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Safety climate scale for vineyards: an external validity study

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Running title: Safety climate scale for vineyards

ABSTRACT

Objectives: Agriculture entered the discussions about safety climates late, despite being one of the most hazardous industries. We recently developed a safety climate scale in Bordeaux vineyards, for which we provided good evidence of reliability and construct validity (Grimbuhler and Viel, 2019). In this study, we aimed to establish the external validity of this safety climate scale with the help of an independent national sample of vineyard professionals.

Population and methods: We approached vineyard managers and operators during compulsory training and certification procedures for pesticide-related activities. Trainees giving informed consent for participation in the study were asked to complete a safety climate questionnaire at the start and end of a training session. In total, 406 vineyard managers or operators completed the questionnaire at the start of the study, 37 of whom declined to complete the questionnaire at the end of the training session, leaving 369 subjects available for pre-training/post-training comparisons. Statistical comparisons were based on *t*-tests and mixed models for repeated measures.

Results: A mean safety climate score of 82.91 (standard deviation [SD]: 9.06) was obtained in the initial survey in the Bordeaux region, whereas the safety climate score was estimated at 83.78 (SD 10.39) in this nationwide survey ($p=0.23$). A significant increase was observed after the training course, for safety climate score (7.5 %, $p<10^{-15}$) and for each of its seven dimensions ($p<10^{-4}$ or less), in both univariate and multivariate analyses. However, the magnitude of these increases varied with dimension, ranging from 2.4% for rules and best practices to 15.5% for communication and feedback.

Conclusions: External validity was demonstrated by transferability and sensitivity to intervention. This safety climate scale can now be considered to provide a good inference of the safety culture, with a meaning generalizable across vineyards.

Keywords: Safety climate; vineyards; pesticides; certification; training; external validity

Abbreviation: MMRM, mixed model for repeated measures

What's important about this paper?

The “safety climate” concept is widely considered important, but this study is of the very few to consider external validity. We demonstrated external validity of a safety climate scale in vineyards by transferability and sensitivity to intervention. With a meaning generalizable across vineyards, this scale, which is brief and psychometrically sound, can therefore be used in safety promotion approaches and for assessing national safety intervention programs.

Introduction

The safety climate is defined as the workers' shared perception of their organization's policies, procedures, and practices in terms of the value and importance of safety within the organization (Huang *et al.*, 2013). It is considered a leading indicator of safety because of its ability to predict safety behavior and safety-related outcomes (Zohar, 2010; Huang *et al.*, 2013). This concept occupies an important position in the domain of occupational health and safety generally, but has been little considered in agriculture, despite the hazardous nature of the agricultural industry, which has a poor reputation regarding safety attitudes and behaviors (Hanson and Boland, 2020).

Fargnoli and Lombardi (2020) have conducted a thorough review of the limited literature (17 documents) on safety climate in the agricultural sector. Their findings suggest that existing research primarily focuses on investigating the safety climate among workers belonging to minorities and vulnerable groups, or on analyzing the relationship between safety climate and specific health issues. This limited focus restricts the generalizability of the research findings to these specific contexts only. Most studies used the Perceived Safety Climate which was originally developed for the construction industry (Gillen *et al.*, 2002). In general, farmers have a low perception of safety climate, which highlights their high risk-taking attitude and low prioritization of safety. In the same paper, Fargnoli and Lombardi (2020) used the Nordic Safety Climate Questionnaire (tested first in the construction and food industries) (Kines *et al.*, 2011) to investigate safety climate among farmers in Central Italy.

However, in the agricultural sector, safety considerations extend beyond machinery-related accidents in the workplace, as pesticide use involves the exposure of the operators,

workers, residents and bystanders to the chemicals concerned and the potential hazards associated with them (Calliera and L'Astorina, 2018; EFSA, 2022). Thus, in the context of agriculture, the concept of "safety climate" should be extended to pesticide risk awareness and pest management practices (Grimbuhler and Viel, 2019). Along with many authors whose definition of safety climate relies on the shared perception of security matters (see the review by Luo, 2020), we considered safety climate as the combination of shared perceptions among workers regarding procedures, practices, attitudes, and behaviors related to occupational safety (Fagnoli and Lombardi, 2020).

Careful assessments of safety climate are required with instruments displaying strong psychometric properties. Generic safety climate scales (focusing on managerial commitment and safety management) can be used across diverse industries, but industry-specific safety climate scales can identify context-dependent processes underlying the emergence of a particular safety climate (Zohar, 2010).

