the data. Muthén (1991) formerly stated that this involves decomposing the variances into between-group and within-group estimates.

The main aim of this study is to propose a questionnaire which combines different approaches to safety climate, trying to give a contribute about the theoretical and methodological safety climate issues still open. Particularly, the present study tries to combine specific facets of the previous work, namely of Melià (e.g. Melià 1998, 2002; Melià and Sesè 2007; Melià et al. 2008), Zohar (e.g. 1980, 2000, 2010; Zohar and Luria 2005), and Griffin and Neal (Griffin and Neal 2000; Neal and Griffin 2002, 2004, 2006; Neal et al. 2000). These specific facets concern the selection of items related properly to safety climate, the identification of the agents involved in safety activities connected with safety climate, the identification of safety climate structure and specific dimensions, and the statistical analyses used with safety climate data. Another aim is to focus the questionnaire on the industrial sector, giving special attention, in this specific context, to blue-collar workers.

Finally the present study also intends to contribute for understanding safety climate in Italy, where the construct of safety climate has been considered in a very limited number of studies (e.g. Cavazza and Serpe 2009; Bisio 2009; Dal Corso 2008). Furthermore, at present no validate scales exist in the Italian language, focusing exclusively on the safety climate.

By safety climate literature and particularly by meta-analysis studies (e.g. Christian et al. 2009; Nahrgang et al. 2007; Beus et al. 2010) the importance of safety climate emerges because of its ability to predict safety behaviour, accidents and injuries. So safety climate has become a leading indicator of safety performance.

Safety climate is considered a subset of organizational climate with a specific domain, safety. The definitions of safety climate varied across the studies. Zohar (1980, p. 96) defines it as “a summary of molar perceptions that employees share about their work environments . . . a frame of reference for guiding appropriate and adaptive task behaviors”. Coyle et al. (1995) define safety climate as the objective measurement of attitudes and perceptions toward occupational health and safety issues. Williamson et al. (1997) speaks of safety climate as a summary concept describing the safety ethic in an organization or workplace which is reflected in employees’ beliefs about safety.

This plurality of definitions may be explained by differences in approaching this issue in each study. Clarke (2006) was able to discern three distinct approaches in her review of the literature: (1) an attitudinal approach; (2) a perceptual approach; and (3) mixed models, combining attitudes and perceptions. The present study followed the perceptual approach, and referred to the most common and used definition of perceived safety climate which refers to the individual perceptions of individuals on policies, procedures and practices relating to safety in the workplace (Griffin and Neal 2000).

On Table 1 a synthetic overview on safety climate studies by Melià, Zohar, Griffin and Neal are presented.

1.1 A multilevel construct

Zohar and Hofmann (2010) identify two processes which mainly promote the emergence of climate: symbolic interactionism (Blumer 1969; Schneider and Reichers 1983) and collective sense-making (Weick 1995, 2005), i.e., members of organizational units interact to create mutual understanding of extracted cues. Since group members interact more often with each other than with workers of other groups, it is likely that shared perceptions about their unit or about their organization emerge among them.

Climate can be conceptualized at both the individual level (e.g., Barling et al. 2002) and the group or unit level (e.g., Zohar 2000). Taken at the individual level, climate is assessed via individual level perceptions of climate (Barling et al. 2002), and taken at the group or organizational level (see Table 1 examples), climate is the sharing of such perceptions commonly focusing a specific leader, supervisor, or group or organization (Zohar 2002). James et al. (1978) termed the individual level climate perception as psychological climate and defined it as “the individual’s cognitive representations of relatively proximal situational conditions, expressed in terms that reflects psychologically meaningful interpretations of the situation” (p. 786).

Under specific conditions researchers can operationalize organizational (or group) safety climate by aggregating psychological climate perceptions within the organizational (or group) level. Therefore organizational (or group) safety climate refers to the shared perceptions of work environment characteristics as they pertain to safety matters that affect a group of individuals (Neal and Griffin 2004; Zohar and Luria 2005).

Table 1 Different approaches concerning safety climate scales

Topic	Compared studies with different approaches in measuring safety climate			
	Melià (1998, 2002); Melià and Sesè (2007); Melià et al. (2008)	Zohar (2000); Zohar and Tenne-Gazit (2008); Zohar and Luria (2005)	Griffin and Neal (2000, 2008); Neal and Griffin (2004)	Present study
Levels	Organizational level Group level (supervisor, coworkers) Individual level	Organizational level Group level (supervisor)	Organizational level	Organizational level Group level (supervisor, coworkers)
Themes	Org. safety response (OSR)	Organizational safety climate: management commitment to safety, priority of safety over competing operational goals	Safety climate as a higher order factor comprised of more specific first order factors. Higher order factor concerns the extent to which employees believe that safety is valued within organization. First order factors reflect perceptions of safety related policies, procedures and rewards	Safety climate as a higher order factor comprised of more specific first order factors. Higher order factor concerns the extent to which employees believe that safety is valued within organization. First order factors reflect perceptions of safety related policies, procedures and rewards
	Supervisor safety response (SSR)	Group safety climate: priority of safety versus competing goals		
	Coworkers' safety response (CSR)			
	Workers safety response (WSR)			
Dimensions and items	OSR (the presence of safety structures, fulfilment of safety rules, safety inspections, safety training and information, safety meetings, promotional campaigns, safety incentives and sanctions: 10 items); SSR (8 items), CSR (8 items) and WSR (7 items) (providing models of safe or unsafe behaviour through their own safe or unsafe behaviour, reactions to the safe or unsafe behaviour of the worker, active encouragement of safety)	Organizational safety climate (16 items): active management practices, proactive practices, declarative action	Griffin and Neal (2008): manager values (4 items), safety communication (4 items), safety systems (3 items), safety training (4 items)	Organizational Safety Climate scale combines items from Zohar and Luria scale (2005) and from Griffin and Neal scale (2008); 4 dimensions: manager values, safety communication, safety systems, safety training. Supervisor's Safety Climate scale adapts group safety climate scale of Zohar and Luria scale (2005); 4 dimensions: supervisor values, safety communication, safety systems, safety coaching; Coworkers'

Table 1 continued

Topic	Compared studies with different approaches in measuring safety climate			
	Melià (1998, 2002); Melià and Sesè (2007); Melià et al. (2008)	Zohar (2000); Zohar and Tenne-Gazit (2008); Zohar and Luria (2005)	Griffin and Neal (2000, 2008); Neal and Griffin (2004)	Present study
				Safety Climate scale is inspired by group safety climate scale of Zohar and Luria scale (2005) and by coworkers response scale of Melià et al. (2008); 4 dimensions: coworkers values, safety communication, safety systems, safety mentoring
		Group safety climate (16 items): active practices, proactive practices, declarative action		
Data analysis	Unilevel statistical analyses	Multilevel statistical analyses	Unilevel statistical analyses	Multilevel statistical analyses
Structure	Supervisor response (Melià and Sesè 2007: identification of two first order factors (supervisors' response toward workers' safety behaviour and supervisors' selfapplied safety response) or one first order factor by confirmatory factor analysis	Org. SC: Identification of three factors (MonitoringEnforcement, LearningDevelopment, DeclaringInforming) or one global factor by EFA; Group SC: Identification of three factors (Active practices (MonitoringControlling), Proactive practices (InstructingGuiding), Declarative practices (DeclaringInforming)) or one global factor by EFA	Identification of One second order global factor and four first order factors or four first order factors with covariances between them by confirmatory factor analysis (Griffin and Neal 2000)	Identification of One second order global factor and four first order factors or four first order factors with covariances between them by confirmatory factor analysis (Griffin and Neal 2000)
Contributes for the present study	Attention to select items which allow to analyse different agents' safety responses	Attention to select items which concerns properly to safety climate	Attention to identify safety climate specific dimensions and safety climate factor structure	

Table 1 continued

Topic	Compared studies with different approaches in measuring safety climate			
	Melià (1998, 2002); Melià and Sesè (2007); Melià et al. (2008)	Zohar (2000); Zohar and Tenne-Gazit (2008); Zohar and Luria (2005)	Griffin and Neal (2000, 2008); Neal and Griffin (2004)	Present study
	Analysis of safety climate statements from the point of view of the agent that performs or is responsible for the safety activity or issue involved (organization, supervisors, coworkers, workers)	Multilevel statistical analyses of safety climate		

1.2 The factorial structure of safety climate

Another important issue concerning safety climate scales is their factorial structure. In the present study safety climate is considered as having a hierarchical structure—within psychological, group and organizational levels (e.g. James and James 1989)—in which a singular, higher order factor is comprised of more specific first order factors (Griffin and Neal 2000).

In the literature there is not clear agreement about safety climate structure especially about the specific first order factors (dimensions) involved by the second order factor. The meta-analytic work of Christian et al. (2009) demonstrates the success of Neal and Griffin safety climate modelling work, and many other scholars (e.g. Zacharatos et al. 2005; Probst and Estrada 2010; Zohar and Luria 2005; Zohar 2008; Dal Corso 2008) refer to the Neal and Griffin factor analytic and path modelling research (Griffin and Neal 2000; Neal and Griffin 2004) to examine specific facets of safety climate.

Griffin and Neal (2000) affirmed that the first order factors of safety climate should reflect perceptions of safety related policies, procedures and practices, and the higher order factor should reflect the extent to which employees believe that safety is valued within the organization. Later Griffin and Neal (2000) identified four first order factors: Management Values, which concern the degree to which managers valued safety in the workplace; Safety Inspections, which refer to the effectiveness of safety systems in the organization; Safety Communication, which is about the way in which safety issues were communicated; Safety Training which refers to the quality and quantity of the employees' opportunities to be trained. In later studies of Neal and Griffin the factor "Safety Inspections" was generalized to "Safety Systems". The present study, as shown in Table 1, adopted this safety climate structure.

