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SAFETY CULTURE ASSESSMENT IN

HIGH RELIABILITY ORGANIZATIONS:

THE USE OF QUESTIONNAIRES IN

THE NUCLEAR INDUSTRY

DOCTORADO EN PSICOLOGÍA DE LOS RECURSOS HUMANOS

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TESIS DOCTORAL

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This doctoral thesis has certainly been a unique journey; little did I know what was awaiting me when I decided to embark on it.

This process has driven me to extreme highs and lows, self-actualization and frustration, joy and despair, determination to run the extra mile and thoughts of giving up. The pressures of juggling a demanding full time job and looking after a beautiful family with scientific research and investigation have made everything thrilling and challenging.

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GENERAL INTRODUCTION AND THESIS STRUCTURE / INTRODUCCIÓN GENERAL Y ESTRUCTURA DE LA TESIS

The birth of nuclear technology in 1942 opened the door to major technological developments and enhancements. After decades of research in the field, nuclear technologies currently offer a wide range of valuable applications, such as in food and agriculture (e.g., less environmentally-damaging fertilizers; genetic variability in plant breeding to develop vegetables and fruits that are more resistant to pests and more adaptable to rough weather conditions; food preservation techniques); in hydrology (e.g., precise tracing and measurement of underground water resources); in transportation (e.g., propulsion systems like nuclear-powered ships or space vehicles); in medicine (e.g., accurate medical diagnostic procedures; less invasive and more effective medical therapies and treatments; cheaper and more effective sterilization of medical products); industry and research (e.g., measurement of nature and levels of presence of gases, liquids and solids; gauging thickness and density of materials); and of course, in electricity generation by means of Nuclear Power Plants (NPPs from this point on).

The use of NPPs for electricity generation has led to increasing controversy since its beginnings. Nuclear energy is efficient, cleaner than fossil fuels, and reliable (i.e., its production does not depend on weather conditions). 447 power reactors are in operation today (2017) to satisfy our energy demands. However, nuclear energy is also the most threatening form of energy production for human beings. Thus, to a greater or lesser extent, safety has been, is, and will be in the spotlight in the operation of NPPs.

The XXI century has signified a new era in the field of energy, bringing major organizational, technological, and regulatory changes, among others, that further challenge the inherent complexities in the safe operation of NPPs. One example is the progressive deregulation of markets, which has increased organizational mergers and acquisitions and competition between producers of nuclear power. This stiffer competition forces NPPs to employ cost-saving strategies, such as reducing qualified operative personnel and outsourcing certain functions that were previously operated and controlled inside NPPs (Itoigawa and Wilpert, 2005). These measures inevitably contribute to a loss of knowledge and competencies within nuclear operations (Itoigawa and Wilpert, 2005).

In addition, the nuclear industry has typically been operated by engineers with a technical background (e.g., physics, chemistry, mechanics, electronics), and therefore from an engineering point of view. Thus, the nuclear industry has given greater weight to the development of safe nuclear technologies, without paying enough attention to the human factor in the safe operation of NPPs (Martínez-Córcoles, 2012).

Despite the secondary role played by the human factor and organizational management (as opposed to technical and engineering concerns) in the nuclear industry, human error has been shown to be a primary contributor to the risks and reliability of High Reliability Organizations[1] (hereinafter, HROs): over 80% of

[1]Although there is no accepted definition of High Reliability Organizations (HRO), they have been distinguished as organizations that achieve reliability and organizations that seek reliability, understanding reliability as the low probability of making errors. An example of the first conceptualization is presented by Roberts (1990), who considers HROs to be a subset of hazardous organizations that has "enjoyed a record of high safety over long periods of time" (p. 160). An example of the second, and probably most accepted conceptualization, is found in Rochlin (1993), for whom HRO are not characterized by "their absolute error or accident rate, but by their effective management of innately risky technologies through organizational control of both hazard and probability" (p. 17). Weick and Sutcliffe (2007) propose that HROs share five characteristics: 1) they are intrinsically preoccupied with potential errors and sensitive to early signs of failure; 2) reluctant to accept simplifications that may improve efficiency but expose to risks; 3) sensitive to operations, to the front line, where the real work gets done; 4) committed to resilience, to face

accidents in chemical and petro-chemical industries (Kariuki and Lowe, 2007); over 75% of marine accidents (Ren, Jenkinson, Wang, Xu and Yang, 2008); over 70% of aviation accidents (Helmreich, 2000; Hollnagel, 1993); and over 90% of accidents in the nuclear industry (Reason, 1990).

The study of the causes behind accidents in HROs has revealed that the existing culture of an organization and how it crystallizes in the behaviors displayed by employees and in the way the organization is managed, are determinant for the organizational safety outcomes (as seen in following reports: Baker, 2007; BEA, 2012; CAIB, 2003; Cullen, 1990; Committee on Lessons Learned from the Fukushima Nuclear Accident for Improving Safety and Security of U.S. Nuclear Plants, 2014; Dawson and Brooks, 1999; Fennell, 1988; HAEA, 2003; Hidden, 1989; IAEA, 1986; Sheen, 1987). In this context, the concept of safety culture has been used in all hazard industries during the past three decades as the guiding principle to understand the influence of organizational cultural elements on safety and as the cornerstone upon which to build safe HROs. However, despite the efforts of researchers and practitioners in all these years, safety culture continues to be difficult to understand as a theoretical concept and difficult to address in organizational practice.

If the safety culture of an organization is at the core of its positive and negative safety outcomes, optimizing this safety culture becomes essential for HROs in general and for NPPs in particular. However, in order to know how to optimize a particular safety culture (which aspects need to be reinforced,

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failures and to learn from them; 5) and prioritize expertise to face complexities and vulnerabilities. Main industries targeting HROs include: nuclear, aviation, space, marine, chemical, gas, petrochemical, firefighting, emergency healthcare, and military.

improved, or eliminated), we first need to able to understand, capture, and assess that safety culture.

The main goal of this thesis is to provide an overview of the current ways of understanding, dealing with, and assessing safety culture, putting a particular emphasis on use of questionnaires in the nuclear industry, and provide guidance to researchers and practitioners about how to capture the safety culture of NPPs. For this purpose, the current thesis includes the following chapters:

CHAPTER I - A brief introduction to the nuclear industry is presented. We will present some of the most noteworthy pros and cons of nuclear energy and some of the most important challenges the nuclear industry has been facing in recent years. The last part of the chapter explains how safety has been particularly understood and preserved in hazardous industries at different times.

CHAPTER II - The concept of organizational culture (its origins and definition) and the socio-anthropological and organizational psychology approaches to organizational culture are described. In this chapter, we also explain that culture is composed of different content levels (from deeper to more superficial levels), and we describe cultural level classifications proposed by different authors.

CHAPTER III - We aim to clarify the concept of safety culture. On the one hand, we perform an analysis of the content of 40 of the most widely used definitions of safety culture and identify the main commonalities of the definitions. On the other hand, we address the relationship between safety culture and the organizational culture and safety climate constructs.

CHAPTER IV - This chapter deals with the assessment of safety culture. It is divided into three blocks: in the first place, pros and cons of qualitative and quantitative strategies for safety culture assessment are described; secondly, 20 of the most relevant safety culture questionnaires are presented, and analyses and conclusions from the contents of these dimensions are offered. And lastly, a further explanation is provided of questionnaires based on models of organizational culture or on models of safety culture, as well as a description of the corresponding models.

CHAPTER V - We present the study goals, samples, and variables used in greater detail, and the statistical analyses performed in the three empirical studies presented in the next three chapters.

CHAPTER VI - This chapter contains our first empirical study on safety culture assessment. We take the first steps to empirically validate the widely used model of safety culture of the International Atomic Energy Agency (IAEA, 2006a).

CHAPTER VII - Our second empirical study. Here, we develop a three-dimensional safety culture model and a safety culture questionnaire (the Safety Culture Enactment Questionnaire [SCEQ]), designed to assess the degree to which safety is an enacted value in HROs and NPPs. The aim of this study is to empirically validate both the questionnaire and the dimensionality of the corresponding model.

CHAPTER VIII - Our third empirical study. By studying the extent to which the Safety Culture Enactment Questionnaire (SCEQ) and the Organizational Culture Inventory (OCI) can predict safety performance in a NPP, we shed light on the usefulness of safety culture and organizational culture assessment tools for the nuclear industry. Moreover, we gather further evidence for the validation of both questionnaires.

CHAPTER IX - This chapter offers a general discussion, which includes a summary of the results obtained, the main contributions of the thesis, the scope of the work presented and future research areas in safety culture.

CHAPTER X - We finish this thesis with five general conclusions for those interested in our work.

INTRODUCCIÓN GENERAL Y ESTRUCTURA DE LA TESIS

El surgimiento de la energía nuclear en 1942 desencadenó importantes cambios y mejoras tecnológicos. Tras décadas de investigación en este ámbito, actualmente la tecnología nuclear ofrece una alta variedad de valiosas aplicaciones, tales como en alimentación y agricultura (p.e., fertilizantes menos dañinos para el medio ambiente; variabilidad genética en el cultivo para desarrollar frutas y vegetales más resistentes a las plagas y más adaptativas ante duras condiciones climáticas); en hidrología (p.e., trazabilidad y medición precisa de los recursos hídricos subterráneos); en el transporte (p.e., sistemas de propulsión nuclear en buques o vehículos espaciales); en medicina (p.e., procedimientos diagnósticos precisos, terapias y tratamientos médicos menos invasivos y más eficaces, esterilización más económica y más eficaz de productos médicos); en industria e investigación (p.e., medición de la naturaleza y niveles de presencia de gases, líquidos y sólidos; calibración del espesor y densidad de los materiales); y por supuesto, en la generación de electricidad a través de centrales nucleares.

El uso de centrales nucleares para la generación de electricidad ha generado una creciente controversia desde sus inicios. La energía nuclear es eficiente, más limpia que los combustibles fósiles y fiable (es decir, su producción no depende de las condiciones climáticas). 447 reactores operan hoy en día (2017) para satisfacer nuestras demandas de energía. Sin embargo, la energía nuclear es también la forma más amenazante de producción de energía para los seres humanos. Así, en mayor o menor medida, la seguridad ha sido, es, y será el centro de atención del funcionamiento de las centrales nucleares.

El siglo XXI ha significado una nueva era en el campo de la energía, con importantes cambios organizacionales, tecnológicos y regulatorios, entre otros, que desafían aún más la complejidad inherente a la operación segura de las centrales nucleares. Un ejemplo es la desregulación progresiva de los mercados, lo que ha aumentado las fusiones y adquisiciones organizacionales y la competencia entre los productores de energía nuclear. Esta feroz competencia obliga a las centrales nucleares a emplear estrategias de ahorro de costos, tales como la reducción de personal operativo cualificado y la subcontratación de ciertas funciones que antes se operaban y controlaban dentro de las centrales nucleares (Itoigawa y Wilpert, 2005). Estas medidas contribuyen inevitablemente a la pérdida progresiva de conocimientos y competencias en operación dentro de las centrales (Itoigawa y Wilpert, 2005).

Además, la industria nuclear ha sido operada típicamente por ingenieros con un bagaje y experiencia técnicos (p.e., física, química, mecánica, electrónica) y, por lo tanto, desde el punto de vista de la ingeniería. Así, la industria nuclear ha dado más peso al desarrollo de tecnologías nucleares y barreras físicas para operar de manera segura, sin prestar la suficiente atención al factor humano en dicha operación (Martínez-Córcoles y cols., 2012).

