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Safety *sans Frontières*: An International Safety Culture Model

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The management of safety culture in international and culturally diverse organizations is a concern for many high-risk industries. Yet, research has primarily developed models of safety culture within Western countries, and there is a need to extend investigations of safety culture to global environments. We examined (i) whether safety culture can be reliably measured within a single industry operating across different cultural environments, and (ii) if there is an association between safety culture and national culture. The psychometric properties of a safety culture model developed for the air traffic management (ATM) industry were examined in 17 European countries from four culturally distinct regions of Europe (North, East, South, West). Participants were ATM operational staff ($n = 5{,}176$) and management staff ($n = 1{,}230$). Through employing multigroup confirmatory factor analysis, good psychometric properties of the model were established. This demonstrates, for the first time, that when safety culture models are tailored to a specific industry, they can operate consistently across national boundaries and occupational groups. Additionally, safety culture scores at both regional and national levels were associated with country-level data on Hofstede's five national culture dimensions (collectivism, power distance, uncertainty avoidance, masculinity, and long-term orientation). MANOVAs indicated safety culture to be most positive in Northern Europe, less so in Western and Eastern Europe, and least positive in Southern Europe. This indicates that national cultural traits may influence the development of organizational safety culture, with significant implications for safety culture theory and practice.

KEY WORDS: Air traffic management; European regions; national culture; safety climate; safety culture

1. INTRODUCTION

The concept of *safety culture* emerges from theory and research showing organizational management, values, norms, activities, and history to shape employee safety behaviors and outcomes.[1] For many high-risk industries (e.g., aviation, energy), safety management transcends national boundaries, and is of international concern. This means the conceptual models used to measure and understand safety culture must be valid for different national contexts. Yet, safety culture has been primarily explored within single organizations and (usually Western) countries.[2] Whilst new research directions have emerged,[3] safety culture remains largely separate from other conceptualizations of culture. For example, research has not established whether safety culture can be reliably measured in different countries, or if there is a relationship between safety culture and national culture. We explore these issues through an investigation of safety culture in European air traffic management (ATM).

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2. LITERATURE REVIEW

Safety culture has multiple definitions,[4] but is generally described as an element of organizational culture, and refers to the norms, values, and practices shared by groups in relation to safety and risk.[5–7] Ambiguities in the definition of safety culture reflect its diverse empirical and theoretical origins. For example, anthropological perspectives emphasize the role of societal belief systems in determining safety culture, while normative perspectives emphasize organizational policies and group interactions.[8] The safety culture concept is seen as useful because a "strong" safety culture is where beliefs and activities in relation to safety are positive, leading to a reduced likelihood of organizational mishaps. Conversely, a "weak" safety culture can reflect poor safety practices, which increases accident probability. Empirical research examining the association between safety culture and safety performance supports this assertion,[4,9,10] and thus despite its somewhat ethereal nature, safety culture is often conceived as an organizational property that is attainable and measurable.[11]

This is similar to "safety climate," and a long-standing debate within the safety literature is on the distinction between safety culture and safety climate.[5] Broadly, safety climate is argued to reflect the "surface features of the safety culture . . . .at a given point in time" (Ref. 12, p. 178), with measures of safety climate investigating and aggregating individual perceptions relating to the prioritization of safety by the organization.[13] These perceptions are argued to shape the safety-related activities of organizational members (e.g., through rewarding or supporting behavior), and thus safety outcomes.[14] Although safety culture and safety climate have similar measurement techniques (surveys) and conceptual focus (e.g., prioritization of safety),[1,5,15,16] safety climate is generally conceptualized as a narrower and more dynamic construct than safety culture,[17,18] which refers to the more stable and fundamental norms, values, and practices that influence safety. In terms of their relationship, it can be understood as somewhat akin to personality and mood. Notably, safety culture research utilizes multiple empirical techniques (e.g., surveys, interviews, incident analyses), and investigates a wider set of dimensions than safety climate (e.g., affect, safety knowledge, values, risk communication).[19]

Crucially, safety culture is understood to emerge from group, organizational, and societal cultural practices, and thus is influenced by wider social contexts.[1,20] This further distinguishes safety culture from safety climate, yet relatively little research (unlike in the general organizational culture literature) has examined whether safety culture interacts with, and is possibly a product of, constructs such as national culture.[21–23] Establishing whether safety culture is associated with wider societal factors such as national culture would be beneficial in terms of theory and practice. In particular, it would (i) provide insight on how national culture might influence safety culture formation and safety practices, (ii) better distinguish safety culture and safety climate, and (iii) add to an evolving literature on the management of safety in international contexts.

2.1. Safety Management in an International Context

Increasingly, safety management is performed internationally, and safety researchers have identified the challenges this creates.[24,25] First, differences in safety culture between and within international organizations (e.g., on risk communication, perceived value of production vs. safety) that coordinate on safety (e.g., aviation, energy) have been identified as contributing to organizational mishaps.[24,26] Second, safety-critical work is often performed by multicultural and co-located teams,[27] which, while being potentially valuable (e.g., for bringing together different perspectives on safety), also presents challenges for safety management.[25,28] For example, where national cultural traits (e.g., for challenging authority) influence the safety-related beliefs of team members (e.g., on the acceptability of highlighting a supervisor's mistake), coordination on safety activities may not be optimal (e.g., expectations and behaviors for speaking up).[27,29,30] Third, globalized industries and organizations operate in different regulatory environments, and must perform to different standards for managing and learning from risk.[31,32] This means a single organization can be required to work to different safety standards depending on the location of operations, which potentially creates confusion (e.g., where safety protocols differ according to national location) and regulatory environments that are weaker than others (e.g., on inspection routines).[33]

Thus, improving the current understanding of safety management in international industries and environments is a priority, with the safety research literature indicating that variations in national safety

practices influence safety outcomes. For example, Spangenberg *et al.*[34] reported, on a joint-venture construction project, Danish workers to have four times the lost-time injury rates of Swedish workers. Differences were partly explained by safety legislation (macro-factors), job stability (meso-factors), and safety training and attitudes (micro-factors). Similarly, variations in accident rates among multicultural groups of seafarers (e.g., Chinese, Philippine, Taiwanese) have been explained by differences in national culture.[35] In aviation, national culture differences have been associated with flight incidents,[36] and variations in the occurrence of medical error have been explained by national differences in safety procedures and management.[37]

Research examining associations between safety and national culture often utilize Hofstede's[22] national culture paradigm. This assumes individuals from a nation to share some core values with fellow citizens, with five key dimensions being reported (power distance, collectivism, uncertainty avoidance, masculinity, long-term orientation).[38,39] While the notion of national culture being homogenous, measurable (and distinguishable between societies), and associated with practice is heavily critiqued (e.g., from a constructivist and symbolic interactionist perspective),[40] good psychometric properties of national trait measurement have been demonstrated,[41,42] and it has been argued that measures of national culture are not absolute and are instead indicative of general tendencies within populations.[43] For example, it is recognized that where cultures encourage individualism, homogeneity of national culture is arguably less likely.[44]

In particular, the observation that differences in national culture account for variations in organizational culture within organizations operating in multiple countries is relevant for safety culture research.[38] Examining whether safety culture is also shaped by national cultural tendencies appears important for interpreting safety-related practices and beliefs in different national contexts. Specifically, the dimensions of power distance (i.e., valuing social and institutional hierarchies), individualism/collectivism (i.e., seeing oneself as independent or closely related to others), and uncertainty avoidance (i.e., feeling uncomfortable with novel/ambiguous situations) have been identified as relevant for safety culture.[45] They have been associated with safety failures in the shipping industry,[35] aviation incidents,[36] aviation safety behaviors (e.g., following orders, adhering to protocols, situational flexibility),[45,46] and human factors accident analyses.[47] We consider this literature further in the section below.