As in other areas of organizational assessment, it is important to determine whether a specific first-order factors or a global higher-order factor is more appropriate according to its purposes (Hogan and Roberts 1996). For some purposes, such as determining the overall impact of safety climate on safety outcomes, a higher order factor of safety climate will be most appropriate. For other purposes, such as determining the impact of distinct organizational practices on task performance, the use of specific first-order climate factors will provide more detailed diagnostic information. In the present work, a system of safety climate scales is developed, trying to satisfy both purposes.

1.3 Safety agents

In the same way, it is important to analyse each safety climate statement from the point of view of the agent that performs or is responsible for the safety activity (see Table 1). In the nineties, a structured multilevel view of safety climate was introduced, based on the identification of the agent responsible for each safety climate statement (e.g. Melià 1998; Melià and Sesè 2007; Melià et al. 2008).

Zohar (2000, Zohar and Luria 2005) split safety climate into two scales: one for organizational level climate and one for group level climate. Organizational level climate indicators refer to issues such as financial expenditure on safety devices and personnel decisions based on safety criteria. Concerning organizational level indicators, the use of "competitive" items (e.g. safety vs. speed) is an important aspect to consider (Zohar 2008). The main agent of organizational level climate is the top management. Group-level indicators, however, refer to issues such as supervisory monitoring and rewarding practices, individualized coaching of group members, and willingness to interrupt production to correct safety hazards. The main agent of group level climate is the supervisor of the group. Supervisor discretion depends on a number of issues such as the presence of competing operational demands, and the fact that procedures rarely cover all the situations. Workers, as members at the same time of units and of the entire organization, perceive signals both from top management regarding policies and from their group supervisor regarding how these policies are implemented in their department.

Recently, Melià and Becerril (2006), in a review of the safety climate literature, organized safety climate dimensions into a comprehensive schema from the point of view of the "agents" of the safety climate actions or omissions. Four main agents, i.e. the subjects that perform or are responsible for each safety issue inside the company, have been identified: the company, i.e. the top management, supervisors, co-workers, and the worker who answers the safety climate questionnaire. Top management and supervisor's role were deeply explored (e.g. Zohar 2000, Zohar and Luria 2005; Clarke 2006; Allen et al. 2010). At the moment the role of co-workers has been explored regarding different facets: co-workers' support (e.g. Chiaburu and Harrison 2008; Burt et al. 2008); social norms (e.g. Hahn and Murphy 2008; Fugas et al. 2009; Kath et al. 2010); co-workers' practices (e.g. Singer et al. 2007; Melià 1998; Melià and Becerril 2006; Melià et al. 2008; Jiang et al. 2009), co-workers' interaction (e.g. Cavazza and Serpe 2009; Zohar and Tenne-Gazit 2008; Zohar 2010); and also regarding a more generalized block as co-workers' safety (e.g. Gyekye and Salminen 2009; Morrow et al. 2010). Almost always these studies considered the set of items about co-workers as a dimension of a whole safety climate scale.

Following Zohar (2010), the present study tries to discern what set of items can be considered a dimension of a safety climate scale and what cannot. Departing from Melià research (Melià 1998, 2002, 2004, 2006; Melià and Sesè 2007; Melià and Becerril 2006; Melià et al. 2008), it will be explored the alternative for the co-workers' safety climate scale. This scale has been thought with a second order factor, which reflects the extent to which employees believe that safety is valued within the co-workers, and four first order factors of safety climate, which reflect perceptions of safety related to co-workers' values, support, practices and interactions with peer about safety.

1.4 Statistical methods

Another issue related to safety climate concerns the statistical methods used in safety climate studies (Shannon and Norman 2009; Zohar 2010). The object of measurement is typically the work group or the company. Because the workers within each group are rating the same object, there is inherent correlation in their scores—the data has a multi-level nature, and this must be considered in determining the factor structure. Hofmann and Stetzer (1996) found that safety climate varied by supervisor group, i.e., the variability between supervisor groups was substantially greater than the variability within such groups. Zohar and Luria (2005) and also other authors (e.g. Huang et al. 2007) suggested a multi-level model of safety. They distinguished responses of workers to questions that capture safety climate at the organizational level from items to capture it at the group level, since the discretion of supervisors of each work group might put into operation management policies differently.

On the basis of all these arguments and combining different approaches to safety climate (see Table 1) the present work identified a questionnaire with three safety climate scales (organizational, supervisor's and co-workers' scales) and for each scale, using confirmatory factor analysis (CFA) and multilevel confirmatory factor analysis (MCFA), the factor structure was identified on a calibration sample, and confirmed on a validation sample. MCFA was performed, to check if the factorial structure identified with CFA was confirmed also considering the multilevel nature of safety climate data.

Considering all these open issues, the main purpose of the present paper is to offer a valid questionnaire which combines different approaches to safety climate, therefore contributing for an advance, theoretical and methodological, for safety climate literature. This questionnaire is addressed to a specific industrial sector, in particular metal-mechanical sector, and to a specific kind of workers, blue-collar workers, with the aim also to offer an adequate setting specific diagnostic instrument for safety climate.

2 Method

2.1 Participants

The present study involved 8 companies, in the metal-mechanical sector, taking into account the main areas of this sector (fabrication of machinery, electrical devices and work vehicles), and data collection involved 1,617 blue-collars (the 80% of blue-collars of these companies), organized in 159 work-groups. From a geographical point of view, attention was focused on a specific zone, the region of Veneto in north east of Italy, a region with a high rate of accidents on workplace and with a high productive reality, particularly in the metal-mechanical sector, which is one of the more relevant industrial sector of this region.

All data were collected at individual level. Considering the whole sample, 84% of the participants were male; 83% were Italian workers; 85% had an educational level from 5 to 13 years of school; only 5% of the participants worked in the company from less than 1 year, and 68% worked for the same company from 5 years or more; 70% of participants had a permanent contract.

The sample was divided in two parts: 7 companies (1185 workers, 118 work-groups) have been used as a calibration sample, to find out the best models, which have been after validated and one big company (432 workers, 41 work-groups), has been used as a validation sample.

2.2 Measure instruments

2.2.1 Safety climate scales development

The first step concerned the identification of the items of the safety climate scales. Referring to some instruments described in the literature (e.g. Zohar and Luria 2005; Griffin and Neal 2000; Zohar 2008; Melià 1998; Melià and Sesè 2007), and choosing items considering specific aspects of companies and work-groups, given from interviews with members of the Safety Commissions of the companies, three initial scales were developed: organizational safety climate scale (OSC scale, 18 items), supervisor safety climate scale (SSC scale; 16 items), and co-worker safety climate scale (CSC scale; 16 items), for a total number of 50 items. Also usability of the instrument by all the stakeholders (top management, supervisors, safety officer, safety commission and unions) was taken into account. Furthermore, it was also considered the final instrument answer duration in order to achieve a more efficient solution. Each item of the three scales was connected to one of the four dimensions considered by Griffin and Neal (2000; 2008): Values, Safety Systems, Communication, and Training. The items of OSC scale were developed merging items from Zohar and Luria (2005) organizational scale and items from Griffin and Neal (2000; 2008) scale. Given item redundancy, three judges independently selected items and matched them to the four dimensions. They coded the items in the same way with the exception of three items. They assigned unanimously these three items after discussing about them together. The first version of SSC scale adopted the group level safety climate scale of Zohar and Luria (2005). The dimension of Training was changed into Coaching, which was more suitable to supervisor role. This dimension refers to supervisor activities concerning supervisor support to worker safety behaviours (i.e. rewards, activities to increase workers safety motivation and knowledge). Three judges independently matched the items to the four dimensions, and the attribution of one item turned out to be ambiguous, but after a short discussion it was unanimously assigned.

The items of the first version of CSC scale were derived from the adjustment to co-workers of the group level safety climate scale of Zohar and Luria (2005), and comparing the resulted items content with other co-workers safety climate scales (e.g. Fugas et al. 2009; Singer et al. 2007; Melià 1998; Melià and Becerril 2006; Melià et al. 2008; Jiang et al. 2009). The Griffin and Neal's dimension of 'Training' was changed into 'Mentoring', which was more suitable to the co-workers' role (Ensher et al. 2001). This dimension refers to co-workers' activities oriented to support colleagues to improve their safety behaviour (i.e. giving them suggestions, calling attention to safety). The same three judges independently matched the items against the four dimensions, and only the attribution of two items first resulted ambiguous, but they were unanimously assigned after discussing together.

These three scales were tested in a pilot study, to discover weak points, and were improved thanks to a qualitative technique, namely cognitive interview (Willis 2005). In particular, the method of Verbal Probing was used. Considering that study participants were workers from different cultures, sometimes with difficulties in language comprehension and/or production, and in some cases with a very low school level, it was necessary to remove sentence and term ambiguities, and to be sure that each participant comprehends the meaning (Jobe 2003).

In detail, the first version of the questionnaire with the three scales was given to a first sample of 22 workers of the metal-mechanical sector, with two tasks: the first task was to answer the 50 items on a response 7-point Likert scale (from 1 = "never" to 7 = "always"); the second task was to judge comprehensibility of each item on a 5-point Likert scale (from 1 = "extremely easy to understand" to 5 = "extremely difficult to understand"). Items that were judged difficult to understand were submitted to a second sample of 15 workers, with the "cognitive interview" technique (Willis 2005). This technique explicitly focuses on the cognitive processes that respondents use to answer survey questions; therefore, uncovers processes that are normally hidden, and these observations permit not only to improve comprehensibility, but even to improve construct validity. In the present study the method of Verbal Probing was applied using the 6 basic probes categories identified by Willis (2005) (namely, comprehension/interpretation probe, paraphrasing, confidence judgement, recall probe, specific probe and general probes). After these interviews, a second version of the questionnaire was made, and a third sample of 25 workers gave new comprehensibility judgements on each item; all the items were judged easy or very easy to understand.