A pesar del papel secundario desempeñado por el factor humano y la gestión organizativa (en oposición a la gestión técnica y de ingeniería) en la industria nuclear, se ha demostrado que el error humano contribuye de manera fehaciente a los riesgos y a la fiabilidad de las organizaciones[2] (de ahora en adelante, "HROs"): más del 80% de los accidentes en las industrias química y petroquímica (Kariuki y Lowe, 2007); más del 75% de los accidentes marítimos (Ren, Jenkinson, Wang, Xu y Yang, 2008); más del 70% de los accidentes de aviación (Helmreich, 2000; Hollnagel, 1993); y más del 90% de los accidentes en la industria nuclear (Reason, 1990) se deben al factor humano.

[2]Aunque no hay una definición aceptada de las Organizaciones de Alta Fiabilidad (HRO), éstas se han distinguido como organizaciones que (1) logran una operación fiable y (2) buscan la alta fiabilidad en sus operaciones, entendiendo la fiabilidad como la baja probabilidad de cometer errores en la operación pese a la complejidad de los sistemas involucrados. Un ejemplo de la primera conceptualización es presentado por Roberts (1990), quien considera que los HRO son un conjunto de organizaciones peligrosas que han "gozado de un registro de alta seguridad durante largos períodos de tiempo" (p.160). Un ejemplo de la segunda conceptualización, y probablemente la más aceptada, se encuentra en Rochlin (1993), para quien las HROs no se caracterizan por "su error absoluto o tasa de accidentes, sino por el manejo efectivo de tecnologías inherentemente peligrosas mediante el control tanto de los riesgos como de la probabilidad"(p.17). Weick y Sutcliffe (2007) proponen que las HROs comparten cinco características: 1) están intrínsecamente preocupadas por errores potenciales y son sensibles a los primeros signos de fallo/error; 2) son reacias a aceptar simplificaciones que puedan mejorar la eficiencia, pero que al mismo tiempo puedan exponer la operación a riesgos; 3) son sensibles a las operaciones, especialmente en la primera línea, donde se realiza el trabajo de base (p.e., mantenimiento de equipos); 4) están comprometidas con la resiliencia, enfrentando fallos/errores y aprendiendo de ellos; 5) y priorizan la toma de decisiones por experiencia/especialización para hacer frente a complejidades y vulnerabilidades surgidas. Las principales industrias consideradas HROs son: nuclear, aviación, espacial, marina, química, gas, petroquímica, cuerpos de bomberos, asistencia médica de emergencia, y la industria militar.

El estudio de las causas de los accidentes en los HROs ha revelado que la cultura existente de una organización y cómo ésta cristaliza en los comportamientos mostrados por los empleados y en la forma en que se gestiona la organización, son determinantes para los resultados organizacionales de seguridad (como muestran diferentes estudios e informes tales como: Baker, 2007, CAIB, 2003, Cullen, 1990. Comité de Lecciones Aprendidas del Accidente Nuclear de Fukushima para Mejorar la Seguridad de las Plantas Nucleares en Estados Unidos, 2014, Dawson y Brooks, 1999, Fennell, 1988, HAEA, 2003, Oculto, 1989, IAEA, 1986, Sheen, 1987). En este contexto, el concepto de cultura de seguridad se ha utilizado en todas las industrias de alta fiabilidad durante las últimas tres décadas como principio guía y piedra angular sobre la cual comprender la influencia de los elementos culturales organizativos en la seguridad y construir HROs seguras. Sin embargo, a pesar de los esfuerzos de investigadores y profesionales en todos estos años, la cultura de seguridad sigue siendo un concepto teórico difícil de entender y de abordar en la práctica organizativa.

Si la cultura de seguridad de una organización es el factor más importante que explica sus resultados de seguridad positivos y negativos, la optimización de esta cultura de seguridad es esencial para las HROs en general y para las centrales nucleares en particular. Sin embargo, para saber cómo optimizar una cultura de seguridad en particular (cuáles son los aspectos que necesitan ser reforzados, mejorados o eliminados), necesitamos primero poder entender y evaluar esa cultura de seguridad.

El objetivo principal de esta tesis es proporcionar una visión general de las formas actuales de entender, tratar, y evaluar la cultura de la seguridad (poniendo un énfasis particular en la industria nuclear y en la utilización de cuestionarios), y proporcionar orientación a los investigadores y profesionales sobre cómo capturar la cultura de seguridad de las centrales nucleares. Para ello, la tesis actual incluye los siguientes capítulos:

CAPÍTULO I - Se presenta una breve introducción a la industria nuclear. Asimismo se presentan algunos de los más destacables pros y contras de la energía nuclear y algunos de los desafíos más importantes que la industria nuclear ha estado enfrentando en los últimos años. La última parte del capítulo explica cómo la seguridad ha sido particularmente comprendida y preservada en industrias de alta fiabilidad en diferentes momentos de la historia.

CAPÍTULO II - Se describe el concepto de cultura organizacional (sus orígenes y definición), así como los enfoques socio-antropológico y de la psicología organizacional de la cultura organizacional. En este capítulo, también se explica que la cultura está compuesta por diferentes niveles de contenido (desde niveles más profundos hasta niveles más superficiales), y se describen distintas clasificaciones de niveles culturales propuestos por diferentes autores.

CAPÍTULO III - El objetivo es clarificar el concepto de cultura de seguridad. Por un lado, se realiza un análisis del contenido de 40 de las definiciones más ampliamente utilizadas de cultura de seguridad y se identifican los principales puntos en común de éstas. Por otro lado, se aborda la relación entre los constructos de cultura de seguridad, cultura organizacional y clima de seguridad.

CAPÍTULO IV - Este capítulo trata de la evaluación de la cultura de seguridad. Se divide en tres bloques: En primer lugar, se describen los pros y contras de estrategias tanto cualitativas como cuantitativas para la evaluación de la cultura de seguridad. En segundo lugar, se presentan 20 de los cuestionarios de cultura de seguridad más relevantes y se ofrecen análisis y conclusiones de sus contenidos. Por último, se ofrece una explicación adicional de cuestionarios basados en modelos de cultura organizacional o en modelos de cultura de seguridad, así como una descripción de los modelos correspondientes.

CAPÍTULO V - Se presentan los objetivos del estudio, las muestras y las variables utilizadas con mayor detalle, así como los análisis estadísticos realizados en los tres estudios empíricos presentados en los próximos tres capítulos.

CAPÍTULO VI - Este capítulo contiene el primer estudio empírico sobre la evaluación de la cultura de seguridad. Se presentan los primeros pasos para validar empíricamente el modelo ampliamente utilizado de cultura de seguridad de la Agencia Internacional de Energía Atómica (IAEA, 2006a).

CAPÍTULO VII - Este capítulo contiene el segundo estudio empírico. Aquí desarrolla un modelo de cultura de seguridad tridimensional y un cuestionario de cultura de seguridad (el SCEQ), diseñado para evaluar el grado en que la seguridad es un valor en acción en las HROs y las centrales nucleares. El objetivo de este estudio es validar empíricamente tanto el cuestionario como la dimensionalidad del modelo correspondiente.

CAPÍTULO VIII - Este capítulo contiene el tercer estudio empírico. Se estudia hasta qué punto el Cuestionario de Cultura de Seguridad en Acción (SCEQ) y el Inventario de Cultura Organizacional (OCI) pueden predecir el desempeño de la seguridad en una central nuclear, arrojando luz sobre la utilidad de las herramientas de evaluación de la cultura de seguridad y la cultura organizacional para la industria nuclear. Además, se reúnen más pruebas para la validación de ambos cuestionarios.

CAPÍTULO IX - Este capítulo ofrece una discusión general, que incluye un resumen de los resultados obtenidos, las principales contribuciones de la tesis, el alcance del trabajo presentado, y las futuras áreas de investigación en cultura de seguridad.

CAPÍTULO X - Se finaliza esta tesis con cinco conclusiones generales para los interesados en nuestro trabajo.

CHAPTER I.

THE NUCLEAR INDUSTRY

To begin this thesis, we present a brief introduction to the current situation of the nuclear industry and the important role safety has played in it since its conception as a form of energy. In this chapter, we highlight some of the undeniable benefits and risks of using nuclear technologies for electricity generation. Next, three main challenges that threaten the operation of NPPs in recent years (rapid technological changes, changing regulatory policies, and increasing aggressive competition) are explained. Finally, five phases of safety concerns (technological, human performance, socio-technical, safety culture, and inter-organizational) in the nuclear industry are described.

1.1. Presence, pros and cons of nuclear energy

As of March 2017, 30 countries worldwide are operating 447 civil nuclear power reactors for electricity generation, supplying around 11.5% of the world's electricity production. Furthermore, 59 new reactors are under construction in 15 countries, 164 new reactors are planned (mostly expected to be in operation within 8-10 years) and 350 other reactors are proposed (see Table 1, updated monthly by the World Nuclear Association, 2017). Moreover, there are currently hundreds of other (not civil) nuclear reactors in operation, such as research reactors used at universities and other research institutions, reactors used to power ships and submarines, and reactors used to make medical isotopes.

Today, fossil fuels are consumed faster than they are produced. Consequently, these resources will soon be reduced, and their price will dramatically increase. Fossil fuels are also the largest source of ‘greenhouse gas’ emissions from human activities in a number of countries (e.g., the United States, as reported by the U.S. Government, 2017). On the other hand, renewable energies depend on natural aspects, where energy production varies depending on the hours of sun or wind, which do not always coincide with the hours with the most energy demand. This dependency questions the reliability of solar and wind energy to satisfy the World´s energy consumption.