2.2. Cross-Cultural Investigations of Safety Culture

Despite growing interest in the topic, relatively little research has examined associations between national culture and safety culture. Cross-cultural studies of safety in the energy industry have shown that risk-taking behaviors are simultaneously influenced by national culture and beliefs on management commitment to safety.[24] Health-care research has shown that, alongside interorganizational differences in safety culture, cross-cultural variations in safety culture are potentially explained by national differences (e.g., in the United States, Thailand, and the Netherlands).[48] Yet, the relationship between safety culture and national culture has not been systematically examined, and to do this it is necessary to develop measurement models of safety culture that function reliably in different cultural environments, and to associate these with metrics of national culture. Yet, this is problematic for the following reasons.

First, safety culture models previously demonstrated to work through questionnaires in Western settings have been shown (when tested through confirmatory factor analysis) to function poorly in other (e.g., Asian) cultural environments.[49] Explanatory reasons include the lack of relevance of safety culture questionnaire dimensions to the local environment, and cultural differences in national response patterns. This indicates that generic safety culture models cannot automatically be applied from one cultural setting to another, and may require substantial customization (e.g., to a particular industry).

Second, participants from different cultural backgrounds (e.g., Hispanic and white non-Hispanic) have been shown to respond differently to latent safety culture questionnaire dimensions (in the same organization).[50] This means that the construct equivalence of item meanings cannot be assumed between participants from different cultural backgrounds, and that data may vary due to differences in response styles and interpretations of safety culture dimensions.

Third, the relationship between safety culture variables can differ in culturally diverse environments. This means that predictive models developed to explain safety culture (and its relationship with safety) in one setting may not hold in another.[51] It indicates a need for either culturally distinct

predictive models of safety culture, or the development of models designed from the outset to function in cross-cultural environments.

Thus, to effectively measure and examine safety culture in cross-cultural environments, measurement equivalence is required to address these issues. Furthermore, to examine how safety culture is associated with national culture (e.g., to explain national variations in safety culture), it is necessary to associate metrics of the two.

3. THE CURRENT STUDY

In the current study, we examine the psychometric properties of a questionnaire designed to assess safety culture in different cultural environments (i.e., nations, regions), and then examine whether national variations in safety culture are associated with national culture.

To do this, we investigate safety culture within the field of air traffic management (ATM) in 17 European countries. ATM is one of the safest components of the highly reliable civil aviation industry.[52,53] In Europe, national air navigation service providers (ANSPs) operate in a single interconnected industry, and ANSP staff are primarily nationals of the host country, with practices being influenced by both European-wide standards and organizational characteristics (e.g., traffic demand, resources, team structures).[54] However, because ATM performance is prefaced upon having a reliable and safe system, when mishaps do occur (e.g., the Überlingen mid-air collision in 2002, which resulted in 71 fatalities) they are catastrophic.[55] Stability is essential for ATM, with safety being shaped by a wide range of constructs (e.g., incident reporting, learning from near-events, resource management, safety communication, collaboration), and thus safety culture appears useful for investigating ANSP safety practices (in comparison to safety climate, which is a more dynamic and narrow construct).[12] Adopting an international perspective on safety culture would allow for an examination of how safety practices are influenced by national cultural factors (e.g., with possible implications for activities within and between ANSPs), and aid in understanding how gradual change within ATM (e.g., automation, commercialization, increased integration between ANSPs) might shape safety management.

3.1. Measuring Safety Culture in Different Cultural Environments

The first aim of this study is to test the psychometric properties of a safety culture questionnaire tool developed for European ATM. The survey items underlying the tool were developed through literature review and qualitative investigations (interviews, focus groups, incident analyses). The questionnaire is part of a broader toolkit developed for understanding and improving safety culture in ATM, and its purpose is to measure staff (e.g., operational, management) assessments and beliefs on safety culture within their ANSP. Data from the survey are used to structure qualitative investigations of safety culture (e.g., workshops with groups of operational, engineering, and management staff to identify and understand specific safety problems), and to study safety culture longitudinally. A prototype version of the questionnaire was tested in four ANSPs in 2008, and a preliminary safety culture model was partially supported.[56] Further refinement was required, with the final model identifying six dimensions of safety culture relevant to ATM across Europe. These are outlined in Table I, and the study method.

To test the ATM safety culture model, we examine whether it operates reliably across 17 countries in four European regions. These four regions are significant because cross-cultural research often clusters groups of people according to commonality.[57] Clusters are based on geographic proximity, mass migrations, religious and linguistic characteristics, sociopolitical and economic development, and attitudes, values, and work goals.[58] Within Europe, four macro-geographic clusters are outlined by the United Nations,[59] with their cultural differences and similarities documented:[60–63] Northern Europe (e.g., Scandinavian countries, the United Kingdom), Eastern Europe (e.g., former Eastern Bloc nations), Southern Europe (e.g., Mediterranean nations), and Western Europe (e.g., France, Germany, Benelux).

For safety culture in European ATM, regional clusters are important for understanding how nations compare against neighboring countries with similar cultural profiles. In particular, if safety culture is influenced by national culture, it may be useful to compare safety culture scores within groups of similar neighboring countries in order to account for mediating and potentially confounding relationships. This could facilitate organizational learning and the sharing of good practice at a regional level. The U.N.

Table I. Safety Culture Dimensions for European Air Traffic Management (ATM)

Dimension	Definition	Relevance for Safety Management	Questionnaire Items
Management commitment to safety	Extent to which management prioritize safety	Indicates organizational prioritization of safety within an ANSP	• *My manager is committed to safety* • *My manager takes action on the safety issues we raise* • *My manager would always support me if I had a concern about safety*
Collaborating for safety	Group attitudes and activities for safety management	Indicates normative behaviors and attitudes among ANSP staff toward safety	• *Other people in this organization understand how my job contributes to safety* • *People who raise safety issues are seen as troublemakers* • *There are people who I do not want to work with because of their negative attitude to safety* • *My involvement in safety activities is sufficient*
Incident reporting	Extent to which respondents believe it is safe to report safety incidents	Essential for identifying system weaknesses and learning	• *People who report safety related occurrences are treated in a just and fair manner* • *Voicing concerns about safety is encouraged* • *We get timely feedback on the safety issues we raise*
Communication	Extent to which staff are informed about safety-related issues in the ATM system	Important for ensuring staff are aware of system changes that might shape safety-related activities	• *Information about safety related changes within this organization is clearly communicated to staff* • *We learn lessons from safety related incident or occurrence investigations* • *I have good access to information regarding safety incidents or occurrences within the organization* • *There is good communication up and down the organization about safety*
Colleague commitment to safety	Beliefs about the reliability of colleagues' safety-related behavior	Highlights reliability of ANSP staff for engaging in safety activities	• *Everyone I work with in this organization feels that safety is their personal responsibility* • *I have confidence in the people that I interact with in my normal working situation* • *My colleagues are committed to safety*
Safety support	Availability of resources and information for safety management	Indicates active support within the institution for maintaining safety	• *We have sufficient staff to do our work safely* • *People in this organization share safety related information*

clusters provide an initial and pragmatic place to begin testing an international safety culture model.