We recently developed a specific psychometric model for two reasons (Grimbuhler and Viel, 2019). First, the agricultural sector is highly segmented with regulations, organization structures and lines of command and communication different from those of other industries. In particular, long-term vineyard employees work regularly or occasionally on their own, without access to immediate support from work colleagues or managers. Second, our goal in this initial study was not to shed light on the organizational and cultural factors that are precursors of accidents but to evaluate pesticide-related safety. The research strategy and the tools used to develop this safety climate scale have been fully described elsewhere (Grimbuhler and Viel, 2019).

This new instrument is based on seven dimensions (management commitment, communication and feedback, rules and best practices, knowledge, safety compliance, safety

participation, teamwork climate), covered by 20 items (Table 1). This safety climate scale was developed and assessed on 312 farm managers or pesticide operators working in the Bordeaux vineyards in France, corresponding to the internal sample from which the model was derived. We obtained good evidence of reliability (Cronbach's alpha of 0.81) and construct validity. However, the robustness and generalizability of the scale to other similar contexts (Steckler and McLeroy, 2008; Boateng *et al.*, 2018) were not assessed in the framework of this initial study.

The goal of this study was, therefore, to establish the external validity of this safety climate scale with the help of an independent national sample of vineyard professionals.

Population and methods

Study population

We approached vineyard professionals to request their participation during compulsory training and certification procedures for pesticide-related activities. Most trained farmers have a greater knowledge of pesticide use, a higher level of belief in pesticide hazard control, and better safety behavior than untrained farmers (Damalas and Koutroubas, 2017). Under Directive 2009/128/EC of the European Parliament and Council on the sustainable use of pesticides (OJEC, 2009), France requires farmers to obtain and hold an individual certificate (commonly known as "Certiphyto") for the purchase and application of pesticides. This certificate is awarded after mandatory training, as part of the certification scheme in place, which includes requirements and procedures for the awarding, renewal and withdrawal of certificates.

Certification is initially awarded for a period of five years after the completion of a two-day training program designed to ensure that farmers acquire sufficient knowledge to use pesticides safely and to reduce the amounts of pesticides used. The main features of the training program are: relevant legislation regarding pesticides and their use; hazards and risks associated with pesticides; measures to minimize risks to humans and the environment; integrated pest management strategies and techniques; occupational and environmental risk assessment at the farm level; work organization and equipment management to reduce pesticide exposure. A one-day renewal course is also organized, to update the participants' knowledge and to address any issues raised. Furthermore, as a means of ensuring more appropriate pesticide use, Certiphyto training is specifically designed for each of the two different target audiences: decision-makers and operators. Training bodies are accredited by the French Ministry of Agriculture. Chambers of Agriculture, agricultural vocational training and promotion centers, and rural non-profit organizations are the chief providers of Certiphyto training nationwide.

The study population considered here therefore consisted of vineyard managers and operators attending an initial or renewal Certiphyto training course.

External validation methods

External validity is the extent to which the implications of a given score on the scale are similar across different vine-growing regions and vineyards. We used a two-step procedure to assess the generalizability of the initial findings. We first addressed the issue of transferability (or ecological validity) by replicating and extending the study to other French

vine-growing regions (rather than just the Bordeaux vineyards). We compared scores between the development (Bordeaux) sample and the national sample for this study.

In the second step, we asked vineyard professionals to complete the questionnaire before and after attending the compulsory Certiphyto training course. We considered this course to be an intervention that would probably lead to a change in score (sensitivity to intervention) (Glasgow *et al.*, 2005), as safety climate can change with time and circumstance (Luo, 2020). We therefore assumed that safety climate score (and at least some of its seven subscores) would increase between the start and end of the course, as the *perceptions* of the course attendees regarding safety-related policies, procedures, and practices (reflected by the different dimensions of the safety climate scale), could become more accurate thanks to training content and group dynamics. In other words, our research hypothesis was that improved knowledge and skills could translate into increased perceptions of occupational safety. This pre-intervention/post-intervention comparison should not be confused with an assessment of test–retest reliability, which is used for the opposite purpose: to assess score stability across time.

Data collection

The instructors of 125 training sessions (organized between March 2021 and April 2023) agreed to allocate time during the training course to the completion of the survey. A total of 1411 trainees gave informed consent to participate in this study and completed a standardized self-administered questionnaire with two sections. As they filled in the questionnaire anonymously during a compulsory training and certification procedure, no

ethics committee approval was required, in accordance with the French regulations in force at the time of the study.

The first section of the questionnaire collected demographic and occupational data and information about the characteristics of the vineyard. The second section of the questionnaire contained the safety climate scale itself. The participants completed the questionnaire anonymously twice: at the start (D0) and end (either D1 for one-day renewal courses or D2 for two-day initial courses) of the training session. Depending on the training course, the data were collected on paper forms of the questionnaire or online (with the LimeSurvey platform).