This second version was then submitted to a new sample of 113 metal-mechanical workers, and exploratory factor analyses (EFAs) were conducted to explore the factor structure of each scale, and to decide the final instrument (Bagozzi and Edwards 1998).

2.2.2 The final Safety Climate Questionnaire

At the end of this process, the Safety Climate Questionnaire consisted of three scales with a total number of 41 items. Each item of the three scales was connected to one of four domains: Values, Safety Systems, Communication, and Training/Coaching/Mentoring. In details, the three scales were the following: OSC scale (Management Safety Values: 4 items, Safety Systems: 5 items; Safety Communication: 4 items; Safety Training: 4 items, total number of items: 17), in which the target of the safety climate judgement given by the worker was the entire organization; SSC scale (Supervisor's Safety Values: 3 items, Safety Systems: 3 items, Safety Communication: 3 items, Safety Coaching: 3 items, total number of items: 12), in which the workers had to judge their direct supervisor in the work-group; and CSC scale (Co-workers' Safety Values: 3 items, Safety Systems: 3 items, Safety Communication: 3 items, Safety Mentoring: 3 items, total number of items: 12), in which the workers gave their judgements explicitly considering their co-workers inside the work-group. Participants were asked about the extent to which their organization, or their direct supervisor, or their co-workers in the work-group showed to consider safety of workers to be really important.

For each scale, Values sub-scale consisted of items related to the real importance given to safety by management (supervisor/co-workers), for instance: "Top management considers safety when setting production speed and schedules". Safety System sub-scale consisted of items related to the importance that management (supervisor/co-workers) assigns to the safety procedures, practices and equipment connected to safety at work (e.g.: "Top management provides all the equipment needed to do the job safely"). The third factor, Communication, consisted of items related to the quality of communication processes concerning safety issues, as in the item: "Top management listens carefully to workers' ideas about improving safety". Training sub-scale considered the importance that management places on safety training, as in the item: "Employees receive comprehensive training in workplace health and safety issues". This factor was called Coaching in the SSC scale (e.g. "My direct supervisor uses explanations to get us to act safely") and Mentoring in the CSC scale (e.g. "If it is necessary, my team members use explanations to get other team members to act safely").

Responses were given on a 7-point Likert scale, from 1 = "never" to 7 = "always".

At the end of the questionnaire there were also two questions about injuries involvements: number of injuries since the participant has entered the company, and number of micro-accidents in the previous 6 months. Responses were given in absolute number, but were then codified in three classes: 0, 1, more than 1. Also some socio-demographic questions were collected, in particular gender, age, educational level, nationality, length of employment in the company, kind of job-contract, department, work shift at the moment of the survey.

2.3 Procedure

Few days before the questionnaire was administered, either during an ad hoc meeting organized by the top management with unions, the Safety Commission and the safety officer, or during a trade-union meeting, workers were told that they were part of a larger sample of workers involved in a research study, and received information about the research program. Participants were told that the questionnaire was anonymous, and that all data were collected and conserved by the research group. They were also ensured that only aggregate results would be given to the management of the company.

All participants answered the questionnaire during working hours, at the end or at the beginning of their work shift, and were asked to answer as sincerely as possible. At the end of the questionnaire participants had to answer questions about their involvement in injuries and to some socio-demographic questions. Along with the Italian version, English and French versions were also provided for foreign workers. Researchers were available during all time, to help participants, if necessary. All the procedure took about 15 min.

2.4 Data analysis

To test construct validity, confirmatory factor analysis (CFA) and multilevel confirmatory factor analysis (MCFA) were performed. While CFA at a single level of analysis uses the total variance–covariance matrix of the observed variables, MCFA decomposes the total sample covariance matrix into pooled within-group and between-group covariance matrices and uses these two matrices in the analyses of the factor structure at each level. With MCFA it is possible to evaluate a variety of models including those that have the same number of factors and loadings at each level, those that have the same number of factors but different loadings at each level, and those that have a different number of factors at the two levels.

Muthen (1994) suggested that MCFA had to be preceded by four important analysis steps: (1) conventional confirmatory factor analysis on the sample total covariance matrix S_T, (2) estimate between-group level variation, (3) estimation of within structure with confirmatory factor analysis on the sample pooled-within covariance matrix S_{pw}, and (4) estimation of between structure with confirmatory factor analysis on the sample between-group covariance matrix S_b.

Step 1 Conventional confirmatory factor analysis on the sample total covariance matrix S_T. This step is useful to test different model structures identified in the literature and see which could be more adequate. It is important to remember that the parameters estimates and fit indexes resulting from this step models may be biased when data is multilevel due to the correlated observations, when group sizes are large or when within factor structure is different from between factor structure. Muthen underlined that in any case the test of fit may help the researcher giving an idea of fit.

Step 2 Estimate between-group level variation. This step helps to understand whether a multilevel analysis is appropriate for the considered data. Before estimate between-group level variation, in the present study some preliminary operations were conducted. First the group size of each group considered was checked. Each group were composed of workers of the same department, of the same shift and with the same supervisor. Groups with less than 4 members were eliminated from the sample. Then homogeneity of climate perceptions was assessed with $r_{wg(j)}$ (Bliese 2000), deleting groups with $r_{wg(j)}$ lower than critical values identified by Dunlap et al. (2003). The variability between groups on each item was examined by computing the intraclass correlation (ICC) for each item of the three scales. Muthen (1994) suggested to estimate a unique type of ICC to determine potential group influence. Muthen's ICC index is conceptually similar to ICC(1). The difference between the two indexes is that Muthen's ICC is obtained by random effects ANOVA, while ICC(1) is obtained by fixed effects ANOVA. ICC ranges in value from 0 to 1. If values are close to zero (e.g. .05) the multilevel modelling will be meaningless (Dyer et al. 2005).

Step 3 Perform a factor analysis on the sample pooled-within covariance matrix (S_{pw}). S_{pw} matrix is an estimator of the population within-group covariance matrix, and its values reflect the factor structure at the within-group level. When the model estimated using the S_{pw} matrix shows better fit that those of the model estimated using S_T this means that the factor structure differs at the between and at the within level, or that the construct-relevant variance is primarily at the within-group level. It concerns estimates of individual-level parameters only. As Muthen (1994) affirmed, estimates from S_{pw} model usually are close to the within parameters of the MCFA. This analysis is the preferred way to explore construct variance at the individual level.

Step 4 Estimation of between structure with confirmatory factor analysis on the sample between covariance matrix S_b. In this step the adequacy of the between-group factor structure is studied. In the present study this matrix is calculated with MPLUS, but it could be created also with conventional software. S_b is the covariance matrix of observed group means, corrected for the grand mean. This correction is obtained multiplying the elements of the matrix by the typical divisor for the covariance matrix $(N - 1)$ and then dividing the appropriate divisor $(G - 1$, where G is the number of groups). S_b reflects the between-group population covariance matrix (Dyer et al. 2005). However it is not an unbiased estimator because, for example, it is also a function of the within covariance matrix (Muthen 1994). When the purposed factor structure is not found using the S_b matrix, an exploratory factor analysis could be performed to find alternative factor structure.

For this study, at the end of these four steps, a multilevel confirmatory factor analysis was conducted, testing the alternative models identified in the previous steps. Two levels were considered: group level and individual level. The organizational level was not considered because of the small number of companies which are considered in the study. Therefore, in the multilevel analyses of this research, when perceptions on organizational safety climate are considered, the reader should refer to group perceptions about the organizational safety climate.

For CFA and MCFA, Chi-square values and delta Chi-square values between competitive models are reported. Goodness of fit of the models was evaluated also using the Tucker Lewis Index (TLI; Bentler and Bonett 1980), the Comparative Fit Index (CFI; Bentler 1990), the Root Mean Square Error of Approximation (RMSEA; Hu and Bentler 1999), the Standardized Root Mean Square Residual (SRMR). Also GFI and AGFI, that are common indexes in many SEM packages, are reported, even if they are affected by sample size and can be large for models that are poorly specified, and the current consensus is not to use these measures (Kenny 2010 http://davidakenny.net/cm/fit.htm). Values close to .95 reflects a good fit. Akaike Information Criterion (AIC; Akaike 1974), Bayesian Information Criterion (BIC; Schwarz 1978) and Expected Cross-Validation Index (ECVI; Browne and Cudeck 1989, 1993) were considered to compare different models.

To test reliability, the most popular coefficient is Cronbach's α, but its use with multidimensional measures is limited (Raykov 1998; Raykov and Shrout 2002). In the present study the scales are presumed to be multidimensional, with the scale score representing the underlying factors. In this case it's better to use construct reliability (the degree to which the scale indicators reflect an underlying factor), and average variance extracted (AVE, the average percentage of variation explained among the items) (Hair et al. 1998; Fornell and Larker 1981).

All statistical analyses were performed using R Statistical Package (free software available through www.R-project.org), and MPLUS Version 5.1 (Muthen and Muthen 1998–2008) for multilevel confirmatory factor analysis (MCFA).

3 Results

3.1 Descriptive statistics

Considering one of the three scales at a time, all cases with missing values were removed, because it was considered more correct, from a psychometric point of view, to perform the analyses using a sample without any estimation of missing values. To be sure that this choice did not invalidate our sample, examination of missing values considering the socio-demographic characteristics was made, using Chi-square test.