We first hypothesize that the safety culture model (described in Table I) will operate reliably for operational staff and management across the four European clusters, indicating equivalence of constructs, measurement, and causal relations (**hypothesis 1a**), and support for the initial use of the four U.N. regions to cluster national ANSPs (**hypothesis 1b**). We expect to find this due to the bottom-up development of the safety culture questionnaire, which examines concepts that are critical to safety culture in all ANSPs (e.g., incident reporting practices), and was developed (i.e., items and dimensions) through an iterative process of interviews, observations, incident reports, and systematic literature review.[56,64]

To further examine the equivalence of responses to the safety culture questionnaire, it is necessary to test for the presence of acquiescent response styles, whereby individuals provide socially desirable answers and avoid negative extremities.[65] In short, high power distance, collectivism, and uncertainty avoidance can result in unwillingness to critique or disagree with the superiors or established state of affairs, presenting a potential confound in eliciting negative responses on safety culture questionnaires. Thus, in regions where these traits are highest, we expect to find a larger acquiescence response bias (**hypothesis 1c**).

3.2. Associations Between Safety Culture and National Culture

We also investigate whether variations in safety culture (at both the European-country and regional level) are associated with national cultural traits. We examine the relationship between individual country data on safety culture and independent data on Hofstede's national culture dimensions. To do this, we focus on country-level (and independent) national culture data to avoid common method bias. In particular, questionnaire measures of safety culture and national culture have notable similarities (e.g., beliefs on speaking up to authority), and to rigorously examine the association between safety culture and national culture, independence between measures is required.

Research investigating national culture within Europe indicates that while individual countries vary considerably in terms of norms and belief structures,[22,66] countries within a region (e.g., Northern Europe) tend to be reasonably similar.[67] We examine whether this is also the case for safety culture, and the relationship between safety culture and national culture. Short definitions of the dimensions described by Hofstede, their potential associations with safety management in ATM, and their variations in Europe are reported in Table II.

3.2.1. Examining Associations Between Safety Culture and National Culture

We initially consider the country-level relationship between safety culture and national culture. In terms of hypotheses, and using national norm data on Hofstede's dimensions,[22] we draw on the cross-culture and safety culture literatures to make a number of predictions on the relationship between these data and safety culture in European ANSPs.

First, we predict that safety culture will have a negative relationship with national norms on *collectivism* (**hypothesis 2a**). Soeters and Boer[36] indicate that low collectivism (i) reduces fear of endangering the harmony of relationships (e.g., through identifying problems), (ii) increases explicit communication behaviors, (iii) reduces embarrassment for making an error (increasing voluntary reporting), and (iv) decreases career-defensive behaviors (e.g., speaking up to authority). Furthermore, high collectivism, through emphasizing in-group harmony, can reduce willingness to critique or break group norms.[63] Thus, collectivism might be expected to be negatively associated with safety culture.

Second, we predict that safety culture will have a negative relationship with national norms on *power distance* (**hypothesis 2b**). High power distances are identified as influencing safety through (i) discouraging the correction of errors by superiors, (ii) placing primacy of communication and debate on a superior,[36] (iii) generating unwillingness to challenge authority, and (iv) creating asymmetrical communication between management and subordinates.[24] Conversely, low power distances facilitate open discussion of safety issues and proactive safety actions.[68]

Third, we predict that safety culture will have a negative relationship with national norms on *uncertainty avoidance* (**hypothesis 2c**). Uncertainty avoidance is indicated to aversely influence safety by (i) placing a greater reliance on technical solutions,[69] (ii) restricting innovation, (iii) defining more rigid rules and regulations, which (iv) make people more

Table II. Hofstede's National Culture Dimensions, Potential Associations with Safety Culture in Air Traffic Management, and National Norms Within European Regions

Dimension	Definition	National Culture Dimension Level (Low or High) and Potential Relevance for Safety Management in ATM	Norms in European Regions (1 Low to 4 High)
Collectivism	Societal members act predominantly as members of a long-standing group, or independently from the group	Low. Explicit communication on safety occurrences even when this contradicts group beliefs High. Concerns for group or organizational reputation is a barrier to error reporting	1. North Europe 2. West Europe 3. East Europe 4. South Europe
Power distance	Acceptance and expectation that power is distributed unequally	Low. There is willingness to report incidents and errors, and to challenge decision making High. Operational staff are unable to challenge management on safety-related issues	1. North Europe 2. West Europe 3. South Europe 4. East Europe
Uncertainty avoidance	The need to minimize anxiety caused by the occurrence of unknown and unusual circumstances	Low. Teams are able to collaborate and work flexibly during nonroutine scenarios High. Teams follow routines and do not innovate to solve novel and urgent problems	1. North Europe 2. West Europe 3. East Europe 4. South Europe
Masculinity	Balance of "masculine" values (e.g., materialism, competitiveness, power) over "feminine" values (e.g., relationships, quality of life)	Low. Management pay attention to personal matters (e.g., stress) that may adversely affect safety High. Teams overly focus on clear operational targets (e.g., increasing traffic demand) versus safety	1. North Europe 2. South Europe 3. West Europe 4. East Europe
Short-term orientation	Importance placed on the future (e.g., saving, adaptation) or past and present (e.g., respect for tradition, fulfilling social obligations)	Low. Past safety incidents are learnt from, with procedures and changes being gradually introduced so not to disrupt operations High. Increased pressure from management to increase and boost short-term performance	1. North Europe 2. West Europe 3. East Europe 4. South Europe

reliant on procedures that cannot prescribe all scenarios or when breaking rules is in the interest of safety.[70] This creates an overreliance on established practice and limits adaptive improvisation in normal and emergency situations. Uncertainty avoidance may also shape willingness to engage in behaviors that have threatening consequences (e.g., admitting an error, critiquing management on safety). Conversely, low uncertainty avoidance promotes flexibility, innovation on safety, and a willingness to engage in safety-related behaviors that have socially ambiguous outcomes.

Fourth, we predict that safety culture will have a negative relationship with national norms on *masculinity* (**hypothesis 2d**). Although the relationship between safety culture and masculinity has not generally been discussed, tentative hypotheses can be proposed. High masculinity might influence safety aversely by supporting competitive and target-focused behaviors that obstruct collaboration.[24] Conversely, low masculinity favors solidarity, consensus, and promotes collaboration.

Fifth, we predict that safety culture will have a negative relationship with national norms on *short-term orientation* (**hypothesis 2e**). As with masculinity, the relationship between safety culture and short-term orientation is relatively little discussed within the safety culture literature. Short-term orientation may impact negatively upon safety culture as it leads to (i) pressure on employees to focus on immediate gains, (ii) less planning and perseverance to attain long-term goals (e.g., a good safety record), and (iii) less awareness of safety culture from a holistic systems perspective. A short-term orientation may therefore lead to a focus on immediate safety challenges instead of on-going safety improvements.