Certiphyto training courses are organized for farmers generally, not just those working in vineyards. We considered only participants declaring vineyard activities in the analyses. In total, 406 vineyard managers or operators completed the safety climate questionnaire on D0, 37 of whom declined to complete the questionnaire a second time on D1 or D2. We therefore had 369 subjects with paired responses for pre-training/post-training comparisons.

Statistical analyses

Independent *t*-tests were performed to compare mean safety climate scores between the initial 312-subject sample from Bordeaux vineyards and the national sample of 406 subjects completing the questionnaire at the start of the training course.

For the comparison of pre-intervention and post-intervention mean scores (for the 369 subjects with paired scores), we initially performed paired *t*-tests in a univariate approach.

We then used a mixed model for repeated measures (MMRM) including terms for risk

factors, time (D0 and D1 or D2), and risk factor-by-time interactions to assess differences in safety climate scores. The type of questionnaire-by-time interaction was forced into the models to account for the potential effect of the way in which the data were collected. Covariate-by-time interactions ($p < 0.20$) in univariate analyses were included in multivariate MMRMs. We performed sensitivity analyses for each subscore in turn, to gain insight into the efficacy of Certiphyto training, to help agricultural authorities and instructors to design more effective training components.

P -values < 0.05 were considered statistically significant, and all tests were two-tailed. Statistical analyses were performed with the base and mrmr packages of R software (R Development Core Team, 2023).

Results

Survey participants

The demographic characteristics and occupational factors for the 406 vineyard managers and operators participating in the safety climate survey are reported in Table 2.

Most of the respondents were male, under the age of 40 years, and with less than five years of experience in pesticide use. They were involved in all pesticide-related activities, worked in vineyards practicing reasoned agriculture, and were not members of an agricultural cooperative.

Comparison of safety climate score between the initial and current surveys

A mean safety climate score of 82.91 (standard deviation [SD]: 9.06) was obtained in the initial survey carried out in the Bordeaux region. The mean safety climate score for this nationwide survey was 83.78 (SD: 10.39). The difference in safety climate scores between the two surveys was not statistically significant ($p=0.23$).

Mean safety climate scores before and after training

A significant increase was observed after the Certiphyto course, for safety climate score (7.5%, $p<10^{-15}$) and for each of its seven dimensions ($p<10^{-4}$ or less) (Table 3). However, the magnitude of these increases varied with dimension, ranging from 2.4% for rules and best practices and 4.9% for management commitment to 9.6% for knowledge and 15.5% for communication and feedback.

Adjustment for covariate-by-time interactions found to be significant ($p < 0.20$) in univariate analyses yielded identical p -values for score changes (Table 4). Very few risk factors were found to be significant: experience of pesticide use for the safety compliance dimension (the increase in score being smaller for vineyard professionals with more experience, $p<0.05$); type of certification for the knowledge dimension (the increase in score being smaller for those on the renewal course, $p<0.01$); type of agricultural system for management commitment (the increase in score being smaller for conventional and reasoned systems, $p<0.05$); agricultural cooperative membership for the communication and feedback dimension (the increase in score being lower for those with membership, $p<0.05$).

Discussion

In this study, we evaluated the external validity of a safety climate scale across vineyard settings throughout France. The safety climate scale had robust external validity in terms of transferability and sensitivity to intervention. The mean scores obtained were highly consistent with previous findings for the Bordeaux vineyards. Furthermore, the safety climate summary score and all its subscales improved significantly following the intervention.

This study has several strengths. First, safety climate concept is widely considered important, but this study is one of the very few reporting an indication of external validity (Seo *et al.*, 2004). Second, the subjects included had a relatively wide range of values for age, experience in pesticide use, position, pesticide-related activities and type of agricultural system. This diversity should ensure reasonable representativeness and transportability. Third, this study followed a pre/post-intervention design (D0 and D1 or D2), holding individual risk factors constant and providing evidence for the intervention effect. Fourth, the number of measurements and the large impact of the intervention under study (Certiphyto training course) resulted in excellent statistical power and highly significant differences between mean scores.

However, this study was also subject to several limitations. First, data were not collected using a new device, but through the use of a regulatory "gate" through which pesticide users have to pass. However, this did have the advantage of reducing the potential for selection bias. Second, the results of this study were dependent on the participants giving sincere and honest responses, and the behaviors of the participants were not validated against actual use. We used the levers of voluntary participation in the survey, anonymity, and confidentiality to encourage honesty in the participants' responses. Third, this study

considered only a few factors potentially underlying the workers' perception of the safety climate before and after the Certiphyto training course. Nevertheless, residual confounding is unlikely to explain the observed differences given the effect size of the intervention.