At the end of this process, for each item means and standard deviations were computed, and items were also checked for normal distribution, computing skewness and kurtosis and considering normally distributed all the items with values into the range $-1/+1$.

3.1.1 Organizational safety climate scale

Two hundred and seven cases were removed for this scale (13% of the whole sample), because of missing values, and the magnitude of the final sample was of 1,410 workers. Looking at the distribution of these missing values considering socio-demographic characteristics of the sample, differences among groups were not strong. Male and female participants had the same proportion of missing values, and no differences were found also among different groups of workers considering the number of years of work experience in the company. There were no differences among age groups except the 25–36 age group, which has a less number of missing values ($p < .01$). Educational level showed an effect on missing values ($p < .001$): Workers with less than 5 years of school showed the 28% of missing values, but it is important to remember that only 76 workers (on 1,617) fell in this category. Some significant differences were found for other two socio-demographic characteristics: nationality and kind of contract. For this last characteristic, considering only the two main categories, i.e. workers with a permanent contract and workers with a fixed-time contract, the last ones had more missing values (19%, $p < .01$). In the matter of nationality, foreign workers had more missing values (22%, $p < .001$); also for nationality is important to notice that foreign workers were only 17% of the whole sample (268).

For the 1,410 workers without missing values on the organizational safety climate scale, means ranged from 5.54 (SD = 1.63), on the item related to the supply of the equipment needed to do the job safely, to 3.29 (SD = 1.73) on the item concerning whether top management considers a person's safety behaviour when moving–promoting people. Responses were approximately normally distributed, with skewness ranging from $-.87$ to .59 and kurtosis values ranging from -1.08 to $-.33$, indicating a relatively flat distribution. The few values of kurtosis may not be considered as problematic for normality, since the mean of kurtosis values ($|M| = .85$) is less than 1 (Muthén and Kaplan 1985).

3.1.2 Supervisor safety climate scale

For this scale, only 77 cases over 1,617 were removed (5% of the whole sample). No differences in missing distribution were found considering gender, age, educational level, number of years of work experience in the company, kind of contract. Only nationality showed a significant effect on missing values (13% for foreign workers, 3% for Italian workers, $p < .001$); foreign workers, however, as said above, were only the 17% of the whole sample. These results confirmed that removing these cases had no effects on the composition of the original sample.

Considering the 1,540 workers without missing values, the item with the lower mean value (2.97, SD 1.96) was the one that take into consideration the possibility that the direct supervisor praise the qualities of workers who pay special attention to safety, where the higher mean value (4.33, SD 1.99) was found for the item stating that direct supervisor is strict about safety rules also when work falls behind schedule. There was a light positive skewness but all values fell inside the range $-1/+1$ (range from $-.02$ to .80). Concerning kurtosis values, all items had negative values, from −.59 to −1.33, which indicates a distribution more flat than a normal one; for 8 items kurtosis were higher than 1 in absolute value. In this case also the mean of kurtosis values (|M| = 1.08) is lightly over 1. This means that responses to all items in the supervisor safety climate scale were symmetrical, but not completely normally distributed.

3.1.3 Co-workers safety climate scale

Only 36 workers had missing values on this third scale (2% of the sample). No effects of socio-demographic characteristics were found on missing values, except for educational level, because workers who attended school for less than 5 years showed a higher number of missing values (8%, $p < .01$), and for nationality: missing values were 6% for foreign workers, and 1,5% for Italian ones. The number of these two socio-demographic categories (foreign workers and workers with very low educational level) were not high, and for this reason the removal of these 36 cases did not modify the characteristics of the sample.

Means and standard deviations were computed on the 1,581 workers without missing values. Means ranged from 3.08 (SD 1.72) for the item concerning the possibility that team members speak on safety during the week, to 3.76 (SD 1.89) for the item about the care of peers safety awareness showed by team members. The results showed a very short range of mean responses to the item on co-workers concentrated on the middle of the Likert scale. All items of this scale were normally distributed, with skewness ranging from .25 to .71 and kurtosis ranging from −1 (one item) to −.37. The mean of kurtosis values (|M| = .70) is less than 1.

3.2 Construct validity and reliability evaluation

To test construct validity in multilevel confirmatory factor analysis the five steps described above, from the CFA to the final MCFA, were performed. Table 2 shows models' fit indexes, step by step, for the chosen final models for each scale, tested in the CFA—computed on the total covariance matrix first, and then at the within and at the between level—and finally in the MCFA.

At the end of the process described below, the final version of the Integrated Organizational Safety Climate Questionnaire has been produced; a short item description is shown in Appendix.

3.2.1 Step 1: CFA

A CFA with maximum likelihood estimation is used with each scale to examine the four-factor model underlying the safety climate scales. Initially, four different models were tested for each of the three scales, as suggested by several authors (e.g. Byrne 2001; Kline 1998). The first model (Model 1) consisted in a one-factor model, in which each item was predicted by a unique factor (i.e. "safety climate", SC). The second model (Model 2) consisted of a four-factors model, without covariances among the four latent factors; the four latent constructs were the four domains: Values (Va), Safety Systems (SS), Communication (Co), and Training/Coaching/ Mentoring (Tr/Coa/Me). Given that this model had very bad fit indexes for all the three scales, in this report it has never been considered for a comparative evaluation. Then, a four-factor model with covariances among the latent variables (Model 3) was tested. The last model was tested with a second-order CFA, with four latent variable at the first-order level (without covariances), each connected with one latent variable at the second-order level

Table 2 Fit indexes for the final chosen models tested in the CFA and the MCFA, for the three scales

Scale	Model	Model description	Number of items	χ^2	df	TLI	CFI	RMSEA (C.I)	SRMR
OSC	Step 1 (total)	One second-order factor and four first-order factor model	12	378.05	50	.940	.954	.080 (.073–.088)	.033
	Step 3 (within)	One second-order factor and four first-order factor model	12	388.02	51	.918	.936	.086 (.078–.094)	.042
	Step 4 (between)-first model	One second-order factor and four first-order factor model	12	17148.16	51	.458	.548	.59 (.59–.60)	.046
	Step 5 (multilevel)	One second-order factor and four first-order factor model (w&b)	12	440.8	106	.916	.932	.059	.040w .078b
SSC	Step 1 (total)	One second-order factor and two first-order factor model	10	307.83	34	.964	.972	.085 (.076–.093)	.026
	Step 3 (within)	One second-order factor and two first-order factor model	10	207.95	34	.968	.957	.084 (.076–.096)	.030
	Step 4 (between)-first model	Two-factor model with covariances	10	12647.06	34	.504	.622	.719 (.71–.73)	.028
	Step 5 (multilevel)	Two-factor model (w); one second-order factor and two first-order factor model (b)	10	244.79	70	.966	.975	.059	.031w .032b

Table 2 continued

Scale	Model	Model description	Number of items	χ^2	df	TLI	CFI	RMSEA (C.I)	SRMR
CSC	Step 1 (total)	One second-order factor and four first-order factor model	12	480.82	50	.95	.96	.086 (.079–.094)	.031
	Step 3 (within)	One second-order factor and four first-order factor model	12	307	51	.95	.96	.077 (.068–.085)	.040
	Step 4 (between)	One second-order factor and four first-order factor model	12	20152.39	54	.430	.533	.660 (.65–.67)	.035
	Step 5 (multilevel)	One second-order factor and four first-order factors (w); four-factor model (b)	12	244.79	70	.966	.975	.059	.031w .032b

(Model 4), named "safety climate". If none of the four models showed good fit indexes, other alternative models were explored, according to theoretical issues. In this first step sample was split in the calibration sample, to find the best models, and in the validation sample, to verify the goodness of the models with a dataset never used before.

Organizational safety climate scale: The first CFA considered the organizational level. Model 3, the one with four latent variables and covariances among them, could not be considered because the latent variable covariance matrix was not positive definite, and some of correlations between latent variables were greater than one. Nor Model 1, the one with one single factor, neither Model 4, the one with one second-order factor and four first-order factors showed good fit indexes (Mod 1: TLI = .91; CFI = .92; SRMR = .043; RMSEA = .087; Mod 2: TLI = .91; CFI = .92; SRMR = .042; RMSEA = .086; so it has been decided to test a new model, more parsimonious, removing some items from each sub-scale. In Model 5 three items acted as indicators of each of the four latent variables, for a total number of 12 items in the new version of the OSC scale. This model showed a better fit based on Chi-square value ($\Delta\chi^2_{(68,\mathrm{N}=1019)} = 654.7$, $p < .001$), and on AIC, BIC and ECVI measures. All the other fit indexes were good (TLI = .95; CFI = .96; SRMR = .031; RMSEA = .076). Finally, a higher order factor analysis was conducted, using the same 12 items, with the four first-order safety climate factors acting as indicators of one higher order organizational safety climate factor. This model showed a good fit to the data (TLI = .94; CFI = .95; SRMR = .033; RMSEA = .080, see also Table 2, OSC, Step 1), although there was a significant decrease in the fit measures of this model, compared with the previous model in which the four first-order factors were free to correlate ($\Delta\chi^2_{(2;\mathrm{N}=1019)} = 46.84$, $p < .001$; higher AIC, BIC and ECVI measures). Correlation between the original version of the scale (the one with 17 items) and this new short version (12 items) was very high and (r = .99, $p < .001$). To verify whether a one-factor model with the same 12 items showed better fit measures, Model 7 was tested. All fit indexes were worse, though acceptable. Standardized factor loadings for Model 6 were high, ranging from .68 to .98.