3.2.2. *Examining Regional Differences in Safety Culture*

Having examined the relationship between safety culture and national culture at a country level, we extend our investigations to the European regional level. Interpretations of national data on safety culture may be better served if they are situated within a culturally relevant context. In particular, for each dimension of national culture, notable differences exist between the four European regions.[22] These are reported in Table II. The cross-cultural psychology literature highlights a range of factors that explain these differences. These factors include the valuing of intellectual self-expressiveness[60,63] and innovation[69] in Northern Europe, societal preferences for workplace egalitarianism in Western Europe,[60,61] and organizational preferences for authoritarian leadership[62,71] and reduced interpersonal directness[61] in Southern Europe and Eastern Europe.

In summary, regional differences in national culture at the European level are as follows. For Hofstede's dimensions of collectivism, power distance, and uncertainty avoidance (the three dimensions primarily associated with safety), the lowest scores are typically reported by countries in (1) Northern Europe, (2) Western Europe and Eastern Europe (alternating), and (3) Southern Europe (see Table II).

In terms of the hypotheses, we expect that safety culture data will follow a similar pattern of results, with responses being significantly different between regions, and the most positive scores being reported by (1) Northern Europe, then (2) Western Europe and Eastern Europe, and (3) Southern Europe. We test this for the six safety culture dimensions of: *management commitment to safety* (**hypothesis 3a)**; *incident reporting* (**hypothesis 3b**); *communication* (**hypothesis 3c**); *collaborating for safety* (**hypothesis 3d**); *colleague commitment to safety* (**hypothesis 3e**); and *safety support* (**hypothesis 3f**).

4. METHOD

4.1. Participants

The data were collected through a pan-European project for exploring ATM safety culture. In collaboration with EUROCONTROL (the ATM network manager for Europe), a methodology for investigating and improving safety culture was developed. The purpose was to aid ANSPs in identifying strengths and areas for development in safety management, to assess differences in safety culture between ANSPs, and to help ANSPs manage change in the ATM industry. Over a six-year period, 27 ANSPs have participated in the project (with access facilitated by EUROCONTROL).

For the current study, we report on recent safety culture questionnaires completed by staff in 17 ANSPs during the period 2011–2013. They were selected from the following European regions: Northern Europe (four countries), Western Europe (four countries), Eastern Europe (four countries), and Southern Europe (five countries). For reasons of anonymity and political sensitivity, the identities

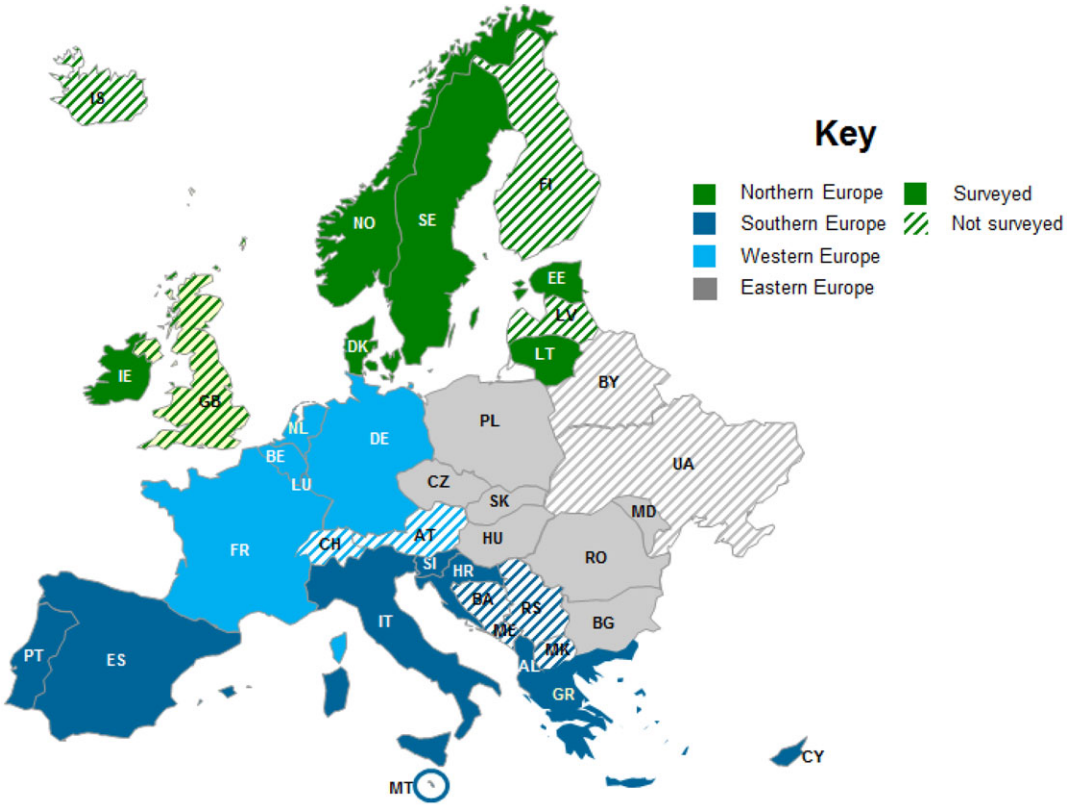

Fig. 1. Map of Europe showing the regions and 27 countries that have participated in the safety culture study up to April 2013 (countries that have used alternative surveys are presented as not surveyed).

of individual countries are not reported.[4] However, a map of all countries that have participated in the survey (since 2008) is reported in Fig. 1. All countries were given the opportunity to participate, but each chose to participate at a time that suited internal constraints (e.g., availability of staff, other surveys, and research).

In total, 10,717 members of staff responded, with an average response rate of 61% (see Table III). The mean size of the ANSPs was 1,191, while the range was 177 to 2,116. Of all participants, 5,176 (48.3%) had an operational role (i.e., air traffic controller, operational supervisor, aeronautical information services [AIS] specialist), and 1,230 (11.5%) had a managerial role. Demographic data on gender and age were not collected to ensure the anonymity of individuals and minority groups. To adjust for sampling differences across regions and occupational groups, weights were applied proportionally.

[4]The data collected within this study are highly sensitive for individual ANSPs, and for reasons of anonymity, we cannot specify the country locations. This is because the identification of a "nonoptimal" safety culture score can bring public and political pressure onto an ANSP (or any organization) to improve. Yet, conversely, such pressure can actually weaken safety culture through organizations feeling the need to (i) disguise safety problems (to avoid further embarrassment), and (ii) encourage "gaming" of safety culture (e.g., through staff being encouraged to respond positively to surveys) in order to achieve a "target" rather than a genuine improvement in safety culture.