Table1

Facts and figures of World nuclear power reactors in 2017 (World Nuclear Association, 2017)

COUNTRY	NUCLEAR ELECTRICITY GENERATION 2015		REACTORS OPERABLE March 2017		REACTORS UNDER CONSTRUCTION March 2017		REACTORS PLANNED March 2017		REACTORS PROPOSED March 2017		URANIUM REQUIRED 2016
(Click name for Country Profile)	Billion kWh	% e	No.	MWe net	No.	MWe gross	No.	MWe gross	No.	MWe gross	tonnes U
Argentina	6.5	4.8	3	1627	1	27	2	1950	2	1300	215
Armenia	2.6	34.5	1	376	0	0	1	1060			88
Bangladesh	0	0	0	0	0	0	2	2400	0	0	0
Belarus	0	0	0	0	2	2388	0	0	2	2400	0
Belgium	24.8	37.5	7	5943	0	0	0	0	0	0	1015
Brazil	13.9	2.8	2	1901	1	1405	0	0	4	4000	329
Bulgaria	14.7	31.3	2	1926	0	0	1	950	0	0	327
Canada	95.6	16.6	19	13553	0	0	2	1500	3	3800	1630
Chile	0	0	0	0	0	0	0	0	4	4400	0
China	161.2	3.0	36	32637	21	23086	40	45700	139	160000	5338
CzechRepublic	25.3	32.5	6	3904	0	0	2	2400	1	1200	565
Egypt	0	0	0	0	0	0	2	2400	2	2400	0
Finland	22.3	33.7	4	2764	1	1700	1	1200	1	1500	1126
France	419.0	76.3	58	63130	1	1750	0	0	1	1750	9211
Germany	86.8	14.1	8	10728	0	0	0	0	0	0	1689
Hungary	15.0	52.7	4	1889	0	0	2	2400	0	0	356
India	34.6	3.5	22	6219	5	3300	20	18600	44	51000	997
Indonesia	0	0	0	0	0	0	1	30	4	4000	0
Iran	3.2	1.3	1	915	0	0	2	2000	7	6300	178

Israel	0	0	0	0	0	0	0	0	1	1200	0
Italy	0	0	0	0	0	0	0	0	0	0	0
Japan	4.3	0.5	42	39952	2	2756	9	12947	3	4145	680
Jordan	0	0	0	0	0	0	2	2000			0
Kazakhstan	0	0	0	0	0	0	2	600	2	600	0
Korea DPR (North)	0	0	0	0	0	0	0	0	1	950	0
Korea RO (South)	157.2	31.7	25	23081	3	4200	8	11600	0	0	5013
Lithuania	0	0	0	0	0	0	0	0	2	2700	0
Malaysia	0	0	0	0	0	0	0	0	2	2000	0
Mexico	11.2	6.8	2	1600	0	0	0	0	2	2000	282
Netherlands	3.9	3,7	1	485	0	0	0	0	1	1000	102
Pakistan	4.3	4.4	4	1040	3	2662	0	0	0	0	270
Poland	0	0	0	0	0	0	6	6000	0	0	0
Romania	10.7	17.3	2	1310	0	0	2	1440	1	655	179
Russia	182.8	18.6	35	26865	7	5904	25	27755	23	22800	6264
Saudi Arabia	0	0	0	0	0	0	0	0	16	17000	0
Slovakia	14.1	55.9	4	1816	2	942	0	0	1	1200	917
Slovenia	5.4	38.0	1	696	0	0	0	0	1	1000	137
South Africa	11.0	4.7	2	1830	0	0	0	0	8	9600	304
Spain	54.8	20.3	7	7121	0	0	0	0	0	0	1271
Sweden	54.5	34.3	9	8849	0	0	0	0	0	0	1471
Switzerland	22.2	33.5	5	3333	0	0	0	0	3	4000	521
Thailand	0	0	0	0	0	0	0	0	5	5000	0
Turkey	0	0	0	0	0	0	4	4800	4	4500	0
Ukraine	82.4	56.5	15	13107	0	0	2	1900	11	12000	2251
UAE	0	0	0	0	4	5600	0	0	10	14400	0
UnitedKingdom	63.9	18.9	15	8883	0	0	4	6100	9	11800	1734
USA	798.0	19.5	99	99535	4	5000	18	8312	24	26000	18161
Vietnam	0	0	0	0	0	0	4	4800	6	6700	0
WORLD	**2,441**	**c 11.5**	**447**	**391,94**	**59**	**63,420**	**164**	**170,84**	**350**	**395,3**	**63,404**

Nuclear energy does not discharge any primary ‘greenhouse gasses’, such as methane and carbon dioxide. The cost of uranium in relation to the energy it can produce is very low, and the World’s present measured resources of uranium are expected to last for another 90 years (World Nuclear Association, 2016). Furthermore, NPPs can operate in rough weather conditions, producing power 24/7 and being shut down only for maintenance purposes.

The benefits of nuclear energy are therefore undeniable (e.g., efficiency, availability, easy transportation, lower greenhouse gas emissions, etc.). However, the production of nuclear energy also has the greatest potential to destroy people´s health and lives when compared to other sources of electricity generation. Although the ratio of accidents to active nuclear power reactors in the nuclear industry is extremely low, consequences of the release of radioactive substances into the environment can be devastating, as in the case of the Chernobyl (in 1986) and Fukushima Daiichi (in 2011) disasters, regarded as the most lethal accidents in the history of nuclear energy.

Whether one is a supporter or detractor of the operation of NPPs, the reality is that nuclear energy exists and continues to progress as a solution to fulfill energy needs in modern societies. And while nuclear energy exists, practitioners and researchers from all disciplines (engineers and organizational psychologists, among others) must try their best to guarantee the safe operation of every single NPP in the world, avoiding future nuclear catastrophes.

1.2. Safety challenges in the nuclear industry

Compared to the stable conditions of past decades, the nuclear industry currently faces higher levels of pressure and continuous changes in the conditions of industrial risk management. Already in 2001, Rasmussen described three main challenges (to guarantee safety of operations) that the increasingly dynamic nuclear industry is experiencing.

1.2.1. Rapid Technological Changes

Technology is changing and evolving at a frenetic pace in almost all the domains of society. Technological innovations, such as the introduction of advanced computer-based control and safety systems, challenge the rate of change of management structures and legislation (Rasmussen, 2001). The safety of NPPs (and their rather slow-changing technologies) can therefore be challenged when NPPs try to keep up with the pace of development of other industries (e.g., transport, manufacturing, computer, etc.) and implement their innovations. During a period of fast change, NPPs must take care of any and every factor that has the power to threaten the safety of the plant, such as the communication between system designers, constructors, and system operators (Rasmussen, 2001).

1.2.2. Changing Regulatory Policies

Organizations such as NPPs are often subject to changing government policies in terms of a move from prescriptive legislation toward performance-based legislation and industrial deregulation (Rasmussen, 2001). NPPs are often required to carry out generic functions to maintain the safety of their operations, but the details about how these functions should be carried out are left to the

NPPs. According to Baram (1996), the new performance rules and reinforcement policies result in a number of potential difficulties, such as: uncertainty about how to put into practice broadly expressed requirements and rules; or managing rule compliance efforts. All these changes in the operation and management of NPPs represent a challenge for the safety of NPP operations.

1.2.3. Aggressive Competition

Companies today live in an aggressive and competitive environment that "focuses the incentives of decision-makers on short-term financial criteria rather than long term criteria concerning welfare, safety, and environmental impact" (Rasmussen, 2001, p. 24). HROs are increasingly being privatized, and strategies to financially outperform competitors are sometimes put into place by decision-makers and top managers who do not fully understand and consider the actual hazardous processes found at the production level. In this context, among others, NPPs must count on decision-makers with broad knowledge about the nuclear industry (and not only a long-record of financial achievements), about the risks and challenges inherent to nuclear technologies, and about managing people in HROs. In addition, the management of incentives and economic rewards for all NPP members has to be carefully designed (see López de Castro, Gracia, Tomás and Peiró [2017, p. 48] for a further discussion of this topic).

1.3. Phases of safety concerns

Although safety has always been a challenge in the operation of NPPs, it has not always been understood and preserved in the same way. Reason (1993) distinguished among three overlapping phases of safety concerns, applicable to

HROs and to the nuclear industry in particular: the technical phase, the human error phase, and the socio-technical phase. Along the lines of Reason's proposal, Frischknecht (2005) also distinguished among three phases (also highlighted by Martínez-Córcoles [2012]): the technology phase, the phase of ergonomics and human performance, and the safety culture phase. The first two phases of Reason and Frischknecht's proposals are equivalent, but not the third one. Moreover, the safety culture phase explained by Frischknecht begins later than the socio-technical phase described by Reason. Next, we integrate these two classifications into the following four phases of safety concerns: the technological phase, the human performance phase, the socio-technical phase, and the safety culture phase. Furthermore, the inter-organizational phase of safety concerns highlighted by Wilpert and Fahlbruch (1998) is also described at the end of this section.

1.3.1. Technological phase

The first human-made self-sustaining nuclear chain reaction was initiated in the Chicago Pile-1 reactor (CP-1) on 2nd December 1942, giving birth to nuclear technology. In the first decades of nuclear technology, safety in nuclear installations was guaranteed by a continuous optimization of the design and materials of technical components. Engineers were responsible for the development and implementation of safe and reliable nuclear technologies. Thus, technology and technical concepts were the key to maintaining the nuclear process at the necessary level of reliability and safety. Employees were trained to control this process and intervene in case of technological malfunctions. In the technical phase, humans were considered a means to correctly operate technology, but they were not seen as part of the system (Frischknecht, 2005). Technologies were intrinsically dangerous, not the workers who operate them. Thus, safety was solely guaranteed by creating safe nuclear technologies.

1.3.2. Human performance phase

It took some years until it became evident that erroneous human actions and behaviors often produce accidents in spite of technically solid and reliable machines. The trigger for this shift in thinking was the Three Mile Island accident that occurred on the 28th of March 1979 in the Three Mile Island Nuclear Generating Station (TMI-2) in Pennsylvania, United States. The partial nuclear meltdown in TMI-2 was a shock to the industry, bringing a strong focus on human factors, human error, and the need for a better way to manage human reliability. As a response to the accident, the Nuclear Regulatory Commission[3] (NRC) established programs to minimize human errors in plant designs, procedures, operations, and maintenance. It also created a number of organizations responsible for addressing human factor issues in operator licensing, procedures, training, staffing, and management. The use of full-scope simulators for training reactor operators became important from this point on. In this phase, the preferred choice for combating human threats was to select capable operators and provide training in their competencies (Wilpert and Itoigawa, 2001). Humans were now considered part of the system, like components, which either acted correctly or failed (Frischknecht, 2005).

[3]The U.S. Nuclear Regulatory Commission (NRC) was created as an independent agency by Congress in 1974 to ensure the safe use of radioactive materials for beneficial civilian purposes while protecting people and the environment. The NRC regulates commercial nuclear power plants and other uses of nuclear materials, such as in nuclear medicine, through licensing, inspection and enforcement of its requirements.

1.3.3. Socio-technical phase

During the 1980s it was recognized that the complex and often poorly understood interaction between social (human) and technical features was the main cause of large-scale system failures. Reason (1993) acknowledged the leading role of this interaction in a number of disasters, e.g., Bhopal, Chernobyl, Zeebrugge, King's Cross, Piper Alpha, and Clapham Junction. As Reason (1993) highlighted, although general systems theory and the notion of socio-technical systems were well known for quite some time, decades had to pass until their implications for accident prevention and safety were recognized. Technology itself or human actions themselves could no longer be understood as being able to produce nuclear accidents separately. The socio-technical phase drew attention to the development of safety improvement strategies directed at the joint optimization of the social and technical subsystems.

1.3.4. Safety culture phase

The Chernobyl disaster, which took place on 26th April 1986 during a power-failure stress test when safety systems were deliberately turned off, triggered a shift in safety thinking. Experts from the International Nuclear Safety Advisory Group (INSAG[4]) of the International Atomic Energy Agency analyzed the catastrophe and came to the conclusion that the occurrences could not be attributed only to human error, technology, or even the socio-technical system. The identified cause was a set of organizational and management factors, which they labeled as safety culture (IAEA, 1986). Safety culture gained strength and

[4]The International Nuclear Safety Group (INSAG) is a group of experts on nuclear safety convened under the auspices of the IAEA with the objective of providing authoritative advice and guidance on nuclear safety approaches, policies and principles.

popularity quickly and was soon identified as being behind other large-scale accidents in the 1980s, like those mentioned above (Section 1.3.3.). In particular, the concern for safety culture took off in the 1990s and gained momentum with the onset of the XXI century. This growing interest in safety culture is also depicted in the presence of the concept in scientific publications (See Figures 1 and 2). In the safety culture phase, strategies to improve safety take into account all the aspects identified so far (technology, individuals, and the interaction between the two sub-systems), as well as organizational management and inter-organizational factors (see the next section for an explanation of Inter-organizational safety concerns) and their impacts on systems safety (Wilpert, 2001). From this point on, the development and maintenance of pervasive and strong safety cultures became a priority for NPPs.