In conclusion, a model with four correlated factors (Values, Safety Systems, Communication, and Training) was the best one—after removing 5 items to obtain better fit indexes, but the model with one second-order factor comprised of four more specific first-order factors was also plausible. The factors composite reliability coefficients of the four-factor covariance model and of the second-order factor model were in both cases above the threshold value for acceptable reliability: For the four correlated factor model, construct reliability and variance extracted (AVE) were: Values (.81; AVE .59), Safety System (.78; AVE .54), Safety Communication (.79; AVE .56) and Training (.82; AVE .60); for the second-order factor model construct reliability and variance extracted were: Values (.81; AVE .59), Safety System (.78; AVE .54), Safety Communication (.79; AVE .56) and Training (.82; AVE .60).

The factorial structure of the second-order factor model identified on the calibration sample was tested on the validation sample. The goodness of the factorial structure was confirmed: all factor loadings were statistically significant and adequate (all greater than .65 on a standardized solution); fit indexes were acceptable (TLI = .94; CFI = .95); the obtained factors composite reliability was above the threshold value: Communication .76, Training .81, Safety System .81 and Values .81. The average variance extracted for each factor was also acceptable: Communication .51, Training .59, Safety System .58 and Values .59.

Supervisor's safety climate scale: The second group of CFA was performed on the scale in which workers had to evaluate their direct department supervisor. SSC scale reflects the extent to which employees believe that safety is important for their direct supervisor. In this scale, as in the OSC scale, the 12 items could be grouped in four factors (Values, Safety Systems, Communication, and Coaching).

The one-factor model (Model 1) did not show good fit indexes, especially RMSEA (TLI = .95; CFI = .93; SRMR = .031; RMSEA = .121), as well as Model 3—the one with four factors free to correlate—even if better than Model 1 ($\Delta\chi^2_{(6;N=1226)} = 27.47$, $p < .001$; TLI = .93; CFI = .95; SRMR = .031; RMSEA = .108). Model 4 (with one second-order factor and four first-order factors) was worse than the previous one, though still better than Model 1, and RSMEA was not acceptable at all (RMSEA = .115). Looking at estimates of correlations among the four latent variables, it was clear that Values and Safety Systems were very highly correlated, and Communication and Coaching were very highly correlated too. For this reason, in order to find a model that better fits the observed data, a two-factor model with covariances among the two factors was tested, merging Values and Safety Systems on one side, and Communication and Coaching on the other side (Model 5). This model was not good either, and, therefore, two items were removed from the original 12-item scale, one from the original Communication sub-scale, and one from the original Coaching sub-scale. The two-factor model based on 10 items (Model 6) showed good indexes ($\Delta\chi^2_{(19;N=1226)} = 438.26$, $p < .001$; TLI = .96; CFI = .97; SRMR = .026; RMSEA = .085). The same good fit measures were showed on Model 7, considering the same 10 items, with two first-order safety climate factors acting as indicators of one higher order supervisor safety climate factor (fit indexes for this model are shown in Table 2, SSC, Step 1). To verify whether a one-factor model with the same 10 items showed a better fit, Model 8 was tested, but all fit indexes were worse.

In conclusion, the four-factor structure of the SSC scale was not confirmed by the CFA. The purposed model with two correlated factors, and the one with a singular second-order factor and two more specific first-order factors seems to be the most plausible ones. Correlation between the original scale with 12 items and the second with 10 items was very high (r = .996, $p < .001$). Model with two correlated factors and second-order factor model had the same construct reliability and variance extracted (AVE): Values-Safety Systems (.93; AVE .70), Coaching-Communication (.91; AVE .72).

The factorial structure of the second-order factor model identified on the calibration sample was tested on the validation sample. The factorial structure was confirmed: all factor loadings were statistically significant and adequate (all greater than .73 on a standardized solution); fit indexes were acceptable (TLI = .92; CFI = .94). RMSEA value was over the acceptable threshold (.08) however SRMR value (.05) indicated a good fit. The obtained factors composite reliability was above the critical threshold: Values-Safety System .92 and Communication-Coaching .90. The average variance extracted for each factor was also acceptable: Values-Safety System .67 and Communication-Coaching .70.

Co-workers' safety climate scale: The third CFA focused on co-workers as "agents" of the safety climate actions or omissions. Model 1, the one-factor model, showed good fit indexes, except RMSEA (TLI = .89; CFI = .91; SRMR = .043; RMSEA = .125). Model 3, the one with four latent variables and covariances among them, showed better fit indexes based on Chi-square value ($\Delta\chi^2_{(48,N=1154)} = 433.47$, $p < .001$) and on AIC, BIC and ECVI measures than Model 1. All the other fit indexes were good (TLI = .95; CFI = .96; SRMR = .029; RMSEA = .083). Model 4, the one with four first-order factors acting as indicators of one higher factor, just like the previous one, showed a good fit to the data (see Table 2, CSC, Step 1), although there was a little decrease in the fit of this model compared to the previous one, in which the four first-order factors were free to correlate ($\Delta\chi^2_{(50,N=1154)} = 480.82$, $p < .001$; higher AIC, BIC and ECVI measures). Factor loadings for Model 4 ranged from .74 to .96 on a standardized solution.

In conclusion, both Model 3 and Model 4 showed good fit to the data. As for the other scales, this equivalence between these two models, namely, one with covariances among factors and the other with a second-order factor, allows to choose the second-order factor structure to determine the overall impact of the safety climate agent's scale on safety outcomes, and to choose the other model to determine the impact of distinct agent practices on task performance.

The factors composite reliability coefficients of the four-factor covariance model and of the second-order factor model were above the threshold value for acceptable reliability. For the four-correlated factor model, construct reliability and variance extracted were: Values (.84; AVE .63), Safety System (.90; AVE .75), Safety Communication (.86; AVE .67) and Mentoring (.87; AVE .68). For the second-order factor model, construct reliability and variance extracted were: Values (.84; AVE .63), Safety System (.90; AVE .75), Safety Communication (.86; AVE .67) and Mentoring (.87; AVE .68).

Analysis on the validation sample confirmed also for CSC scale the factorial structure of the second-order factor model. All factor loadings were statistically significant and adequate (all greater than .74 on a standardized solution); fit indexes were acceptable (TLI = .94; CFI = .95; SRMR = .04; RSMEA = .096); the obtained factors composite reliability was above the threshold value (Communication: .83, Mentoring: .90, Safety Systems: .91, Values: .85). The average variance extracted for each factor resulted acceptable (Communication: .63, Mentoring: .74, Safety Systems: .77, Values: .65).

3.2.2 Step 2: estimate between-group level variation

Prior to conducting the MCFA, for each scale some preliminary analyses were done. First, work groups with less than four members and with $r_{wg(j)}$ less than critical values identified by Dunlap et al. (2003) were excluded from the analyses.

Then, ICC(1) for each of the observed items was computed, to verify the affection of group membership to individual level observation. For OSC scale, a sample of 896 workers in 77 work groups remained, with ICC(1) ranging from .13 to .21; the sample for SSC scale, after case exclusions, was composed of 718 workers in 53 work groups, with ICC(1) ranging from .22 to .35. The sample for CSC scale was composed of 855 workers in 65 work groups. ICC(1) ranged from .07 to .18 (for three items was under .10, but mean and median values were .12).

3.2.3 Steps 3 and 4: estimation of within and between structure with CFA

For each scale, the CFA model with the best fit identified in Step 1 was analysed on the sample pooled-within covariance matrix S_{pw} and on the between covariance matrix S_b. In Step 4 more models were tested because of the poor fit of factor structure identified in Step 1 CFA. Table 2 (Step 3 and Step 4) shows models' fit indexes for the final chosen models tested in the CFA performed at the within and at the between level.

Since factor loadings at Steps 3 and 4 were very close to those ones respectively at within-level and between-level MCFA, they are not reported in this section.

Organizational safety climate scale: As shown in Table 2 (OSC, Step 1 and Step 3), fit indexes at Step 3 are worse than fit indexes at Step 1. Dyer et al. (2005) explained it saying that this happens because Step 1 results on the total covariance matrix also had the contribution of systematic between-group relationships which was removed from Step 3 pooled-within covariance matrix. This underlines the importance of between-group level analysis. From a comparison between factor loadings of Steps 1 and 3, Step 3 parameters estimates were lower than those at Step 1, confirming the importance of between-group contribution. At Step 4 the workgroup-level factor structure was analysed. Because of the poor fit of second-order model identified at Step 1, the four-factor structure and the one-factor structure were also explored. For all these models fit indexes were very poor see Table 2, OSC, Step 4 for an example). This could depend on the fact that the proposed factor structures did not fit the data very well. However, as it will be shown in the next section, MCFA results seemed adequate, supporting the idea that the between-level factor structure was highly influenced by the within-level modelling. In the literature, however, no reference was found supporting this hypothesis.

Supervisor's safety climate scale: Fit indexes are good (see Table 2, SSC, Step 3). As for OSC scale, indexes were a little lower than ones for the same model estimated on the total covariance matrix. The same trend with lower values was also found for factor loadings, indicating the importance of between-level analysis. Many different factor structures were tested at Step 4 (e.g. two-factor structure, one second-order factor structure and one-factor structure), but, as for the previous scale, no one showed acceptable indexes (see Table 2, SSC, Step 4 for an example). The same hypothesis of explanation identified for OSC scale was supported also in this case.

Co-workers' safety climate scale: Fit indexes of CFA that resulted at Step 3 were very similar to the ones of Step 1 (see Table 2, CSC, Step 1 and Step 2). As for SSC, the model fit well. RMSEA value was a little high, but lower than RMSEA value at Step 1. Parameters estimates were lower than those at Step 1, showing the role of between-matrix contribution to improve model fit at the individual level. As for the previous scales, it seemed very difficult to identify an adequate structure for the between covariance matrix (Step 4). In this case, many factor structures were also tested (e.g. four-factor structure, one second-order factor structure and one-factor structure), but none produced acceptable indexes (see Table 2, CSC, Step 4 for an example).