4.2. Procedure

Questionnaires were administered electronically in 10 ANSPs (4,405 operational staff and 1,095 management staff, average 57% response rate); however, seven smaller ANSPS preferred a pen-and-paper method (711 operational staff and 135 management staff, average 67% response rate). No significant differences were found in the responses using different data-collection methods. ANSPs chose one format or the other for practical reasons (e.g., staff access to computers). In the case of paper questionnaires, ANSP safety management staff distributed the questionnaire (paper or electronic link), following onsite

Table III. Participant Response Rate for 17 ANSPs

		Operational Staff		Management Staff		
ANSP	Year	*N*	% of Survey Sample	*N*	% of Survey Sample	Overall Response Rate (%)
NE-1	2013	379	71%	42	8%	66%
NE-2	2013	231	50%	72	15%	69%
NE-3	2012	252	53%	46	10%	46%
NE-4	2012	86	49%	30	17%	70%
EE-1	2011	91	28%	21	6%	69%
EE-2	2011	105	59%	13	7%	22%
EE-3	2011	319	45%	41	6%	98%
EE-4	2013	83	42%	22	11%	63%
SE-1	2013	172	34%	58	12%	52%
SE-2	2011	47	57%	11	9%	92%
SE-3	2012	1,258	61%	128	6%	50%
SE-4	2012	311	60%	29	6%	78%
SE-5	2013	128	67%	9	5%	70%
WE-1	2012	904	43%	244	12%	36%
WE-2	2011	48	39%	9	7%	77%
WE-3	2012	226	58%	39	10%	57%
WE-4	2011	536	33%	416	26%	23%
Total		5,176	47%	1,230	11%	61%

promotion activities by both EUROCONTROL and ANSP safety management personnel. Due to shift rotations, questionnaires were available for completion for a period of four weeks. For practical reasons, questionnaires could be completed at work or home (poststudy feedback indicated most to be completed at work). The questionnaires were part of a mixed-methods investigation of safety culture at each ANSP, described previously,[56] with the results from the survey disseminated and discussed in workshops and interviews with staff from all backgrounds. Based on these workshops, a set of safety recommendations were developed.

4.3. Measures

The safety culture questionnaire scale was developed through theoretical analysis, interviews, and workshops with European ANSP staff, discussions with safety managers, pilot testing, experience reviews, and exploratory and confirmatory factor analysis (CFA).[56,64] The questionnaire is designed to reflect safety culture issues specific to ATM, to be understandable in all study locations, and uses well-established safety culture themes (e.g., management commitment to safety, incident reporting, and communication).[12] It was developed through pilot testing of a 36-item (six-dimension) scale, of which an earlier CFA showed a limited subset of items to operate reliably.[56] Further adaptations were made to develop the six-dimension model (see Table I) outlined in this article (i.e., removing items that did not operate reliably). The dimensions are: "Management commitment to safety" (three items), "Collaborating for safety" (four items), "Incident reporting" (three items), "Communication" (four items), "Colleague commitment to safety" (three items), and "Safety Support" (two items). Questionnaires were translated and back-translated (or partially translated, depending on the usage of English with the ANSPs) into the national language(s) of the ANSPs.

4.4. Analysis

To test the cross-cultural and cross-occupational measurement equivalence of the safety culture model (**hypotheses 1a–1b**), a multigroup confirmatory factor analysis (MGCFA) was performed on the eight groups (2: occupation × 4: region) using AMOS 19 (Amost Development Corp., Crawfordville, FL, USA). The steps taken followed Chen *et al.*'s[72] outline for second-order models, and the measurement equivalence literature.[50,72–74] After testing the model independently in each of the groups (step 0), measurement equivalence is tested through nine consecutive steps (summarized in Table IV) in order to establish the extent of measurement equivalence of the model. Goodness of fit was indicated by the

Table IV. Model Specification and Interpretation

Model		Model Interpretation
0	Separate tests for each group	The model holds in each group independently
1	Configural model, no constraints (bar identification)	The model holds across groups
2	First-order factor loadings invariant	First-order dimensions relate similarly to items across groups
3	First- and second-order factor loadings invariant	Second-order dimensions relate similarly to first-order dimensions across groups
4	First-order intercepts invariant	Groups have similar means on items[a]
5	First- and second-order intercepts invariant	Groups have similar latent means[a]
6	Covariance constrained	Second-order dimensions are equally correlated across groups
7	Factor variances constrained	Equal factor variances across groups
8	Residual errors constrained	Groups have equal residual errors
9	Measurement variances constrained	Groups have equal measurement errors

[a]Due to model's identification constrains put on the latent means these are similar in interpretation.

RMSEA (<0.08 a moderate fit; <0.06 a good fit) and CFI (≥0.90). Model comparison was based on ΔCFI (a more pragmatic approach than comparison of the chi-square[75]). The cut-off for a decrease in model fit was placed at ΔCFI < 0.01. To treat missing values, means and intercepts were estimated by AMOS 19 following full information maximum likelihood (FIML) estimation. As this procedure specifies a means structure, GFI and RMR fit indices were undefined and not calculated.[76]

To test for acquiescence effects (**hypothesis 1c**), acquiescence was measured by calculating the balance between having an acquiescent response style (i.e., agree/strongly agree) and a nonacquiescent response style.[65] Taking into account reversed items, the number of nonacquiescent responses was subtracted from the number of acquiescent responses and divided by the total number of items in the model. The acquiescence balance was taken up as a covariate and set to zero to eliminate the influence of the response style (the formula used was: acquiescence balance = $(n_{\text{agree, strongly agree}} - n_{\text{disagree, strongly disagree}})/ n_{\text{items}}$).

Subsequently, missing data were imputed following SPSS 21's estimation maximization (EM) procedure.[76] EM produces unbiased estimates when data are missing at random and is preferable over list- and pair-wise deletion.

Associations between safety culture and Hofstede's dimensions (**hypotheses 2a–2e**) were tested using Pearson correlations based on country scores and regional aggregates of scores. All European countries in Hofstede's work[22] were identified and ordered into the four European regions. Regional scores were calculated by averaging the country scores.

A Multivariate ANalysis Of VAriance (MANOVA) was performed using SPSS 21 (SPSS, Inc., Chicago, IL, USA) to test cross-regional effects on the dimensions of the model (**hypotheses 3a–3f**). A MANOVA is a statistical test procedure for comparing multivariate (population) means of several groups. Though a significance level of $p \leq 0.05$ was used, effect sizes were given interpretative weight due to the large sample and increased possibility of statistical significance (small ≥ 0.01; medium ≥ 0.06; large ≥ 0.14).[77]

5. RESULTS

5.1. Descriptive Data

For the study dimensions, means and standard deviation scores were calculated for each country, region, and occupational group. These are reported in Table V.

5.2. Multigroup Confirmatory Factor Analysis (Hypotheses 1a–1b)

The MGCFA tested **hypotheses 1a–1b** (that a reliable model for measuring safety culture would be found) through establishing the cross-cultural equivalence of the factor model (see Table VI). Independent tests (model 0) showed moderate to good fit for operational and management staff across Europe (CFIs 0.884–0.936; RMSEAs 0.061–0.074). The results indicated that the model had a possible weaker fit for Western European operational staff (CFI 0.884; RMSEA 0.069 [0.066–0.073]). The model, however, held consistently across groups as the configural model (model 1) had a good fit (CFI

Table V. Mean Scores and Standard Deviations of the Safety Culture Dimensions Shown by European Region and Occupational Group