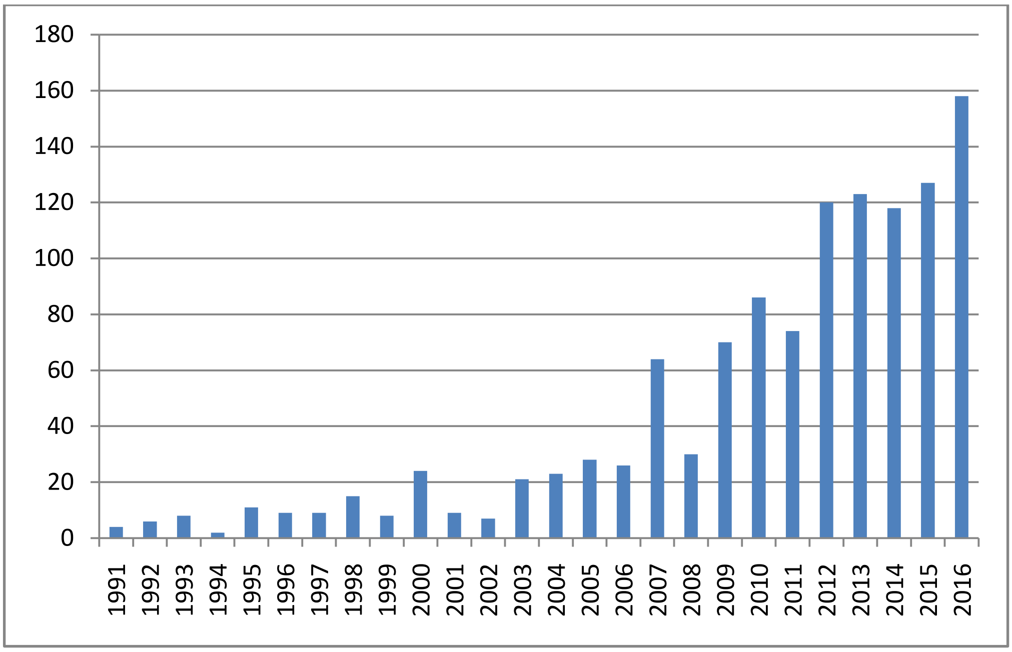

Fig. 1. Number of publications per year that included ‘safety culture’ in the title, appearing in the Web of Science[5] (WOS) database.

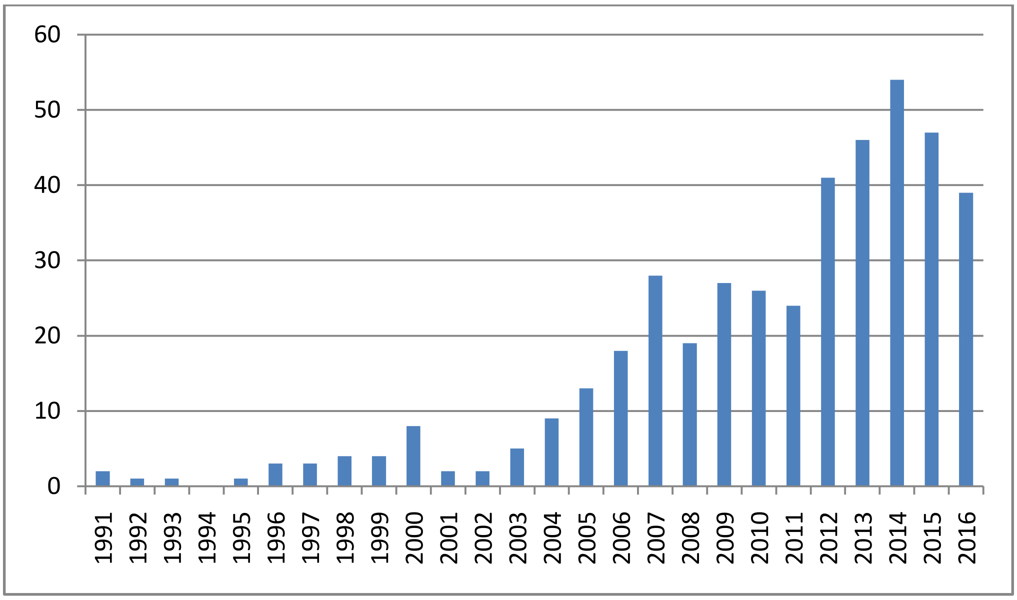

Fig. 2. Number of publications per year that included ‘safety culture’ in the abstract, appearing in the PsycINFO[6] database.

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[5]Web of Science (previously known as Web of Knowledge) is a scientific citation indexing service that gives access to multiple databases that reference cross-disciplinary research, which allows for in-depth exploration of specialized sub-fields within an academic or scientific discipline.

1.3.5. Inter-organizational phase

Wilpert and Fahlbruch added the Inter-organizational phase to the classifications of safety concerns. They highlight that the causes behind accidents are not always confined to the organization under study itself. Actually, safety analyses of major industrial catastrophes have shown that inter-organizational dysfunctions also play an active role in accident causation (Wilpert and Fahlbruch, 1998). In the inter-organizational concerns, attention is directed at nuclear safety-oriented relationships among governments, regulatory agents, utilities and plant management, research institutions, manufacturers, consultant bodies, and nuclear power plant staff. In order to ensure sustained system safety, dysfunctional relationships among these different actors must be looked after and corrected, when needed (Wilpert and Itoigawa, 2001).

[6] Produced by the American Psychological Association (APA), PsycINFO is a database of abstracts and citations of behavioral and social science research, with special emphasis on the field of psychology.

CHAPTER II.

ORGANIZATIONAL CULTURE

This chapter deals with the concept of organizational culture, without which safety culture could not be understood. The origins and the most widely used definition of organizational culture are briefly presented. Next, two broad categories are described, where existing theoretical and empirical approaches to organizational culture can be classified, the socio-anthropological and organizational psychology approaches to organizational culture. Thirdly, we explain that organizational culture has been understood by most researchers as being composed of distinct facets that are hierarchically ordered from deeper and more intangible levels to more superficial and visible ones. Some of the most relevant and influential cultural level classifications are given.

2.1. Origins and definition

The concept of culture can be applied to social units of any type that have been able to learn and establish a vision of themselves and the surrounding environment, that is, those that have their own basic assumptions (Schein, 1985), e.g., cultures belonging to Eastern and Western civilizations, specific countries, ethnic groups, occupations, families and whole organizations, such as NPPs, or groups within their limits. Schein (1992) proposes one of the most accepted and widely used definitions of culture:

> “Culture is a pattern of shared basic assumptions that was learned by a group as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems” (p. 12).

When the group the definition refers to is the organization, then we are talking about organizational culture.

In the 1980´s, the concept of culture started to gain strength in the corporate world. One reason may have been the increased alertness to the cultural differences in a global economy, such as between the United States and Japan, which have a noticeable effect on business practices and management. Since then, organizational culture has been a subject of study for a variety of disciplines, which have struggled to understand the complex nature and usefulness of this omnipresent construct. The different theoretical and empirical approaches used by researchers and practitioners from different industries and academic/professional backgrounds have contributed to the lack of consensus on the topic, complicating research efforts and attempts to build knowledge on previous literature and learnings. Nevertheless, the integration of multidisciplinary efforts has also helped to develop a richer conception of the construct.

Existing approaches to organizational culture can be classified into two broad categories: the socio-anthropological and organizational psychology approaches.

2.2. Approaches to organizational culture

2.2.1. Socio-anthropological approach

One famous remark that illustrates the socio-anthropological approach was made by Geertz (1973, p. 5): “Man is an animal suspended in webs of significance he himself has spun; I take culture to be those webs”. For him, culture becomes “the fabric of meaning in terms of which human beings interpret their experience and guide their action” (Geertz, 1973, p. 145). This ‘meaning’ is comparable to

Schein´s (1992) 'basic assumptions' or the deepest, underlying and usually unconscious level of culture that determines perceptions, thought processes, feelings, and behavior (a description of the basic assumptions level and other cultural levels is given in Section 2.3.). From a socio-anthropological point of view, it is hardly possible to observe this level. Whereas an organization's culture is revealed in its general patterns of attitudes and actions, the deeper structure of its culture is not immediately interpretable by outsiders (Wiegmann, Zhang, Thaden, Sharma and Gibbons, 2004).

The socio-anthropological approach considers organizational culture to be "more than the sum of its parts". It cannot be entirely understood by means of traditional analytical methods that breakdown a phenomenon to study its individual components, but rather by methods that account for the activity or the nature of what is being studied (Creswell, 1998; Glaser and Strauss, 1967; Suchman, 1987; Wiegmann et al., 2004). The anthropological answer to 'measurements' will usually be 'thick descriptions' (Geertz, 1973, p. 3) and the preferential method is often ethnographic fieldwork (Haukelid, 2008). Studying organizational culture requires the use of ethnographic approaches, including intensive and extensive observations and employee interviews (Schein, 1991).

Organizational culture is often considered an 'evolved construct', deeply rooted in history, collectively held, and sufficiently complex to resist any attempts at direct manipulation (Mearns and Flin, 1999). At least when talking about its deepest levels, as Haukelid (2008) observes, it may be possible to change the manifest levels of culture in a relatively short time, but the more basic levels of culture are hard to change – and even harder to manage. From a socio-anthropological point of view, culture can hardly be controlled.

2.2.2. Organizational psychology approach

One of the major contributions from organizational development is to support the evolution of organizations in the right direction, this is, enhance cultural elements that are critical to maintaining identity and promote the 'unlearning' of cultural elements that are increasingly dysfunctional (Argyris, Putnam and Smith, 1985; Argyris and Schon, 1978; Beckhard and Harris,1987; Hanna, 1988; Lippitt, 1982; Schein, 1990; Walton, 1987). In the organizational psychology approach, the focus is not only on understanding, but also on benefiting from organizational culture. Management consultants and psychologists find this to be the most powerful resource for shaping organizations according to their interests and long-term organizational goals.

Psychologists, unlike anthropologists, believe in the possibility of measuring culture. They rely on observational and analytical methods to a larger extent. Cooper (2000) is a good illustration of the organizational psychology perspective. As Haukelid (2008) explained, Cooper (2000) wants to create a reciprocal model that can be used to measure and analyze safety culture. In this model, culture is broken down into sub-components and observable behavior (or what Cooper calls the 'safety culture product'), which are more easily measured: "since each of these safety culture components can be directly measured in their own right, or in combination, it becomes possible to quantify culture in a meaningful way at many different organizational levels, which hitherto has been somewhat difficult"

(Cooper, 2000, p. 121). Therefore, from the organizational psychology approach, organizational cultures can be measured and often described with a limited number of dimensions. These dimensions are usually sought through organization-wide questionnaires with the ultimate goal of description or diagnosis and intervention, if required (Guldenmund, 2000).