3.2.4 Multilevel confirmatory factor analysis

In the present study, four multilevel measurement models for each scale, chosen after Step 3 and Step 4 analyses, were examined. The first model consisted of four factors (two for SSC scale) with covariations for individual-level and group-level, with item loadings freely estimated across levels. Model 2 consisted of one second order factor and four first-order factors (two for SSC scale) for each level, with item loadings freely estimated across levels. Model 3 consisted of four factors (two for SSC scale) with covariations for individual-level and one second order factor and four first-order factors (two for SSC scale) for group-level. Model 4 consisted of one second order factor and four first-order factors (two for SSC scale) for individual-level and four factors (two for SSC scale) with covariations for group-level. For OSC scale also another model was considered which consisted of one second order factor and four first-order factors at the individual-level and a one-factor model for the group-level. Table 3 shows fit indexes for the tested models, for each of the three scales.

Organizational safety climate scale: Table 3 (OSC) shows fit measures for all the two best tested models. Model 1 (four factors with covariances among them, at individual and group level), Model 3 (four factors with covariations at individual-level, and one second-order factor and four first-order factors at group-level) and Model 4 (one second-order factor and four first-order factors at individual-level, and four factors with covariations at group-level) could not be considered because the latent variable covariance matrix was not positive definite, and some correlations between latent variables were greater than one. Model 2, the model with one second order factor and four first-order factors for each level, showed acceptable fit indexes (TLI = .92; CFI = .93). Nevertheless, $SRMR_b$ was high (.078), showing that perhaps at the between level another factorial structure could be more appropriate. For this

Table 3 Fit indexes for some of the tested in the MCFA, for the three scales

Scale	Model	Model description	χ^2	df	$\Delta\chi^2$	df $\Delta\chi^2$	p value $\Delta\chi^2$	TLI	CFI	RMSEA	$SRMR_w$	$SRMR_b$	BIC	AIC	ECVI
OSC	Mod 2	One second-order model and four first-order factor model (w&b)	440.8	106	45.3	9	.000000	.92	.93	.059	.04	.078	36561	384.8	.43
	Mod 5	One second-order model and four first-factor model (w), one-factor model (b)	477.91	105	40.1	3	.000000	.91	.92	.063	.042	.054	36576	421.9	.47
SSC	Mod 1	Two-factor model with covariations among factors (w&b)	246.2	69	246.2	14	.000000	.96	.97	.06	.031	.030	23279	218.2	.304
	Mod 2	One second-order factor and two first-order factor model (w&b)	257.89	71	11.69	2	.002894	.95	.96	.060	.049	.032	23280	225.89	.315
	Mod 3	Two-factor model (w), one second-order factor and two first-order factors model (b)	244.79	70	13.1	1	.000295	.96	.97	.059	.031	.032	23273	230.2	.300
	Mod 4	One second-order factor and two first-order factor model (w), two-factor model (b)	260.2	70	15.41	0	–	.95	.96	.062	.049	.032	23286	230.2	.321

Table 3 continued

Scale	Model	Model description	χ^2	df	$\Delta\chi^2$	df $\Delta\chi^2$	p value $\Delta\chi^2$	TLI	CFI	RMSEA	$SRMR_w$	$SRMR_b$	BIC	AIC	ECVI
CSC	Mod 2	One second-order factor and four first-order factors (w&b)	365.99	106	55.7	8	.000000	.94	.95	.054	.031	.090	33310	309.99	.363
	Mod 3	Four factor model (w), one second-order factor and four first-order factor model (b)	344.86	104	21.13	2	.000026	.94	.96	.053	.031	.081	33313	318.86	.373
	Mod 4	One second-order factor and four first-order factor model (w), four-factor model (b)	336.72	104	8.14	0	–	.95	.96	.051	.035	.056	33289	284.72	.333

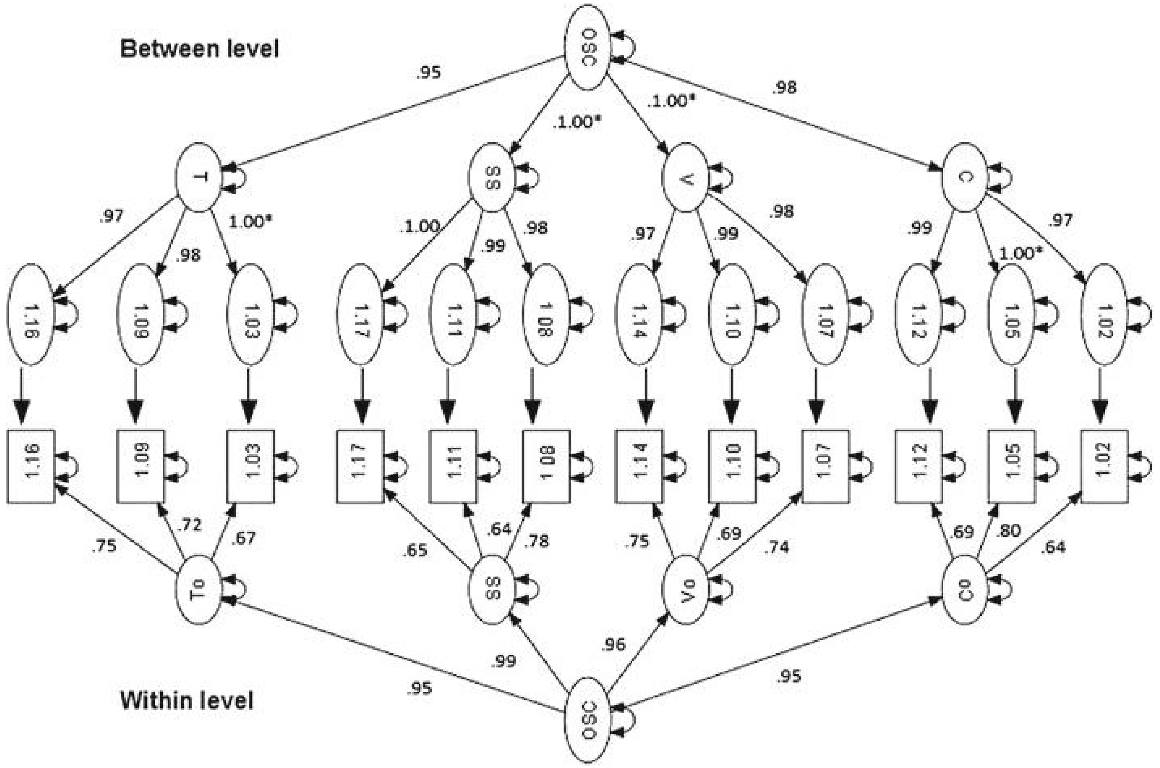

Fig. 1 Path diagram and standardized parameters estimates of the multilevel model for the organizational safety climate scale (Model 2). *OSC* organizational safety climate, *C* organizational safety communication, *T* organizational safety training, *SS* organizational safety systems, *V* organizational safety values. *At the between level residual variance of items 1.03 and 1.05 were fixed at .0001

reason, a model with one factor at the between level was tested (Model 5). Fit indexes were a little lower than the those of Model 2, $SRMR_b$ was better (.054), but RMSEA was worse (.063), and also BIC was greater than in Model 2. For this reason, it is possible to say that results support Model 2, the one with one second-order factor and four first-order at both individual and group level, identified by the Step 3 analysis, too. The path diagram of Model 2 is displayed in Fig. 1. Results for the factor structure at the work-group level showed the adequacy of either a second-order factor structure or a one-factor structure, but the first one seemed a little better also on Step 4 CFA. The items of second-order model load strongly at within and between level. Between-level loadings were stronger than those at individual level, underlining the importance of the group level for climate scales.

Supervisor's safety climate scale: As shown in Table 3, fit indexes for all the tested models considered in analysing SSC scale were very good. The adequacy of both the second-order factor with two first-order factor model or the two-factor model confirmed the findings of the CFA. From the analysis at Steps 3 and 4 and the comparison of the four models analysed with MCFA, the best model seemed to be Model 3, the one with a two-factor structure at the individual level and a second-order structure at the between level: TLI and CFI were higher (respectively .96 and .97) than those of the other models; RMSEA and $SRMR_w$ were a little better, AIC was smaller (214.8), so as BIC and ECVI. For this model, at the individual level, loadings ranged from .73 to .88. As for OSC scale, factor loadings at the between level were higher than those at the individual level, showing the theoretical importance of MCFA for work-group safety climate. The path diagram of Model 3 is displayed in Fig. 2.