		Northern Europe		Eastern Europe		Southern Europe		Western Europe		Total	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Management commitment to safety	Operational	4.24	0.72	3.71	0.86	2.50	1.19	3.47	0.87	3.48	1.12
	Managers	4.44	0.62	4.03	0.77	4.03	0.91	3.90	0.76	4.10	0.80
Collaborating for safety	Operational	3.99	0.61	3.40	0.74	2.80	0.77	3.31	0.66	3.37	0.82
	Managers	4.06	0.58	3.66	0.67	3.60	0.65	3.60	0.59	3.73	0.65
Incident reporting	Operational	4.08	0.69	3.00	0.99	2.26	0.93	3.23	0.84	3.14	1.09
	Managers	4.17	0.65	3.37	0.84	3.55	0.81	3.42	0.74	3.63	0.83
Communication	Operational	3.93	0.64	3.22	0.83	2.42	0.89	3.33	0.66	3.22	0.94
	Managers	3.97	0.70	3.55	0.83	3.58	0.81	3.41	0.56	3.63	0.76
Colleague commitment to safety	Operational	4.31	0.57	3.91	0.67	3.87	0.74	3.90	0.66	3.99	0.69
	Managers	4.24	0.63	3.87	0.65	3.88	0.69	3.77	0.66	3.94	0.68
Safety support	Operational	4.14	0.73	3.37	0.96	2.51	1.00	3.24	0.87	3.31	1.07
	Managers	4.03	0.74	3.52	0.92	3.48	0.83	3.21	0.83	3.56	0.88

0.918; RMSEA 0.024 [0.023–0.024]). This established model validity across regions and occupations (**hypotheses 1a–1b**).

Consecutive steps indicated that across the eight groups relations were equal among items and first-order dimensions (model 2), and between first- and second-order dimensions (model 3). Constraining first- and second-order factor loadings did not result in a significantly worse fit (i.e., ΔCFI = –0.011 and –0.008). Constraining first-order intercepts across all groups (model 4), however, resulted in a significantly worse fit (i.e., ΔCFI = –0.152). This was likely explained by variation among operational staff as the partial intercept invariance model (model 4a) constraining only managers across Europe resulted in a borderline decrease of fit (i.e., ΔCFI = –0.015). Model 5 had no significant additional meaning due to model identification constraints and therefore model 4a indicated possible latent mean differences among operational staff, but not management staff.

Taking this partial first-order intercept invariance into account, the final steps (models 6 to 9) indicated that constraining covariances (ΔCFI = –0.007), factor variances (ΔCFI = –0.010), and residual errors (ΔCFI = –0.013) did not result in a significantly worse fit. Measurement error invariance could, however, not be established as it resulted in a significantly worse fit (ΔCFI = –0.091). Although beyond step 3 CFIs dropped below 0.90, the RMSEAs indicate a good fit. These results are summarized in Table VI, and support **hypotheses 1a and 1b**. Additionally, step 4a indicated that regional differences between managers and operational staff may exist in safety culture scores.

*5.2.1. Acquiescence Effects (**Hypothesis 1c**)*

Results suggested that responses across regions may have been influenced by an acquiescence effect $F(3,6465) = 725.07$, $p < 0.001$, $\eta^2 = 0.252$. Yet this was present for every region, and thus no support was found for **hypothesis 1c**.

5.3. Associations Between Safety Culture and Hofstede's Dimensions (Hypotheses 2a–2e)

Safety culture dimensions were expected to have a negative relationship with collectivism, power distance, uncertainty avoidance, masculinity, and short-term orientation. Pearson's correlations indicated that Hofstede's country-level national cultural traits had small to moderate and negative associations with

Table VI. Multigroup Confirmatory Factor Analysis

	Model	$\chi 2$	*df*	CFI	Compare	ΔCFI	$\Delta\chi 2$	RMSEA	90% CI RMSEA	
0	Operational Staff	2,812.731	143	0.951				0.060	0.058	0.062
	Management	693.260	143	0.937				0.056	0.052	0.060
	Northern Europe (NE)	777.617	143	0.938				0.062	0.058	0.067
	Eastern Europe (EE)	704.868	143	0.936				0.062	0.057	0.066
	Southern Europe (SE)	1,399.423	143	0.932				0.070	0.066	0.073
	Western Europe (WE)	1,648.875	143	0.892				0.066	0.063	0.069
	NE Operational staff	691.289	143	0.936				0.064	0.059	0.68
	NE Management	272.008	143	0.929				0.069	0.057	0.082
	EE Operational staff	660.507	143	0.932				0.063	0.058	0.068
	EE Management	214.283	143	0.929				0.063	0.045	0.080
	SE Operational staff	1,227.284	143	0.925				0.069	0.065	0.072
	SE Management	302.886	143	0.919				0.074	0.062	0.085
	WE Operational staff	1,322.281	143	0.884				0.069	0.066	0.073
	WE Management	517.137	143	0.900				0.061	0.055	0.067
1	Configural, no constraints	5,209.517	1,144	0.918				0.024	0.023	0.024
2	First-order factor loadings invariant	5,855.917	1,235	0.907	2 vs. 1	−0.011	646.400	0.024	0.024	0.025
3	First- and second-order factor loadings invariant	6,237.763	1,256	0.899	3 vs. 2	−0.008	381.846	0.025	0.024	0.026
4	First- and second-order factor loadings; first-order intercepts invariant	13,900.640	1,389	0.747	4 vs. 3	−0.152	7,662.877	0.038	0.037	0.038
4a	Constrain managers only	7,025.874	1,313	0.884	4a vs. 3	−0.015	788.111	0.026	0.025	0.027
5	First- and second-order factor loadings; first- and second-order intercepts invariant	7,025.874	1,313	0.884	5 vs. 4a	0.000	0.000	0.026	0.025	0.027
6	Covariance constrained	7,432.136	1,334	0.877	6 vs. 5	−0.007	406.262	0.027	0.026	0.027
7	Factor variances constrained	7,570.422	1,355	0.874	7 vs. 6	−.010	138.286	0.027	0.026	0.027
8	Residual errors constrained	8,103.821	1,397	0.864	8 vs. 7	−0.013	533.399	0.027	0.027	0.028
9	Measurement variances constrained	12,251.038	1,530	0.783	9 vs. 8	−0.091	4,147.217	0.033	0.033	0.034

all safety culture dimensions (confirming **hypotheses 2a–2e**).

At the regional level, these effects were in the same direction as at the country level, but the correlations were slightly stronger for most safety culture dimensions' associations with collectivism, except for *colleague commitment to safety*. Regional effects of power distance, uncertainty avoidance, short-term orientation, and masculinity were roughly similar to country-level effects. The correlations are summarized in Table VII.

5.4. Multigroup Analysis of Variance (Hypotheses 3a–3f)

To test for a main effect of European regions, a MANOVA with Bonferroni *post hoc* analysis was conducted. Mean scores and standard deviations are presented in Table V. An initial 2 (occupational group) by 4 (European regions) MANOVA indicated that European regions differed moderately to largely on the safety culture dimensions, $F(3,6399)$s ≥ 155.41, ps < 0.001, η^2s between 0.067 and 0.234.