Fourth, because of the short training time (2 days) only short-term effects could be highlighted without prejudging what the long-term results might be.

We found evidence of sensitivity to intervention effects, with increases in safety climate score and each of its subscores following the Certiphyto training course. Obviously, a short educational session cannot change the work environment which is primarily influenced by policies and procedures. However, our findings show that a training session can change individual perceptions of the work environment through the acquisition of new knowledge and skills. The magnitude of the increase in scores (7.5% for the global score) was unexpectedly high, yielding highly significant results. The largest increases were observed for the dimensions "knowledge", and "communication and feedback" and supported causal inference, as these topics constitute the core of the training program. These results are consistent with those of previous studies highlighting the importance of perception-oriented, context-specific training tools for improving the intentions and behavior of farmers with respect to safe pesticide handling (Levesque *et al.*, 2012; Damalas and Koutroubas, 2017; Jallow *et al.*, 2017; Calliera and L'Astorina, 2018).

The intervention had an overwhelming influence on the results, with the change in scores generally unaffected by demographic or occupational characteristics. In particular, no significant association was found between any score and the job position in viticulture (Table 4), at variance with discrepancies in perceptions of safety climate found across hierarchical groups (workers, supervisors and upper managers) in the restaurant industry (Huang *et al.*,

2012) and the construction industry (Marin et al., 2019). This inconclusive result could be partly explained by the specific characteristics of the agricultural sector. Autonomy is a core value in farming, and is relatively unrelated to actual ownership of the land and/or of the farm business (Stock and Forney, 2014). Non-commercial vineyards have a relatively flat organizational structure, as managers are often directly involved in the day-to-day operations. Moreover, scattered vineyards require real-time and site-specific decisions, made on the ground and blurring the lines between manager and operator.

The signs of the few significant modest time interactions were in the expected direction. Indeed, as most trained farmers (assessed here in terms of experience in pesticide use or attendance of a certification renewal course) and farmers with a certain awareness of the issues concerned (assessed here in terms of agricultural cooperative membership) display safer behavior in pesticide use (Damalas and Koutroubas, 2017), their margin for improvement is smaller, and their scores increase to a lesser extent after the intervention. Conversely, the margin for improvement is larger for those involved in conventional and reasoned agricultural systems (as opposed to organic systems), and this was reflected in larger increases in scores after the Certiphyto training course.

Conclusion

External validity was demonstrated by transferability and sensitivity to intervention. This safety climate scale can now be considered to provide a good inference of the safety culture, with a meaning generalizable across vineyards. This scale, which is brief (20 items compared to 50 items for the Nordic Safety Climate Questionnaire) and psychometrically sound, can therefore be used in safety promotion approaches and for assessing national safety

intervention programs. In the long term, we envision that stakeholders (e.g. the agricultural industry, farmers' unions, health insurance schemes, researchers, regional labor authorities, local communities) will adopt this survey tool to support improvements in worker well-being and health, and to promote good agronomic practices to improve the sustainable use of pesticides and minimize risks to the environment and human health.

Author contribution

Grimbuhler S: Conceptualization, Supervision, Investigation, Writing – Original Draft; Werlen

T: Investigation, Data Curation, Software, Writing – Review & Editing; Viel JF:

Conceptualization, Methodology, Software, Formal Analysis, Funding Acquisition, Project

Administration, Writing – Original Draft.

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Conflict of interest statement

The authors declare that they have no known competing financial interests or personal

relationships that could be seen to influence the work reported here.

Data availability statement

The data that support the findings of this study are available from the corresponding author,

upon reasonable request.

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Table 1. Safety climate scale for vineyards (from Grimbuhler & Viel, 2019, reprinted with permission from Elsevier).

Dimensions	Items
Management commitment	<p>Pesticide safety is given a high priority by farm management</p> <p>Actions are undertaken to reduce pesticide exposure on the farm</p> <p>Actions taken by health promoters aim at reducing exposure to pesticides</p> <p>I have been consulted about safety issues when using pesticides</p> <p>I am encouraged to become involved in pesticide safety matters</p> <p>I am encouraged to attend safety training programs regularly</p>
Communication & feedback	<p>I know the incident reporting system of health organizations</p> <p>I am encouraged to report any safety matters to improve my protection during pesticide use</p> <p>After an incident during pesticide handling, I have made / I will make improvements</p>
Rules & best practices	<p>Safety regulation and good practices are useful to prevent risk</p> <p>I attach particular importance to the maintenance of work area, equipment and machinery</p>
Knowledge	<p>I know when to use personal protective equipment</p> <p>I know safety regulations</p> <p>I have a "zero-incident" goal</p>
Safety compliance	<p>I use all necessary safety equipment to do my job</p> <p>I respect good practices that protect me from pesticide exposure</p> <p>Personal protective equipment is adapted to my work activities</p>
Safety participation	<p>I put in extra effort to improve my safety when using pesticides</p>
Teamwork climate	<p>My co-workers share the same concerns as me about workplace health</p> <p>My co-workers comply with good practices</p>