Co-workers' safety climate scale: As for OSC scale, at first the four-factor structure model was estimated, but could not be considered because the latent variable covariance matrix was

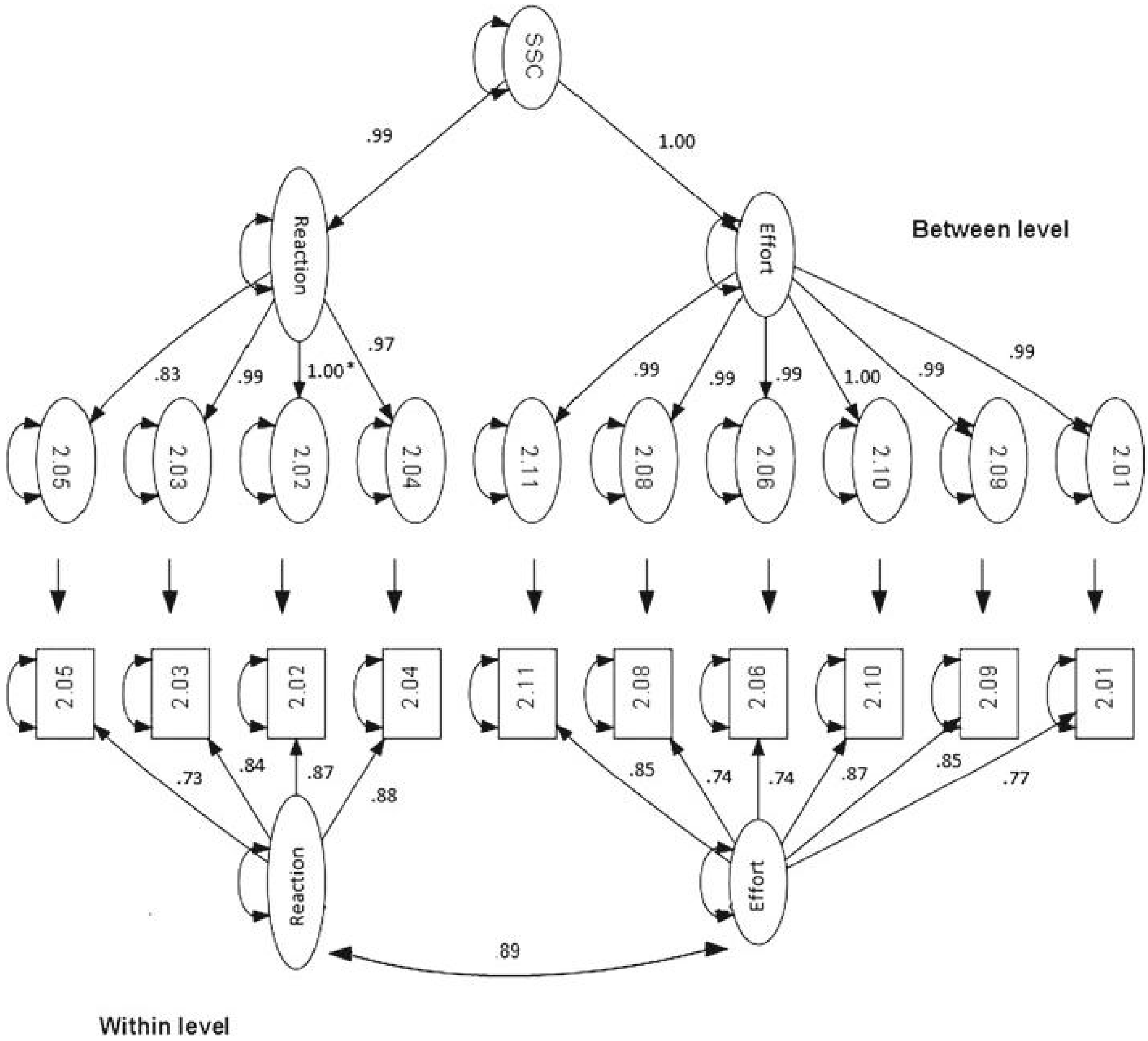

Fig. 2 Path diagram and standardized parameters estimates of the multilevel model for the supervisor safety climate scale (Model 3). *SSC* supervisor's safety climate, *Reactions* supervisor's safety reactions to workers behaviours, *Effort* supervisor's safety efforts. *At the between level residual variance of item 2.02 was fixed at .0001

not positive definite, and some of correlations between latent variables were greater than one. Model 2, the model with one second-order factor and four first-order factors for each level, showed good fit indexes (TLI = .94; CFI = .95), but also in this case $SRMR_b$ was high (.090), showing that at the between level perhaps another factorial structure could be more appropriate. Model 3 (four factors with covariations at individual-level, and one second-order factor and four first-order factors at group-level) indexes were very similar to those of Model 2 (TLI = .94; CFI = .96; $SRMR_w$ = .031 and $SRMR_b$ = .081; RMSEA = .053). Model 4 (one second-order factor and four first-order factors at individual-level and four factors with covariations at group-level) showed an improvement (TLI = .95; CFI = .96; $SRMR_w$ = .035 and $SRMR_b$ = .056; RMSEA = .051), confirmed from BIC, AIC and ECVI indexes too, and so it seems to be the most appropriate model. The path diagram of Model 4 is displayed in Fig. 3.

In conclusion all the compared models showed acceptable fit indexes but the one which seemed to fit better data structure is Model 4, showing that for the co-workers' safety scale two different factorial structures had to be used, at individual-level and at group-level, to incorporate properly the multilevel nature of data.

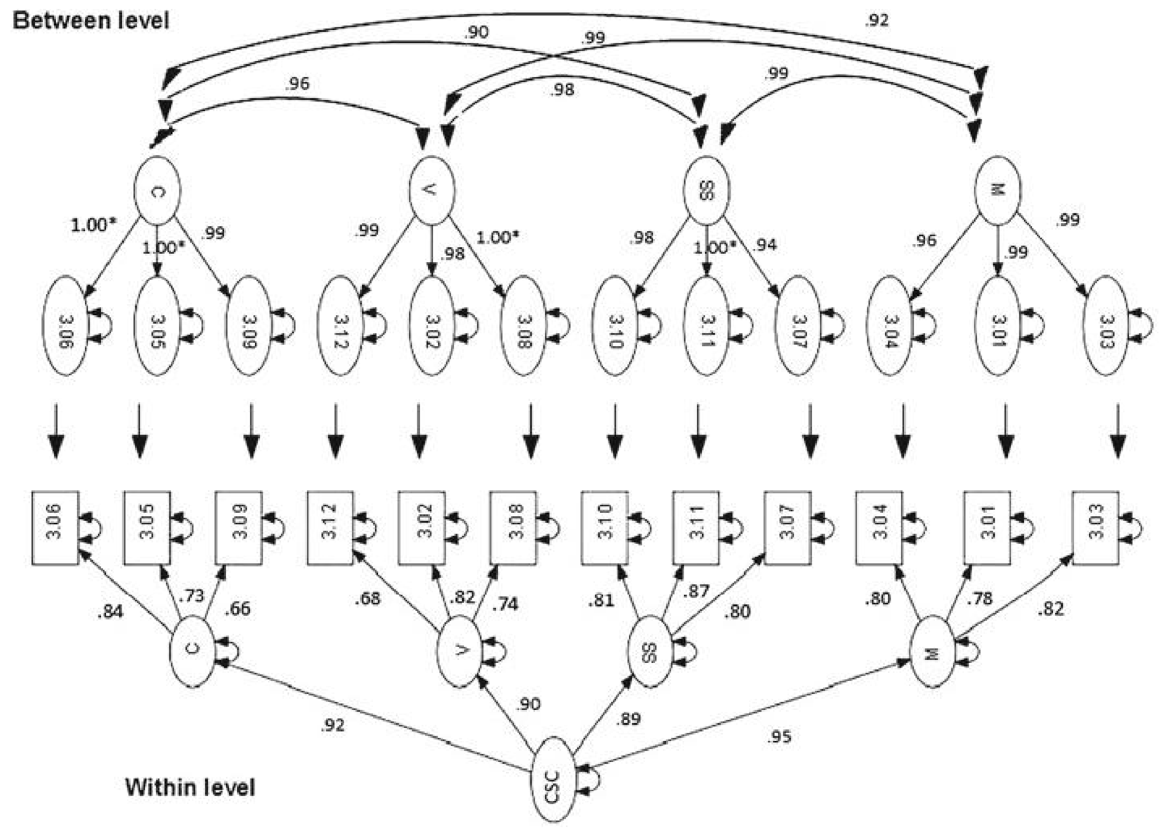

Fig. 3 Path diagram and standardized parameters estimates of the multilevel model for the co-workers safety climate scale (Model 4). *CSC* co-workers' safety climate, *C* co-workers' safety communication, *M* co-workers' safety mentoring; *SS* co-workers' safety systems, *V* co-workers' safety values. *At the between level residual variance of items 3.05, 3.06, 3.08 and 3.11 were fixed at .0001

3.3 Criterion-related validity

A further Step in the process of validation of the safety climate scales concerned the analysis of criterion-related validity. To do this, participants were divided into three groups, on the basis of their answers to the items related to injuries ("How many injuries have you had since you have entered this company?") and micro-accidents (Zohar 2000) ("How many micro-accidents have you had in the last 6 months?"). On the base of number of injuries and micro-accidents, participants were codified, for each variable, in three classes: "none", "one", and "more than one", and mean values on the three safety climate scales were computed for these three groups. Six different ANOVA were conducted, analysing mean safety climate scores differences among the three groups.

Considering injuries, mean scores on each of the three scales were significantly different in the three groups (OSC scale: $F_{(2,1599)} = 22.4$, $p < .001$; OSC scale: $F_{(2,1596)} = 17.1$, $p < .001$; CSC scale: $F_{(2,1598)} = 10.1$, $p < .0014$). Post-hoc analyses (Bonferroni) showed that for the SSC scale each mean group was different from the others, whereas for OSC scale and CSC scale mean scores for groups with none or one injury did not differ, but were different from mean scores for the group with more than one injury. All these significant differences showed that mean scores in safety climate scales were lower for groups with more injuries.

Considering micro-accidents, mean scores on OSC scale and SSC scale were significantly different in the three groups (OSC: $F_{(2,1600)} = 19.1$, $p < .001$; SSC: $F_{(2,1597)} = 10.6$, $p < .001$), but on CSC scale mean scores were not significantly different in the three groups.