5.4.1. Post Hoc *Analysis of Regional Differences*

It was predicted that differences in safety culture would reflect regional norms for Hofstede's dimensions **(hypotheses 3a–3e)**, with (1) Northern Europe most positive, and then (2) Western Europe and Eastern Europe (alternating), and (3) Southern Europe. *Post hoc* ANOVAs (Bonferroni) on the differences between regional means indicated that European regions scored significantly differently from each other on the safety culture dimensions. To summarize, the pattern was that (1) Northern Europe scored most favorably, followed by (2) Eastern and Western Europe, with (3) Southern Europe having the least favorable scores. The relative position of Eastern and Western Europe varied, with mean differences between these two regions being absent or smaller than for other regions (MDs ≤ 0.25, ps between *ns* and 0.001). But they consistently scored between Northern and Southern Europe. This was the case for *management commitment to safety* (MDs ≥ 0.43, ps < 0.001; supporting **hypothesis 3a**), *incident reporting* (MDs ≥ 0.47, ps ≤ 0.001; supporting **hypothesis 3b)**, *communication* (MDs ≥ 0.54, ps < 0.001, supporting **hypothesis 3c**), *collaborating for safety* (MDs ≥ 0.42, ps < 0.001; supporting **hypothesis 3d)**, and *safety support* (MDs ≥ 0.38, ps < 0.001; supporting **hypothesis 3f**). Yet, for *colleague*

Table VII. Pearson Correlations Among the Safety Culture and Hofstede's Dimensions at the Region (R) and Country (C) Level

	Collectivism		Power Distance		Uncertainty Avoidance		Masculinity		Short-Term Orientation	
Dimension	R	C	R	C	R	C	R	C	R	C
Management commitment	−0.25	−0.13	−0.16	−0.16	−0.34	−0.30	−0.08	−0.10	−0.32	−0.36
Collaborating for safety	−0.27	−0.19	−0.21	−0.17	−0.37	−0.33	−0.15	−0.23	−0.32	−0.38
Incident reporting	−0.35	−0.19	−0.32	−0.28	−0.45	−0.40	−0.23	−0.28	−0.37	−0.34
Communication	−0.29	−0.16	−0.22	−0.21	−0.37	−0.35	−0.14	−0.16	−0.33	−0.33
Colleague commitment	−0.13	−0.13	−0.15	−0.20	−0.23	−0.27	−0.18	−0.14	−0.13	−0.13
Safety support	−0.24	−0.20	−0.19	−0.26	−0.38	−0.38	−0.16	−0.14	−0.30	−0.36

ps < 0.001 (two-tailed). $n = 6{,}407$ (weights apply).

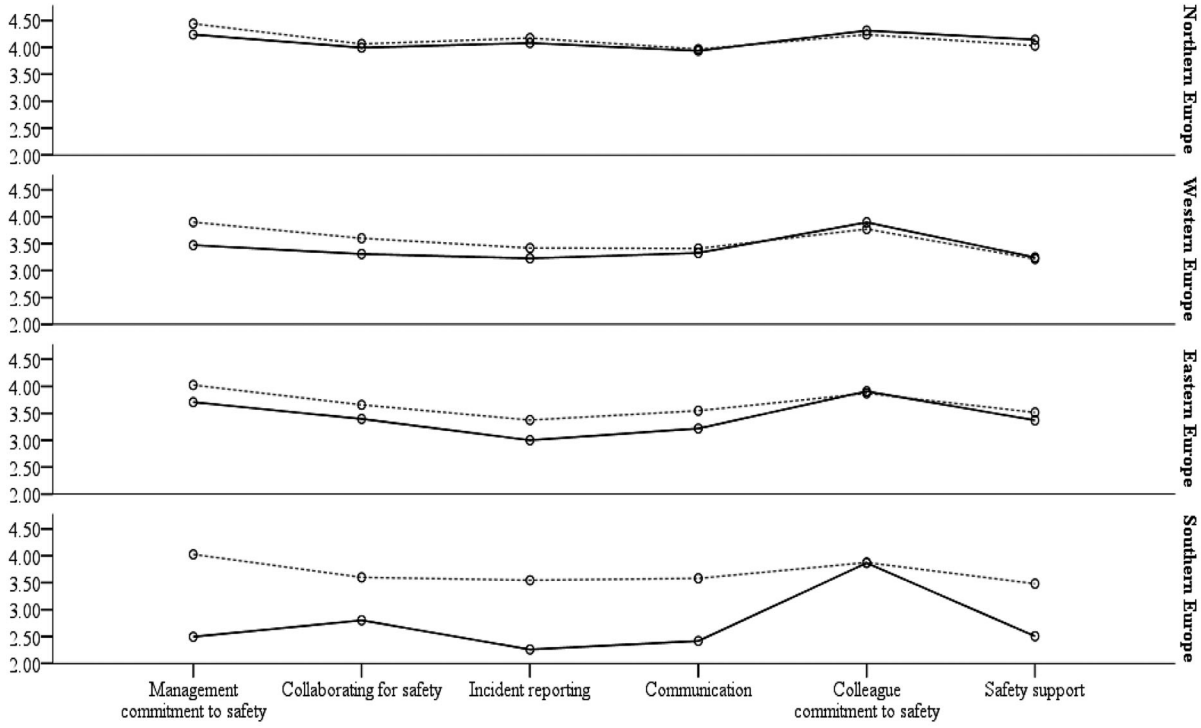

Fig. 2. Cross-regional differences for operational staff (straight line) and management (dashed line).

commitment to safety this trend was not observed, and **hypothesis 3e** was not supported.

5.4.2. Additional Observations

Finally, further inspection of the MANOVAs found managers to perceive safety culture more positively than operational staff across Europe: $F(1,6399)$s ≥ 129.22, ps < 0.001, η^2s between 0.019 and 0.117, except colleague commitment to safety, $F(1,6399) = 11.85$, $p = 0.001$, $\eta^2 = 0.002$. Inspection of effect sizes indicated that differences between operational and management staff on perceptions of safety culture were larger within some regions (e.g., Southern Europe: $F(1,6399)$s ≥ 512.33, ps < 0.001; η^2s between 0.074 and 0.168) than others (e.g., Eastern Europe: $F(1,6399)$s ≥ 56.29, ps ≤ 0.001, η^2s between 0.009 and 0.013). Differences were absent or negligible for Northern Europe, $F(1,6399)$s ≥ 0.87, ps < 0.350, η^2s ≤ 0.004, *colleague commitment to safety* within each region, *safety support* in Eastern and Western Europe, and *incident reporting* and *communication* for Western Europe. Fig. 2 illustrates the differences in group perceptions of safety culture.

6. DISCUSSION

A number of notable findings can be highlighted from the current investigation. First, we established the psychometric properties of a safety culture questionnaire for ATM across four European regions (outlined by the United Nations), with psychometric equivalence being established for the safety culture model. To our knowledge, this is the first time it has been demonstrated that safety culture can be reliably measured and investigated in different cultural contexts.

Second, we found safety culture to be associated with national norms on Hofstede's five dimensions of national culture. In addition, the rank-order of European regions on the safety culture dimensions was generally predicted by regional cultural norms, except for colleague commitment to safety. These findings have not been demonstrated before, and they underline a potential relationship between national cultural tendencies and safety culture, with considerable implications for how safety culture is conceptualized and understood.

Third, managers were observed to assess safety culture more positively than operational staff. This is consistent with the research literature.[24,78]

However, differences between operational and management staff were larger for some regions (e.g., Southern and Eastern Europe) than others (e.g., Northern Europe). This may reflect differences in how operational and management staff communicate on safety (e.g., for sharing employee concerns, or for discussing management commitment to safety),[79] with such practices potentially shaped by national culture (e.g., power distance). Understanding these differences will be the focus of future research.