2.3. Levels of culture

In organizational (and safety) culture research, there has been considerable interest in understanding the extent to which the components of culture are more or less easily observable and measurable. Most researchers agree that organizational culture is made up of distinct elements that are hierarchically ordered from deeper and more intangible levels to more superficial and visible ones. These different levels have been conceptualized in a variety of similar ways (Deal and Kennedy, 1982; Detert, Schroeder and Mauriel, 2000; Furnham and Gunter, 1993; Hatch, 1993; Hofstede, 1991; Kotter and Heskett, 1992; Lundberg, 1990; Ott, 1989; Rousseau, 1990; Sanders and Neuijen, 1987, cited in Guldenmund, 2000; Schein, 1985; Van Hoewijk, 1988, cited in Guldenmund, 2000; Van Wart, 1998). Deeper levels are usually comprised of assumptions, values, and/or beliefs that guide workers' attitudes and behavior because they have been taken-for-granted as the path to success within the organizational context. Surface levels habitually comprise observable artifacts, such as policies, symbols, and myths, considered to be manifestations of the deep-level facets.

Among these authors, Schein´s (1985) model – comprising artifacts, espoused values, and basic assumptions (see Figure 3) – has become the compass in organizational management and change. At the surface of the organization, the layer of artifacts can be found. Artifacts are the most tangible and overt manifestations of culture, including all the phenomena that can be seen, heard, and felt in an organization. According to Schein, artifacts include the physical environment of the organization, its language, its technology and products, myths, stories, observable rituals, emotional displays, observable behaviors, and, in general, any kind of visible product of organizational members. The second cultural layer of Schein´s model contains the espoused values, norms, philosophies, and organizational rules that reflect what the organization would ideally like to be. This level can be expressed in public declarations during meetings or ceremonies, written documents describing the organization's mission and strategy, leaders' messages, etc. At the third, least tangible, and deeper level, the basic beliefs and assumptions shared by the members of the organization can be found. These assumptions, often implicit, are deeply rooted in the history of the organization, as they have been shown to be useful for organizational survival and development. Therefore, to a greater extent than artifacts and espoused values, these underlying assumptions tell the members of an organization how to act, perceive, think, and feel about events and things if they are to be successful. Basic assumptions tend to be those that are never confronted or debated in the organization and, hence, extremely difficult to change. In fact, "if a basic assumption is strongly held in a group, members will find behavior based on any other premise inconceivable" (Schein, 1985, p. 22).

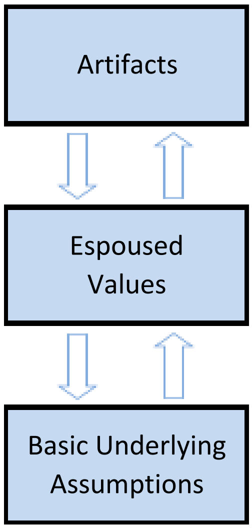

Fig. 3. Schein´s (1985) model of organizational culture

A number of authors have drawn on Schein's model to propose their cultural level classifications. Schein's model was expanded and reconceptualized by Hatch (1993), who affirmed that Schein's model leaves "gaps regarding the appreciation of organizational culture as symbols and processes" (Hatch, 1993, p. 657). Hatch's model, called 'cultural dynamics', combines Schein's theory with concepts from symbolic interpretive perspectives, proposing four cultural levels (assumptions, values, symbols, and artifacts). His model is aimed to articulate the processes of manifestation, realization, symbolization, and interpretation, providing a framework within which to discuss the dynamism of organizational cultures.

Kotter and Heskett (1992) proposed a simplified organizational culture model, also shaped on the same basis as Schein's model, consisting of two levels that differ in terms of their visibility and resistance to change. On the one hand, "culture refers to values that are shared by the people in a group and that tend to persist over time even when group membership changes". On the other hand, "culture represents the behavior patterns or style of an organization that new employees are automatically encouraged to follow by their fellow employees" (Kotter and Heskett, 1992, p. 4). Examples of the level of 'shared values' given by the authors are: managers care about customers; executives like long-term debt. Examples of the level of 'group behavior norms' given are: employees are quick to respond to requests from customers; managers often involve lower-level employees in decision-making. Kotter and Heskett note that each of the two levels of culture has a natural tendency to influence the other one.

Ott (1989), in further refining Schein's proposal, kept his basic assumptions and value levels, but split Schein's artifacts level into two different sub-levels. Level 1A, also labeled 'artifacts', refers to the technology and art in an organizational culture. Level 1B, labeled 'patterns of behavior', contains management tasks, visible and audible behavior patterns, and norms.

Building on the work of Schein and Ott, Van Wart (1998) also distinguished four levels of culture, namely 'basic assumptions', the 'beliefs' level, 'patterns of action' and the 'artifacts and actions' level.

As can be observed, a certain degree of agreement exists among classifications of culture levels, which provides valuable frameworks to understand the composition of organizational culture and where to look for information when trying to understand and/or change the direction of an organization. However, since its conception, Schein's (1985) three-level classification has been the most widespread and influential model in corporate culture research.

CHAPTER III.

SAFETY CULTURE

Having clarified the nature and components of organizational culture, this third section of the thesis addresses the construct of safety culture.

First, we describe how the Chernobyl catastrophe in 1986 gave rise to safety culture. Next, reviews of safety culture and safety climate are mentioned, and the contents of 40 of the most widely used definitions of safety culture are analyzed in order to identify their main commonalities, that is, what safety culture is for most researchers in the field. Additionally, this chapter intends to clarify the relationship of safety culture to the constructs of organizational culture and safety climate.

3.1. Origins

The active role of safety culture in accident causation has long been acknowledged in HROs. A long list of major incident and accident reports shows that they could have been avoided if higher and stronger safety cultures had been present in these organizations. Well-known examples are the reports on the nuclear disaster at Chernobyl (IAEA, 1986); the sinking of the Herald of Free Enterprise passenger ferry (Sheen, 1987); the fire at King’s Cross underground station (Fennell, 1988); the passenger train crash at Clapham Junction (Hidden, 1989); the explosion on the Piper-Alpha oil platform (Cullen, 1990); the accident at the Esso natural gas plant (Dawson and Brooks, 1999); the disintegration of the Columbia space shuttle (CAIB, 2003); the fuel damage at the Paks NPP in Hungary (HAEA, 2003); the accident at the BP Texas City refinery (Baker, 2007); the crash of the Air France plane from Rio de Janeiro to Paris (BEA, 2012); and the nuclear accident at Fukushima Daiichi (Committee on Lessons Learned from the Fukushima Nuclear Accident for Improving Safety and Security of U.S. Nuclear Plants, 2014), to name a few. In light of this ongoing problem, all the hazard industries have adopted safety culture as their banner in the effort to promote safety in their installations and operations (Wilpert and Schöbel, 2007).

The concept of safety culture arose in the aftermath of the Chernobyl catastrophe. Experts from the INSAG group of the IAEA analyzed the catastrophe and came to the conclusion that the occurrences could not be attributed just to human error, just to technology, or even just to the socio-technical system. The INSAG concluded that the disaster was produced by an interaction between the two sub-systems (i.e., socio-technical system), but also by organizational and management factors, as already mentioned in Section 1.3.4. This group of rather vague nonspecific organizational and management factors is what the IAEA baptized back in the 1980s as 'safety culture'. The report was published by the IAEA (1986) as Safety Series No. 75-INSAG-1.

3.2. Safety culture and organizational culture

Most of the existing conceptualizations, definitions, and measures of safety culture have been derived from 'organizational culture', used throughout the social and management science (Cox and Flin, 1998), although scholars show disagreement when linking safety culture to organizational culture. Antonsen (2009) considers safety culture to be a conceptual label that denotes the relationship between culture and safety, shifting the focus to the concept of organizational culture. Díaz-Cabrera, Hernández-Fernaud and Isla-Díaz (2007) highlight that some assume that safety culture is a type of organizational culture;

both are related, but safety culture has distinctive peculiarities and its own identity. Others suggest that safety culture is an expression or manifestation of a specific organizational culture, which is then crystallized into a safety management system (Díaz-Cabrera et al., 2007; Glendon and Stanton, 2000; Guldenmund, 2000; Hale, 2000; Wilpert, 2001). However, Sorensen (2002) warns that some caution should be taken when ascribing what are commonly understood as characteristics of 'culture' to safety culture because the term itself implies that it is a subset of a larger 'organizational culture'.

Summarizing, in general terms most scholars refer to safety culture as a focused aspect (Richter and Koch, 2004), sub-element (Kennedy and Kirwan, 1998), sub-facet (Cooper, 2000; Mohamed, 2003) or subset (Clarke, 1999; IAEA, 1998a; Reiman and Rollenhagen, 2014; Sorensen, 2002) of organizational culture that alludes to organizational and/or worker features related to health and safety (López de Castro, Gracia, Peiró, Pietrantoni and Hernández, 2013).

Next a further analysis of the nature and conceptualizations of safety culture is provided.

3.3. Defining safety culture

Since the conception of the term in 1986, there has been an extensive debate on the interpretation of the safety culture concept, which continues until today. A number of examples in this regard, addressed throughout this thesis, are: 1) An overly broad scope of safety culture that, among other issues, has led the concept to cover numerous elements of the organization and its employees, grouped in very distinct safety culture dimensions (see definitions of safety culture presented later on in this Section); 2) A significant confusion between the nature of safety culture and safety climate (partially inherited from the confusion between organizational culture and organizational climate), which, among others, has resulted in many authors using both concepts indistinguishably and interchangeably (see Section 3.4.); 3) A variety of proposals about how safety culture is related to the more general organizational culture construct (see Section 3.2.), which, among others, does not help us to understand when and for what purposes each of the concepts is to be used.

In light of the lack of clarity surrounding safety culture and the great diversity of meanings and connotations attached to it, López de Castro, Gracia, Pietrantoni and Peiró (2011) aimed to clarify the concept by analyzing 35 definitions of safety culture[7]. Their work is extended in this section of the present thesis with the inclusion of 40 definitions of safety culture from the past 30 years; they are compiled in Table 2.

Although many scholars strive for the clarification of safety culture, many others avoid the confusion behind the term. It is remarkable that the majority of the studies we reviewed avoided the confusion by not giving any definition of the construct. This finding agrees with other studies, as in Choudry, Fang and Mohamed (2007), where only eight of the 27 studies they selected defined safety culture.

A more skeptical posture on safety culture definitions comes from 'The LearnSafe project', which focuses on processes of management of change and

[7] The reader can also find an interesting analysis of 54 definitions of organizational culture, identified in the literature between 1960 and 1993, in Verbeke, Volkering and Hessels (1998).

organizational learning at NPPs across Europe. Reflections from this project show that attempts to define and measure safety culture may be counterproductive (Wahlström and Rollenhagen, 2004). A discussion of different interpretations of the term can sensitize plant personnel to shortcomings that may have a negative influence on safety (Wahlström and Rollenhagen, 2004). Observations have shown that most people have a rather clear interpretation of what the concept means to them (Hammar, Wahlström and Kettunen, 2000), and a "more fruitful approach may be to use the concept to stimulate discussions on how safety is constructed" (Wahlström and Rollenhagen, 2004, p. 2).

Other studies relating management and organization factors to safety of operations not only do not define the term safety culture; they do not even use it (Sorensen, 2002).