Table 2. Demographic characteristics of the vineyard professionals and occupational factors (*N*=406).

	Number	Percentage
Sex		
Female	82	20.2 %
Male	324	79.8 %
Age (years)		
<40	198	48.8 %
40-49	91	22.4 %
50-59	73	18.0 %
≥60	44	10.8 %
Vine-growing region		
Alsace	16	3.9 %
Bordeaux	111	27.3 %
Champagne	37	9.1 %
Charentes	26	6.4 %
Languedoc-Roussillon	97	23.9 %
Loire Valley	23	5.7 %
Provence-Corsica	9	2.2 %
Rhône Valley	52	12.8 %
Savoie-Bugey	1	0.2 %
South West	34	8.4 %
Experience in pesticide use (years)		
< 5	187	46.1 %
5-9	57	14.0 %
10-14	40	9.9 %
≥ 15	122	30.0 %
Position		
Vineyard manager	178	43.9 %
Vineyard operator	182	44.8 %
Other	46	11.3 %
Type of certification		
Initial	217	53.4 %
Renewal	189	46.6 %
Pesticide-related activities		
Decision-making		
No	178	43.8 %
Yes	228	56.2 %
Preparation		
No	142	35.0 %
Yes	264	65.0 %
Application		
No	118	29.1 %

Yes	288	70.9 %
Equipment cleaning		
No	133	32.8 %
Yes	273	67.2 %
Type of system		
Conventional	135	32.3 %
Reasoned	163	40.1 %
Organic	108	26.6 %
Agricultural cooperative membership		
No	315	77.6 %
Yes	91	22.4 %

Table 3. Sensitivity to change of safety climate scores in response to Certiphyto training (univariate analysis, $N=369$).

	Pre- training score	Post- training score	Absolute difference	Relative difference	<i>P</i>-value
Global score	84.01	90.28	6.27	7.5%	<10⁻¹⁵
Dimensions					
<i>Management commitment</i>	25.77	27.04	1.27	4.9%	<10 ⁻¹⁵
<i>Communication and feedback</i>	11.81	13.64	1.83	15.5%	<10 ⁻¹⁵
<i>Rules and best practices</i>	9.07	9.29	0.22	2.4%	<10 ⁻⁴
<i>Knowledge</i>	12.54	13.74	1.20	9.6%	<10 ⁻¹⁵
<i>Safety compliance</i>	12.57	13.43	0.86	6.8%	<10 ⁻¹⁵
<i>Safety participation</i>	4.24	4.58	0.34	8.0%	<10 ⁻¹⁵
<i>Teamwork climate</i>	8.00	8.55	0.55	6.9%	<10 ⁻⁹

Table 4. Results of a mixed model for repeated measures comparing pre- and post-training safety climate scores (multivariate analysis, $N=369$).

	<i>P</i> -value	Adjusting factors
Global score	$<10^{-15}$	Type of questionnaire, age, experience in pesticide use, type of certification, application, type of system
Dimensions		
<i>Management commitment</i>	$<10^{-15}$	Type of questionnaire, age, experience in pesticide use, type of certification, type of system*
<i>Communication and feedback</i>	$<10^{-15}$	Type of questionnaire, age, experience in pesticide use, type of certification, type of system, agricultural cooperative membership*
<i>Rules and best practices</i>	$<10^{-4}$	Type of questionnaire, experience in pesticide use, type of certification**, decision-making, application, type of system, agricultural cooperative membership
<i>Knowledge</i>	$<10^{-15}$	Type of questionnaire, age, experience in pesticide use, type of certification, decision-making, application, type of system

<i>Safety compliance</i>	<10 ⁻¹⁵	Type of questionnaire, age, experience in pesticide use*, position, application
<i>Safety participation</i>	<10 ⁻¹⁵	Type of questionnaire, experience in pesticide use, application, equipment cleaning
<i>Teamwork climate</i>	<10 ⁻⁹	Type of questionnaire, decision-making

* $p < 0.05$, ** $p < 0.01$