Finally, although the study hypotheses were supported, several anomalous findings emerged. In particular, national culture did not interact consistently with the dimension of colleague commitment to safety, and this may be due to this dimension referring primarily to group practices rather than organizational norms.

6.1. Theoretical Implications

The study results raise a number of theoretical considerations. For the first time, a safety culture model that is reliable and functionally equivalent in different cultural environments has been established. This indicates that safety culture can be investigated and measured in a range of cross-cultural environments, yet in doing so, associations between national culture and safety culture must be considered.

In particular, we found safety culture to be associated with characteristics of national culture. Although not causal, the associations are hypothesized to occur because a high power distance culture may reduce the openness of communication on safety (e.g., placing primacy on communication from superiors, generating unwillingness to challenge authority), and a collectivist culture may create tendencies to maintain group harmony (e.g., through not challenging unsafe group activity). High uncertainty avoidance cultures may create an overreliance on established practice that limits innovation and flexibility. Masculinity and short-term orientation may create a focus on competition and immediate gains over long-term interests. The findings are consistent with work showing cultural differences to influence how risks are perceived and accepted,[28,80] and there is a need to understand how other national factors (e.g., regulation, training) might shape safety culture,[81] alongside factors such as language and communication methods.[82]

In terms of safety culture theory, the study indicates the need to consider how safety culture is embedded within societal practices. This further distinguishes safety culture from safety climate, and emphasizes the importance of considering the emergent and shared nature of safety culture[83] in whichever context it is studied. Douglas[84] and other authors,[3,8,86-88] have argued that cultures of risk are inherently social and political, and because definitions of safety are often ambiguous and socially constructed (e.g., by management or government[89–91]), institutions develop safety norms and taboos that are constructed around group boundaries, identity, and conflicts of interest.[3,84,92]

For safety climate, however, there are also implications. In particular, given the conceptual and methodological overlap with safety culture, it is likely that safety climate can also be measured reliably in different national environments. Furthermore, the strong association between "management commitment" and "long-term orientation" scales indicates a potential relationship between societal tendencies and safety climate for short-term goals (i.e., production vs. safety). Finally, acknowledging research demonstrating the importance of supervisors in shaping safety climate in work units,[12] future research may examine whether supervisors moderate the relationship between national culture and safety climate.

The findings of the current study indicate that considering issues such as power, social constructionism, and national worldviews[93] is necessary if safety culture research is to go beyond methodological individualism and become truly cultural. However, some caution is also required. The aim of the current study is not to identify whether some national cultures produce "safer organizations." Rather, it is to understand how national culture might influence safety culture, and how this knowledge can be used to better understand safety-related practices. For example, where national culture shapes behavioral tendencies (e.g., avoiding face-threatening acts[94]) and thus safety (e.g., highlighting supervisor error), interventions to enhance safety will need to reflect the cultural context (i.e., in training, protocols, management engagement with staff). Furthermore, where safety culture scores are lower, this does not necessarily indicate ATM to be unsafe, as what is considered "good" or "poor" is partially contextual. Our future investigations will focus on how, and whether, it is really possible to "benchmark" safety culture data from one country against another.

Finally, as ATM is a global industry, it is necessary to examine whether the safety culture model is generalizable beyond Europe (e.g., the United States, Asia), and whether the associations between

national culture and safety culture are also present. Furthermore, to improve our understanding of how organizations might influence the relationship between national culture and safety culture, future research may wish to examine international safety culture in a single organization (e.g., an airline) that operates globally, yet is managed centrally from one nation (unlike ATM, where each country has its own ANSP).

6.2. Practical Implications

In terms of practical implications, the study has implications for the ATM industry, and also other high-risk industries.

Through developing a model of safety culture that is reliable and functionally equivalent for different national environments, comparisons of ATM safety culture in different countries can be undertaken. This might be useful for identifying problems in safety management, recognizing good practice, and for facilitating learning on safety at a global-level.[95] Such insight would be useful for identifying safety problems across an international system, and for targeting resources and know-how. However, in performing comparisons of safety culture from different countries, interpretation of data and trends will be enhanced through considering the normative cultural properties of countries and regions. For example, through qualitative examination of the survey data (e.g., in workshops), context-specific enablers and barriers to safety culture can be identified. In the current study, post-survey workshops shed light on participant response patterns, and allowed discussion of cultural-relevant stories and scenarios to help understand safety culture (e.g., relating to high power distance). This can support the development of interventions (e.g., focusing on listening and communication skills for management) that are relevant for sharing among peer countries.

Also important is the observation that operational and management staff differ in perceptions of safety culture, with differences potentially indicating mismatching expectations or awareness of safety practices. Such observations lend themselves to practical steps, with clear communication on risk (e.g., incident reporting, change, safety threats) being important for avoiding confusion on safety-related practices, and promoting trust in manager and colleague commitment to safety. The role of national culture as an influencer of risk communication between managers and operational staff is unclear, yet appears important for practice (i.e., for identifying effective modes of communication). While sociocultural theories are well established within the risk communication literature,[93] investigations of risk communications in international industries are few,[96] and we encourage future research.

In relation to the aviation industry more broadly, safety culture assessment might be better integrated into measures of performance in the ATM industry, which primarily focuses on traffic management and cost efficiency. However, to do this it is necessary to identify thresholds whereby safety culture scores are considered poor or good, and protocols for taking action where safety culture is found to be suboptimal (i.e., actively using safety culture as a leading indicator of safety performance). Also, the model developed here might be extended more broadly to measure safety culture across the aviation industry (e.g., airlines, manufacturers), and to develop an integrated domain approach to safety culture measurement in aviation.

6.3. Limitations

Several limitations require discussion. This study primarily relied on cross-sectional data to assess safety culture, yet holistic safety culture assessment includes both quantitative and qualitative research.[18] The safety culture model was developed through a bottom-up process, which is both a strength (i.e., it is tailored to ATM) and a weakness (i.e., it cannot be compared with previous models). The extent to which more generic (i.e., non-industry tailored) measures of safety culture can function cross-culturally is unclear. The research did not collect safety outcome data, and did not link national and safety culture to safety performance. Furthermore, of the safety culture scales themselves, the "safety support" scale only consisted of two items, and its face validity is not ideal.

The utilization of Hofstede's national culture dimensions to conceptualize and measure national culture is debatable,[40] as was the use of theoretically derived (rather than data-driven) national cultural clusters.[58,67] Concerns relate to the simplification of highly complex cultures, the metrication of national culture, cultural relativism, and utilizing national data to explore micro-level problems. We did not sample participants using Hofstede's national culture measures to avoid common method bias, but the national norm data may not reflect the sample used in this study. Finally, local constraints meant

data collection involved two methods (electronic and paper), with a marginal difference in response rates being observed.

6.4. Conclusion

We have demonstrated that industry-tailored safety culture models can operate reliably across national boundaries and occupational groups. This indicates that safety culture can be measured and compared in different countries, with implications for research and practice. Furthermore, we have shown safety culture to be associated with national culture. This has not been demonstrated before, and underlines the importance of understanding national cultural contexts when collecting and interpreting safety culture data, and for establishing the directionality of the national culture and safety culture relationship.

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