Table 2
Definitions of safety culture

Reference	Definition of Safety culture
Wert (1986)	A good nuclear safety culture (NSC) is a work environment where a safety ethic permeates the organization and peoples' behavior focuses on accident prevention through critical self-assessment, pro-active identification of management and technical problems, and appropriate, timely, and effective resolution of the problems before they become crises.
Turner, Pidgeon, Blockley, and Toft (1989)	The set of beliefs, norms, attitudes, roles, and social and technical practices that are concerned with minimizing the exposure of employees, managers, customers, and members of the public to conditions considered dangerous or injurious
Locke and Latham (1990)	That observable degree of effort with which all organizational members direct their attention and actions towards improving safety on a daily basis.

International Nuclear Safety Advisory Group (1991)	That assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.
Cox and Cox (1991)	Reflects attitudes, beliefs, perceptions, and values that employees share in relation to safety.
Confederation of British Industry (CBI, 1991)	The ideas and beliefs that all members of the organization share about risk, accidents and ill health.
Pidgeon (1991), Turner (1991), Pidgeon and O'Leary (1994).	The set of assumptions, and their associated practices, which permit beliefs about danger and safety to be constructed.
Waring (1992)	Those aspects of culture that affect safety.
Ostrom, Wilhelmsen, and Kaplan (1993)	The concept that the organization's beliefs and attitudes, manifested in actions, policies, and procedures, affect its safety performance.
Health and Safety Commission (1993), Lee (1996)	The product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management. Organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventative measures.
Ciavarelli and Figlock (1996)	The shared values, beliefs, assumptions, and norms which may govern organizational decision making, as well as individual and group attitudes about safety.
Berends (1996)	The collective mental programming towards safety of a group of organization members.

Carroll (1998)	Refers to a high value (priority) placed on worker safety and public (nuclear) safety by everyone in every group and at every level of the plant. It also refers to expectations that people will act to preserve and enhance safety, take personal responsibility for safety, and be rewarded consistent with these values.
Helmreich and Merritt (1998)	Safety culture is a group of individuals guided in their behavior by their joint belief in the importance of safety, and their shared understanding that every member willingly upholds the group's safety norms and will support other members to that common end.
Kennedy and Kirwan (1998)	The amalgamation of individual and group perceptions, thought processes, feelings and behaviors, which in turn gives rise to the particular way of doing things in the organization. It is a sub-element of the overall organizational culture.
Minerals Council of Australia (1999)	Refers to the formal safety issues in the company, dealing with perceptions of management, supervision, management systems and perceptions of the organization.
Eiff (1999)	A safety culture exists within an organization where each individual employee, regardless of their position, assumes an active role in error prevention and that role is supported by the organization.
Mearns and Flin (1999)	A more complex and enduring trait (in contrast to safety climate) reflecting fundamental values, norms, assumptions, and expectations, which to some extent reside in societal culture.
Guldenmund (2000)	Those aspects of the organizational culture which will impact on attitudes and behavior related to increasing or decreasing risk.
Reason (2000)	The ability of individuals or organizations to deal with risks and hazards so as to avoid damage or losses and yet still achieve their goals.
Hale (2000)	The attitudes, beliefs and perceptions shared by natural groups as defining norms and values, which determine how they act and react in relation to risks and risk control systems.
Glendon and Stanton (2000)	Comprises attitudes, behaviors, norms and values, personal responsibilities as well as such HR features as training and development.

Cooper (2000)	A sub-facet of organizational culture, which is thought to affect member's attitudes and behavior in relation to an organization's ongoing health and safety performance.
Wiegmann, Zhang, Von Thaden, Sharma, and Mitchell (2002)	The enduring value and priority placed on worker and public safety by everyone in every group at every level of an organization. It refers to the extent to which individuals and groups will commit to personal responsibility for safety, act to preserve, enhance and communicate safety concerns, strive to actively learn, adapt and modify (both individual and organizational) behavior based on lessons learned from mistakes, and be rewarded in a manner consistent with these values.
Mohamed (2003)	A sub-facet of organizational culture, which affects workers' attitudes and behavior in relation to an organization's on-going safety performance.
Collins (2003)	Leadership attitude that ensures a hazardous technology is managed ethically to ensure that individuals and the environment are not harmed.
Clarke (2003)	Relates to the core assumptions and beliefs that organizational members hold concerning safety issues; it is expressed through the beliefs, values and behavioral norms of its managers, supervisors and workforce, and is evident in company safety policy, rules and procedures.
Ciavarelli and Crowson (2004)	Shared attitudes, values, norms, and beliefs about safety, including attitudes about danger, risk, and the proper conduct of hazardous operations.
Institute of Nuclear Power Operations (2004)	An organization's values and behavior – modeled by its leaders and internalized by its members – that serve to make nuclear safety the overriding priority.
Richter and Koch (2004)	The shared and learned meanings, experiences and interpretations of work and safety – expressed partially symbolically – which guide peoples´ actions towards risks, accidents and prevention. Safety culture is shaped by people in the structures and social relations within and outside the organization.
Fang, Chen, and Louisa (2006)	A set of prevailing indicators, beliefs and values that the organization owns in safety.

Jeffcott, Pidgeon, Weymann and Walls (2006)	reflects the attitudes and behaviors that individuals share in considering and reacting to hazards and risks.
Choudhry, Fang, and Mohamed (2007)	Construction safety culture could be defined as: the product of individual and group behaviors, attitudes, norms and values, perceptions and thoughts that determine the commitment to, and style and proficiency of, an organization's system and how its personnel act and react in terms of the company's on-going safety performance within construction site environments
Fernández-Muniz, Montes-Péon, and Vázquez-Ordás (2007)	A positive safety culture is a set of values, perceptions, attitudes and patterns of behavior with regard to safety shared by members of the organization; as well as a set of policies, practices and procedures relating to the reduction of employees' exposure to occupational risks, implemented at every level of the organization, and reflecting a high level of concern and commitment to the prevention of accidents and illnesses.
Faridah, Hashim, Ismail and Abdul Majid (2009)	The product of shared values, beliefs, attitudes, and patterns of behavior based on a top-down approach practices that are concerned with minimizing the exposure to conditions considered dangerous or injurious to the entire group members on a self-regulatory basis.
Ooshaksaraie, Majid, Yasir, and Yahaya (2009)	Refers to a complex structure that includes values and attitudes, most of which are potentially changeable and relate to actual accident behavior.
Attree and Newbold (2009)	Refers to a commitment to safety that pervades the entire organization, from frontline staff to executive management.
EFCOG McDonald, Worthington, Barker and Podonsky (2010)	An organization's values and behaviors, modeled by its leaders and internalized by its members, which serve to make safe performance of work the overriding priority to protect the public, workers, and the environment.

Nævestad (2010)	Shared frames of reference that guide individuals' in workplace settings interpretations of hazards, and that motivate and legitimize preventive practices. Frames of reference are a prerequisite of seeing hazards, as they allocate attention, sensitize members to signals of danger and provide conceptualizations of hazards.
Nuclear Regulatory Commision Workshop (2010)	The core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment.

We believe that the different definitions of safety culture serve as a reference point for guiding research efforts within the construct. They help to align researchers' discoveries in the same directions in order to understand the nature, usefulness, and relationships among the relevant terms included in those definitions. We agree with Guldenmund (2000) that "the definition of a hypothetical construct sets the stage for ensuing research, i.e., it is the basis for hypotheses, research paradigms, and interpretations of the findings. It demarcates the boundaries of the concept and focuses the research" (p. 227).

Definitions of safety culture differ considerably from each other. Several definitions draw on the more general concept of organizational culture, with the scope limited to safety (Cooper, 2000; Guldenmund, 2000; Kennedy and Kirwan, 1998; Mohamed, 2003). Among other factors, the contents of safety culture, the organizational possibilities associated with safety culture, and the way safety culture is constructed bring the definitions closer to one of the two perspectives of culture mentioned in Section 2.2. Few definitions, such of those by Berends (1996) and Richter and Koch (2004), reflect a (more interpretive) socio-anthropological approach to culture. Whereas the majority of the definitions found (e.g., McDonald, Worthington, Barker and Podonsky, 2010; Ooshaksaraie, Majid, Yasir and Yahaya, 2009) follow the (more functionalistic) organizational psychology approach more. Some definitions of safety culture place special importance on the perceptions of organizational members (e.g., Minerals Council of Australia, 1999), and seem to be closer to safety climate than to safety culture (an explanation of the safety climate term is provided in Section 3.4.). Some definitions are exhaustive (e.g., Fernández-Muñiz et al., 2007; Hale, 2000; HSC, 1993; Lee, 1996) and consider that safety culture is composed of a wide variety of components, such as values, perceptions, attitudes, patterns of behavior, policies, practices, and procedures; whereas others are rather restrictive in terms of safety culture elements (e.g., IAEA, 1991; Locke and Latham, 1990; Reason, 2000).

Although there is little consensus on the definition and the implications for the concept of safety culture, a number of commonalities can be identified among the definitions presented. Table 3 presents the most common elements found in the 40 definitions given. Taking these commonalities as a reference, it can be argued that experts in safety culture agree to a greater or lesser extent with the following 10 points:

- Safety culture refers to a high value priority given to safety.
- Safety culture is embedded in organizational members´ assumptions, values, beliefs, and norms.
- Safety culture is manifested in organizational policies, practices, and procedures, as well as in members´ attitudes, perceptions and behaviors.

- Safety culture must be shared by all members of the organization.
- Safety culture is stable and enduring.
- Safety culture requires the responsibility and commitment to safety of all organizational members.
- Leaders play an important role in channeling safety culture.
- Safety culture determines the safety performance of the organization.
- Training/learning and reward systems play a crucial role in safety culture.
- The goal of safety culture is to promote and guarantee safety in the organization, thus protecting the workers, public, and environment from risks, accidents, and illnesses.

Table 3
Most common contents found in definitions of safety culture.

Behaviors / actions (21)	Responsibility (4)
Shared (17)	Assumptions (4)
Values (17)	Practices (4)
Attitudes (17)	Supervising, leadership (4)
Beliefs (12)	Policies (3)
Norms (9)	Procedures (3)
Safety Priority / importance (7)	Endurance (3)
Perceptions (7)	Safety management (2)
Commitment (6)	Rewarding (2)
Safety performance (5)	Training / learning (2)
	Thoughts (2)

Note: Figures in parentheses represent the number of studies (out of 40) in which this theme appears once or more.

With all this in mind, we propose a definition of safety culture aimed to reflect the agreement reached by researchers during the past 30 years:

"*Safety culture is an enduring and high value priority for safety, embedded in the assumptions, values, beliefs, and norms shared by organizational members and manifested in the organizational policies, procedures and practices and in the members' attitudes, perceptions, and behaviors at work, that determines organizational safety performance and serves to protect the workers, public, and environment from risks, accidents, and illnesses.*"

One of the most criticized aspects within the study of safety culture, highlighted by Cox and Flin (1998), has been the extensive debate about definitions and theoretical aspects at the expense of empirical research focused on the usefulness of the concept. The reason has been the heterogeneous application of the construct, which has led safety culture to be equated with concepts such as 'culture of reliability' (Sorensen, 2002), 'safety conscious work environment', 'safety management' (Choudry et al., 2007), and 'safety climate'. In the study of safety in high-reliability organizations, it is especially important to distinguish and integrate safety culture with safety climate, with the latter having received, as Cox and Flin (1998) report, a great deal of empirical research without extended debate on its definition.