Post hoc analyses (Bonferroni) showed that for OSC scale each mean group was different from the others, whereas for SSC the only significant difference was between the "none" group and the "more than one" group. Even in this case, as for injuries, safety climate mean scores were lower for groups with more micro-accidents.

In conclusion, differences among groups by self-report injuries and micro-accidents indicated that organizational safety climate scale and supervisor safety climate scale were negatively related with the injuries and micro-accidents involvements. The third scale, co-worker safety climate scale, was negative related with injuries but not with micro-accidents.

4 Discussion and conclusions

Safety climate is universally regarded as an important construct that represents the "subjective" side of organizational safety and has a huge impact on workers attitudes, behaviours and, ultimately, on work accidents. Safety climate reflects the surface features of the safety culture found in employees perceptions at a given point in time and is an indicator of the underlying safety culture of an organization and/or a work group (Flin et al. 2000; Melià et al. 2008). It corresponds to workers perceptions about safety level (policies, procedures, and practices) in the organization and in the work groups as transmitted by the management, co-workers and supervisors. Given the important role of safety climate in predicting safety behaviours, it is important to translate this concept into an operational measure, either for theoretical or practical reasons. The proliferation of assessment instruments for safety climate, having many differences among them, is probably due to the lack of a unifying theoretical model and emphasizes the need of answering to some questions about the way to assess safety climate.

The present study proposes an instrument that, departing from well-known safety climate measures, represents an effort to operationalize and validate a safety climate questionnaire with a factor structure that reflects specific content dimensions (e.g. values, training, communication) and which considers the safety agents' point of view (organization, supervisor and co-workers). This is also the first attempt to validate safety climate scales with multilevel confirmatory factor analysis using Muthen approach (1994), treating the data, collected from an individual survey, not as completely independent, given their nested nature, but decomposing the variance into between-group and within-group estimates. Moreover, the procedure we used intended to support the development and validation of a questionnaire customized for blue-collar workers and suitable for industrial sector.

The selected content dimensions and the focus on different agents departed from well-known questionnaires (e.g. Griffin and Neal 2000; Melià et al. 2008; Zohar and Luria 2005), and where selected in order to represent safety climate specific facets and considering its adequacy for representing the safety climate construct. To increase the coherence between construct definition and operationalization, qualitative techniques have been used in support of the quantitative ones.

Overall, the questionnaire aimed to fulfil theoretical and methodological gaps in the assessment of safety climate, but had the objective, at the same time, of meeting stakeholders (as companies and workers) perspectives and needs, and of being useful as a diagnostic tool that helps to identify detailed problems critical to improve safety at work.

Several procedures were used to try to achieve this result. The questionnaire development comprised various phases, and involved Judges Content Validation, Cognitive Interview and Exploratory Factor Analysis.

In the main analytical phase 1,617 blue-collar workers were involved from 8 companies, and several analyses were conducted, using Structural Equation Modelling. One of the aims of the study was to develop a measurement instrument which could be useful, on one hand, to determine the overall impact of safety climate, and, on the other hand, to measure the specific features of safety climate for more detailed diagnostic information; for this reason, confirmatory factor analyses were performed, comparing first order with second order latent factorial structures. The factorial structure of each scale was explored using a calibration sample of 7 companies, and the best structures were validated on a different sample, i.e. a large new company; this procedure was useful to confirm the stability of the previous results. The process of construct validation ended with a multilevel confirmatory factor analysis which considered the respondents nested into work groups.

The analysis of criterion-related validity, with injuries and micro-accidents as criteria, was used to demonstrate the link between the safety climate scales and the presumed connected outcomes in the work situation.

At the end of this process, the final version of the questionnaire we are proposing has 34 items, 12 for organizational safety climate, 10 for supervisor's safety climate, and 12 for co-workers' safety climate. The OSC scale evaluates four dimensions of safety climate: values, safety systems, communication and training, with 3 items for each dimension. The SSC scale includes two sub-scales, one for supervisor's reaction to the workers' safety behaviours (4 items), and the second for supervisor's own effort to improve safety (6 items). The CSC scale measures four dimensions, each with three items (values, safety systems, mentoring).

Multilevel confirmatory factor analysis seemed to be the adequate kind of analysis to verify safety climate construct validity.

OSC scale shows a hierarchical structure in which a singular, higher order factor is comprised of more specific first order factors, either at the individual and at the group level. SSC scale and CSC scale better models have some little differences, as such hierarchical structure was found, at the group level for SSC scale, and at the individual level for CSC scale. The individual level of SSC scale and the group level of CSC scale confirm the presence of some specific safety climate factors, not hierarchically connected with a superordinate second order factor, but strongly connected among them. It is important to note, that the one-factor models always showed worse results, and models with one second order factor and some first order factors always showed very good fit indexes, even when they were not the best models. This structure confirms the purpose of Griffin and Neal (2000).

These factors are similar for OSC scale and CSC scale, while SSC scale shows a two factor structure, with the original four safety climate facets joint together underlying a relational factor (the original safety communication and safety training factors) and a personal effort factor (the original safety values and safety systems factor). Since this factor structure at the group level was not explored by Griffin and Neal (2000), it was not possible to compare our results with their research. In the literature there is not any clear agreement on supervisor safety climate structure, especially on the specific first order factors involved by the second order factor. So the attempt of the present study was to explore the possibility to cover Zohar supervisor items classified on a structure similar to that one of Griffin and Neal (2000), which allows the researcher to study the global impact of safety climate and some specific diagnostic facets too. Melià and Sesè (2007) and Zohar (2000) found a two-factor structure similar to the one found in the present study. Melià and Sesè identified a first factor related to supervisor relationship with workers about safety, similar to "Coaching-Communication" factor, and a second factor related to the supervisor's own safety behaviour and effort to work safely, similar to "Value-Safety System" factor. Similarly, Zohar distinguished a factor on supervisor expectation, which referred to supervisor priority on task issues (e.g. safety vs. productivity), and a factor on supervisor action, which referred to supervisor relationship with subordinates (e.g. to supervisor reaction to workers conduct as positive and negative feed-back).

All final models have very good fit indexes, confirming the adequacy of the proposed factor structure for all the three scales, especially for SSC scale and CSC scale. These factor structures appear useful not only for research scopes, but also for providing more detailed diagnostic information to the companies.

Reliability of the scales, evaluated by computing construct reliability and average variance extracted (in place of most popular Cronbach's α, given the multidimensionality of the scales), shows very high levels.

The Criterion-related validity appears good: the more the safety climate scores, the less the self-report number of injuries and micro-accidents.

In our opinion, these results are relevant, because they confirm the theoretical structure of safety climate purposed from Griffin and colleagues, considering not only psychological climate (i.e., the individual level), but also the group level safety climate. The clear distinction, made with the use of three different scales, among safety agents (organization, supervisor, co-workers), gives an instrument that can assess workers' perceptions focused on each level, without sources of confusion for the respondents and giving a picture of the state of safety for each level. This instrument allows to deeply explore, for instance, lateral relationships of supervisor's safety climate and co-workers' safety climate, analysing the interactions between the roles of these two safety agents. These interactions did not receive much attention in previous safety climate researches.

This work purposes, for the first time, a validation of safety climate scales using MCFA. However, it was not possible to use the third level of analysis, which is the company level, because of the small number of companies participating in the survey. This limit is the probable explanation of the fit results for OSC scale models, which appear to be slightly worse than the ones derived from the other two scales. Future studies, focusing on a new survey, would increase the number of companies and work group and allow performing the MCFA also on a validation sample and, in addition, to use a multilevel approach covering the three levels (company level, work group level and individual level).

In conclusion, in this article we present the research which led to the development of a new questionnaire suitable for blue-collar workers and to the confirmation of its validity, reliability and usefulness to measure safety climate in the industrial sector.

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Appendix

The final version of the Integrated Organizational Safety Climate Questionnaire with the short description of items and the specification of the dimensions.

Organizational safety climate scale

Safety communication

1.02. Space to discuss in meeting
1.05. Management attention to workers ideas to improve safety
1.12. Workers consultation on safety issues

Safety training

1.03. Information supply on safety issues
1.09. Investments on safety training
1.16. Quality of safety training

Safety values

1.07. Management care about safety in production schedule
1.10. Management care about safety in moving-promoting people
1.14. Management care about safety on a delay in production schedule

Safety systems

1.08. Management effort on safety improvement
1.11. Management reaction to solve safety hazard
1.17. Power given to safety officers

Supervisor safety climate scale

Supervisor's effort to improve safety

2.01. Supervisor's care about safety rules when a delay in production schedule occurs
2.06. Supervisor's show care to provide workers needed safety equipment
2.08. Supervisor's care about the use of safety equipment
2.09. Supervisor's care concerning safety rules when workers are tired
2.10. Supervisor's care about all safety rules
2.11. Supervisor controls the compliance of all the workers

Supervisor's reactions to workers behaviours

2.02. Supervisor discusses with workers on safety improvement
2.03. Supervisor's care concerning workers safety awareness
2.04. Supervisor's coaching about safety care
2.05. supervisor praise to very careful safety behaviours

Co-workers' safety climate scale

Safety communication

3.05. Team members' speaking on safety on the week
3.06. Team members' discussing about incident prevention
3.09. Team members' discussion about safety hazard

Safety mentoring

3.01. Team members' emphasis to peer on safety care when under pressure
3.03. Team members care about peers safety awareness
3.04. Team members mentoring to peer about working safely

Safety values

3.02. Team members care about safety at the shift end
3.08. Team members care about safety when tired
3.12. Team members care about safety when a delay in production schedule occurs

Safety systems

3.07. Team members care about other workers' safety equipment
3.10. Team members remind safety equipment use
3.11. Team members care about other members' safety compliance

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