3.4. Safety culture and safety climate

Safety culture and safety climate are different, complementary, and indispensable concepts for the understanding and improvement of safety performance in HROs. Although many scholars acknowledge differences between the two concepts, they have often been presented as indistinguishable and interchangeable (Rollenhagen, 2010). This debate about safety culture and safety climate is inherited from the classical debate about organizational culture and organizational climate (Denison, 1996; Pettigrew, 1990; Schneider, Ehrhart and Macey, 2013). The theoretical and empirical development of safety culture and safety climate have followed distinct paths. However, safety culture, the newer term, has existed for some years as safety climate (Lee, 1998). The trend is for safety culture to gain ground at the expense of safety climate, as recognized by the IAEA and other authors (Antonsen, 2009; Guldenmund, 2000; Hale, 2000).

Safety climate studies have been derived from the wider organizational climate, which in turn has been approached as global perceptions or as domain-specific perceptions (Zohar and Hofmann, 2012). The first perspective conceptualizes organizational climate as organizational members' global shared perceptions of key characteristics of the organization, as in the proposal of the IAEA (2002a): "Climate is the characteristic atmosphere within an organization at a given point in time, which is reflected in the way its members perceive, experience, and react to their surroundings" (p. 7). The distinction between organizational climate perceptions and other perceptions of key organizational characteristics and features is not clear, resulting in too much freedom in the inclusion of dimensions of organizational climate and, therefore, a noticeable lack of discriminant validity of the concept (Zohar and Hofmann, 2012). The second perspective recognizes that perceptions for climate are limited to specific organizational facets or domains (e.g., climate for safety, innovation or service). We agree with Zohar that climate should be 'for something'. As

Schneider (1990) has acknowledged, organizational climate is made up of shared perceptions among employees about the procedures, practices, and kinds of behaviors that get rewarded and supported with regard to a specific strategic focus. When the strategic focus involves performance of high-reliability operations, the resulting shared perceptions define safety climate (Zohar, 2000).

Safety climate and safety culture have been typically distinguished from a time-frame point of view. Safety climate is a manifestation or ‘snapshot’ of safety culture (Flin, Mearns, O´Connor and Bryden, 2000; Mearns, Flin, Fleming and Gordon, 1998); it is more transient and less stable. This distinction is stated in a number of definitions of safety climate, such as the one previously mentioned from the IAEA: “climate is the characteristic atmosphere within an organization at a given point in time... ” (p. 7), and the one by Byrom and Corbridge (1997): “...the tangible outputs of an organization's health and safety culture as perceived...at a particular point in time” (p. 3). Lee (1993) points out that safety culture, as opposed to the situationally-based safety climate, highlights a quintessential feature, which is that “the social system is independent of the people who comprise it, it consists of all that has been acquired and then passed on, all that endures” (p. 2).

Most authors also acknowledge differences in content when referring to safety climate and safety culture. Safety climate appears to be closer to operations, and its content generally includes day-to-day perceptions about the working environment, working practices, organizational policies, and management (Yule, 2003), differing from the stable, shared basic assumptions, beliefs, values, and norms (regarding safety at work) typically assigned to the core of (safety) culture.

As explained in Section 2.3., most of the models of culture distinguish between deep and surface-level cultural layers. Although the essence of culture is hidden in the core and deep levels, it manifests itself through the outer layers. Schein (1992) states that "climate will be a reflection and manifestation of cultural assumptions" (p. 230). Thus, (safety) climate is typically located in the outer layers (Guldenmund, 2000; Schein, 1992) of (safety) culture, facilitating ways through which (safety) culture can be partially reached. More precisely, climate perceptions focus on the surface-layer attributes of culture (Zohar, 2012).

Taking all of the above into account, we could arguably state that safety climate is the shared perceptions among the employees of an organization (or its groups) of the role of safety in the policies, procedures, practices, and other artifacts of the organization at a given point in time.

CHAPTER IV.

SAFETY CULTURE

ASSESSMENT

Once the reader has been introduced to the concepts of organizational culture and safety culture, it is time to address the assessment of safety culture.

To begin with, the main pros and cons of using qualitative and quantitative strategies for safety culture assessment are described, as well as the advantages of using a triangulation methodology to reduce the limitations of the single application of qualitative and quantitative safety culture assessment tools. Next, 20 of the most relevant safety culture questionnaires are classified by theoretical background, industry, questionnaire factors, statistical analyses performed by its authors, and evidence of validity. Conclusions from the analysis of the contents of the 180 dimensions of the 20 questionnaires are provided. Finally, the last section of this chapter offers a further explanation of (safety culture) questionnaires based on models of organizational culture or models of safety culture, as well as a brief description of the corresponding models.

4.1. Qualitative vs. quantitative strategies

If safety culture has been shown to be a critical factor in the prevention / causation of nuclear accidents, the use of adequate methodologies and tools for safety culture assessment is fundamental in becoming aware of those organizational and management aspects that have to be improved, changed, or reinforced in order to guarantee the plant's safe operation.

Unfortunately, there are no standardized or 'off-the-shelf' tools that can be used across domains or even within a single domain (Cox and Flin, 1998). Safety culture has been assessed by a variety of methods that have traditionally been classified as qualitative or quantitative.

4.1.1. Qualitative methodologies

The main and most frequently used qualitative methodologies for (safety) culture assessment are employee observations, focus groups, audits, examination of archival data, expert ratings, case studies, and, especially, in-depth interviews. Qualitative approaches provide vast amounts of unstructured information in the form of the participants' own words. They allow participants to raise their concerns and opinions about organizational and safety issues without restrictions, that is, without being limited or confined by researchers' prior ideas about what is to be found in the targeted organization. Thus, individuals serve as 'informants' (Rousseau, 1990). Qualitative methodologies provide rich and unique information from participants because the 'meaning' emerges without imposition (Reichers and Schneider, 1990). They have the greatest potential to provide information about the deepest levels of organizational culture, that is, the levels that ultimately determine the behavior of employees, which in turn influences the safety of the NPP. However, qualitative methodologies do not always guarantee that this information is obtained. Moreover, they may elicit relevant information about the existing (safety) culture in the organization, but the later integration and interpretation of this information can be very complex. As Schein (1992) highlights in his qualitative studies, to understand and interpret the culture of an organization, the researcher or consultant must have extensive previous experience and be able to set aside his/her prejudices and expectations, which is difficult in most cases. Or in the words of Tonn (2003), the process of expert fact-finding is "biased by the prejudices, interests, stereotypes, and moral codes of the investigators" (p. 361). Beyond the difficulties inherent in using qualitative methodologies, they are often rejected because of their high costs in terms of time, money, and personnel.

4.1.2. Quantitative methodologies

The main and most frequently used quantitative methodologies for (safety) culture assessment are surveys, highly structured interviews, Q-sorts, and especially, questionnaires. With quantitative methods, researchers seek only the specific information they consider necessary to address the issue under study. This information is usually obtained by means of participants' answers to standardized sets of stimuli or questions. Thus, individuals serve as 'respondents' (Rousseau, 1990). Therefore, quantitative methodologies provide restricted and targeted information from participants because meaning is imposed on a set of data rather than letting the meaning emerge (Reichers and Schneider, 1990), which makes it difficult to capture the idiosyncrasies and particularities of the deepest cultural levels of the NPP under study. However quantitative methodologies in the nuclear industry, particularly questionnaires, offer clear advantages over qualitative methodologies. Among others, they require significantly less time from participants, allowing access to many organizational members from all hierarchical levels of the NPP; they require a lower budget; and they provide data that can easily be coded, analyzed, and benchmarked among NPPs. As a result, questionnaires allow the safety culture of NPPs to be assessed more frequently and systematically than in-depth interviews and other qualitative methodologies. Frequent monitoring in NPPs is extremely important for the early detection of declining and weakening safety cultures (IAEA, 2006a, López de Castro et al., 2017), allowing time to take remedial action before minimum acceptable safety levels are challenged (IAEA, 2003). Systematic monitoring through the comparison of quantified results at different times makes it possible to detect trends (Hale, 2009; Håvold, 2005; IAEA, 2003) and evaluate the evolution of safety culture. For these reasons, in spite of the merits of qualitative methods, a questionnaire on safety culture is a valuable resource for the nuclear industry (López de Castro et al., 2017).

4.1.3. Triangulation

To reduce the shortcomings from the single application of qualitative and quantitative methodologies and to obtain the best results when assessing safety culture, a triangulation methodology is most likely to be required (Glendon and Stanton, 2000; IAEA, 2002b; Schöbel, Klostermann, Lassalle, Beck and Manzey, 2017). However, it is often not possible to use this approach in HROs. If the appropriate measurement instruments are employed, “triangulation allows researchers to take a multifaceted view of safety culture, so that the reciprocal relationships between psychological, behavioral and situational factors can be examined with a view to establish antecedents, behavior(s) and consequence(s) within specific contexts” (Cooper, 2000, p. 120). A triangulation methodology, including interviews, surveys, audits, document analysis, etc., also allows for multilevel analyses of safety culture (Choudry et al., 2007).

Two examples of triangulation in safety culture assessment in the nuclear industry can be found in the IAEA (2008) and in Schöbel et al. (2017). The IAEA developed a triangulation methodology called SCART (Safety Culture Assessment Review Team), including interviews, observations, and documentation reviews, based on the IAEA five-dimensional safety culture model, which will be explained in Section 4.3.7. Most recently, Schöbel et al. (2017) developed a triangulation methodology that included observations, questionnaires, interviews, and group workshops, which will briefly be described in Section 4.3.8.

4.2. Safety culture dimensions and questionnaires

There are many questionnaires currently available that can be used to gather information about the safety culture of HROs. They claim to assess the construct of safety culture or other aspects related to safety culture, such as safety management systems, safety performance indicators, and particularly, safety climate.

Because safety climate is viewed as a ‘snapshot’ of workforce perceptions of safety (Mearns, Flin, Gordon and Fleming, 2001) that may reflect the current-state of the underlying safety culture (Mearns et al., 2001; Mearns, Whitaker and Flin, 2003), many authors rely on climate studies to capture the state of HROs’ safety cultures. However, caution must be used when ascribing the results of safety climate assessments to the stable cultural elements of an organization (González-Romá and Peiró, 2014) because climate perceptions provide ‘here and now’ information, which, as Mengolini and Debarberis (2007) indicate, is influenced by external and temporary circumstances.

Some authors, such as Flin et al. (2000), Guldenmund (2000), and Yule (2003), have made an effort to compile questionnaires for safety culture assessment, the majority of which measure safety climate perceptions. These reviews clearly support the multidimensionality of safety culture and safety climate; however, they find little consensus among studies about the number and labeling of their dimensions. Inconsistencies can be observed in the labeling of dimensions, even when authors refer to the same contents and sub-contents of these constructs. Despite this confusion, these reviews help to identify some of the most common themes assessed in safety (mainly climate) questionnaires. Flin et al. (2000) highlight five common contents in the following order: management/supervision, safety system, risk, work pressure, and competence. On the other hand, Flin et al. (2000) also identify the most frequently measured dimensions in Guldenmund´s (2000) work, namely: management, risk, safety arrangements, procedures, training, and work pressure (in that order). A number of questionnaires are included in both Guldenmund’s and Flin et al.’s reviews. The work by Clarke (2006) presents a comprehensive source of climate questionnaires; however, it does not present the dimensions in each survey.

We have also included a review of questionnaires for HROs (summarized in Table 4). However, as the main focus of this thesis is safety culture, the present review only includes questionnaires that have been presented by their authors as ‘safety culture questionnaires’, or questionnaires whose dimensions are presented as dimensions, factors, or contents of safety culture.

As part of our work, we calculated the frequency with which different safety culture contents have been identified in these studies. To do so, we took into account each of the 180 dimensions of the 20 questionnaires reviewed. We found eight double-barreled dimensions. In these cases, dimensions were assigned to two different contents (e.g., ‘safety training and competence’ was classified under ‘training’ and ‘competence’, or ‘safety attitude and behavior’ was classified under ‘behaviors’ and ‘attitudes’).

The five most common dimensions mentioned in the studies in our review are in this order: management, training, communication, risk, and support (see Table 5). The ‘Management’ dimension refers to perceptions about management and supervisors’ attitudes and behaviors towards safety, as well as the extent to which leadership styles promote safety at work. ‘Training’ addresses the efforts to maintain a qualified, skilled, and knowledgeable workforce through training in technical, management, and safety issues. ‘Communication’ refers to formal communication among different hierarchical levels about issues related to safety (e.g., safety aims, safety rules, and procedures), as well as the extent to which safety pervades informal discussions. ‘Risk’ dimensions capture the perception and awareness of risks, the management of risks at the worksite, and the extent to which employees take risks to get the work done. ‘Support’ refers to the degree of social support among colleagues, regardless of the hierarchical level (including the support of safety personnel), and the existence of an environment that supports high-quality and safe work.

Table 4
Safety culture questionnaires

Reference	Background (supported or not by theoretical frameworks)	Items	Industry and Sample	Analysis to determine questionnaire factors	Questionnairefactors = culture dimensions	Evidence of validity
Ostrom, Wilhelmsen and Kaplan (1993)	Items developed from interviews and analyses of managers' safety statements. The authors sorted the items into 13 categories identified from a review of literature.	88	US. 4000 respondents from 5 departments of a Nuclear energy laboratory	Not applied. Dimensions identified from literature = questionnaire dimensions	13: Safety awareness; teamwork; pride and commitment; excellence; honesty; communications; leadership and supervision; innovation; training; customer relations; compliance; safety effectiveness; facilities.	Examples were given of few descriptive analyses: one department had a higher number of accidents and lower scores on a number of items than the other departments.
Carroll (1998)	Some items were taken from a prior research questionnaire, some from a safety culture questionnaire used by other consultants at the plant, and some were written by the team for this project. No dimensions specified a priori.	47	US. 115 (88%) respondents from a NPP	Not applied	5: Management support; openness; knowledge; work practices; attitudes.	Apparent differences between groups (hierarchical level, department) on various items were found, but analyses were not conducted beyond descriptives.
Lee (1998)	Focus groups were held to elicit safety-relevant beliefs, attitudes and values, and the material was incorporated into a 172-item questionnaire. The authors grouped the items into 9 different domains: safety procedures; risks: job satisfaction; safety rules; participation; training; control; design of plant.	172	UK. 5296 (80%) respondents from a nuclear reprocessing plant	Principal Component Analysis (PCA) were computed separately for each of 9 the domains	19: Confidence in safety procedures; personal caution over risks; perceived level of risk at work; trust in workforce; confidence in efficiency of PTW system; general support for PTW system; perceived need for PTW system; personal interest in job; contentment with job; satisfaction with work relationships; satisfaction with rewards for good work; personal understanding of safety rules; perceived clarity of	Factor scores were validated against reported number of lost-time accidents and most discriminated at high levels of significance.

					safety rules; satisfaction with training; satisfaction with staff suitability; perceived source of safety suggestions; perceived source of safety actions; perceived personal control over safety; satisfaction with design of plant.	
Grote and Künzler (2000)	A socio-technical model of safety culture was used as a framework for the development of the questionnaire. The items were constructed on the basis of broad definitions of three content areas: operational safety; safety and design strategies; personal job needs.	57	UK and US. 1201 respondents from 6 globally operating petrochemical corporations	PCA for each of the 3 content areas	7: Operational safety (enacted safety; formal safety; technical safety); safety and design strategies; personal job needs (quality of job; general training; safety).	Differences in scores in the three sections of the questionnaire between test sites as well as between different groups of employees within sites were found. Expert evaluations of safety management based on interviews and plant visits as a criterion for testing concurrent validity were used.
Lee and Harrison (2000)	Focus groups were held to elicit safety-relevant beliefs, attitudes and values, and the material was incorporated into a 120-item questionnaire. The authors relied on their judgment and the content of the focus group discussions to allocate the items to 8 domains relevant to safety performance: confidence in safety; contractors; job satisfaction; participation; risk; safety rules; stress; training.	120	UK. 683 (53.7%) respondents from 3 NPPs	PCA for each of the 8 domains	28: confidence in control measures; confidence anticipation/response; confidence in reorganization; confidence in safety standards; company support contractors; satisfaction with contractors' safety; respect for contractors' role; contentment with job; satisfaction with job relationships; interest in the job; trust in colleagues; perceived empowerment; management’s concern for safety; general morale; organizational risk level; personal risk taking; risks of multi-skilling; risk vs. productivity; complexity of instructions; hazard	24 factors were correlated with one or more of nine criteria for accident history. Differences in summary scores (single scores for each respondent which aggregated the score on each of the 28 factors) between and within stations (gender, age, shifts/days and work areas) were found. Correlations were found between several factors and three organizational variables.

					identification/response; response to alarms; emergency procedures; personal stress; job insecurity; management's concern health; quality training induction; effectiveness of staff selection; general quality of training.	
Harvey, Erdos, Bolam, Cox, Kennedy and Gregory (2002)	Items covering 8 contents of safety culture identified in the literature (perception of others' attitudes to safety; perceived trust in management in relation to safety; job interest and satisfaction; perceived judgement of and attitudes to risk; perceived responsibility for and involvement in safety issues; upward and downward communication with respect to safety; attitudes to conventional and radiological safety; perceived changes in work and safety attitudes over the past years) were constructed by the authors.	60	UK. 1003 (64.7%) respondents from two nuclear reprocessing plants	PCA of the entire data set. Confirmatory Factor Analysis (CFA)	6: Management style and communication; responsibility and commitment; risk-taking; job satisfaction; complacency; risk awareness.	Differences in item scores between and within plants (hierarchical groups) were found. Although not intended and not stated in the study, factor analysis partially supported the contents of safety culture chosen from the literature.
Håvold (2005)	Based on review of literature. 19 items selected from existing safety questionnaires and 21 new items. No dimensions specified a priori.	From 40 to 22	Norway. 349 (60%) respondents from a large Norwegian shipping company	PCA of the entire data set	4: Employee and management's attitude to safety and quality; knowledge; attitudes to safety rules/instructions; quality and safety experience.	Correlations were found between factor scores and three 'level of safety' measures. Some differences in factor scores between groups (nations, occupation, and vessels) were found.

Gibbons, von Thaden and Wiegmann (2006)	The authors identified items from literature on organizational culture that could cover the five factors of safety culture (organizational commitment; management involvement; employee empowerment; reporting systems; accountability systems) identified by Wiegmann et al. (2004).	From 84 to 55	US. 503 (29%) pilots of a large airline	CFA and Exploratory Factor Analysis (EFA) for the entire data set and for individual dimensions	4 main factors and 12 sub-factors: formal safety program (reporting system; response and feedback; safety personnel); informal aspects of safety (accountability; pilots' authority; professionalism); operations personnel (chief pilots; dispatch; instructors/trainers); organizational commitment (safety values; safety fundamentals; going beyond compliance).	A pilot study and the opinions of SMEs served to refine the questionnaire and establish face and content validity. The 5-factor structure proposed could not be replicated. A new structure for safety culture was proposed, although it did not yield a good fit to the data.
Baker (2007)	Questionnaire developed on the expertise of SME.	65	US. 7451 (72%) respondents from 5 oil refinery plants of the same company	Not specified	6: process safety reporting; safety values/commitment to process safety; supervisory involvement and support; procedures and equipment; worker professionalism/empowerment; process safety training.	Consistent and wide divergence in most of the items among plants.
Díaz-Cabrera, Hernández-Fernaud and Isla-Díaz (2007)	7 components of safety culture (incident and accident reporting systems; orientation of safety rules and procedures; performance appraisal and safety promotion strategies; motivation patterns used; information and communication systems: and leadership styles) were identified from literature review. Items related to the four cultural orientations proposed by the competing values framework (Cameron and Quinn, 1999) were developed for each of the dimensions.	44	299 respondents from 5 companies in different sectors: gas, petrol, aviation, transport and brewery	PCA of the entire data set	6: company values; leadership styles; motivation patterns; training programmes; downward communication; usage of accident and incident information.	Cluster analyses and discriminant function analysis could not support the simultaneous presence of the 4 cultural orientations proposed by the Competing Values Framework, but results suggested that different safety cultural orientations can coexist in a single organization. Different safety culture profiles in companies operating in different sectors (gas companies, petrol refineries, aviation companies, transport companies and breweries) were found.

Ek, Akselsson, Arvidsson and Johansson (2007)	9 aspects of safety culture were identified in the literature. Items were developed for each of the aspects.	95	Sweden. 391 (61.6%) respondents from one administrative and two operative units in an air traffic control setting	Not applied. Dimensions identified from literature = questionnaire dimensions	9: working situation; communication; learning; reporting; justness; flexibility; attitudes towards safety; safety-related behaviors; risk perception.	Leaders evaluated the items for relevance and appropriateness. Pilot study was conducted. Differences in factor scores were found between managers and non-managers. Correlations between all cultural aspects were found, as well as between each of the cultural aspects and 10 organizational climate dimensions.
Gordon, Kirwan and Perrin (2007)	21 items from literature review were chosen and grouped into four safety culture dimensions. Items should provide info on the stage of maturity of an organizations´ safety culture.	21	France. 36 (90%) respondents from an air traffic management research center	Not applied. Dimensions identified from literature = questionnaire dimensions	4: Management demonstration; planning and organizing for safety; communication, trust and responsibility; measuring, auditing and reviewing.	Compared in terms of various validity criteria against a safety management survey in order to investigate how both questionnaires can be used together to assess safety culture.
Kao, Chung, Lai and Chuang (2007)	Based on review of literature and related measures of safety culture, the authors proposed a number of dimensions of safety culture, which can be grouped under each of the 3 dimensions of the IAEA (1991) model of safety culture: policy level commitment, managers' commitment, and individuals' commitment.	73	Taiwan. 466 (77.2%) respondents from 5 sister plants within a petrochemical company	CFA for individual dimensions. Structural equation modeling (SEM)	8: organization's commitment (safety management system and organization; accident and emergency), managers' commitment (safety supervision and audit; safety commitment and support; rewards and punishment and benefits), and individuals' commitment (safety training and competence; safety attitude and behavior; safety communication and involvement).	The 3-factor structure proposed provided an acceptable fit. Factor scores were validated against two safety performance variables: safety satisfaction and work risk.

Mohamed and Chinda (2008)	Items from previous studies were identified to cover each of the five ‘enablers’ (leadership; people; policy and strategy; partnerships and resources; processes) of the EFQM model, as well as an overall dimension, labeled ‘goals’, which combined the four ‘results’ from the EFQM.	From 34 to 24	Thailand. 115 (53.6%) respondents from over 100 construction organizations	EFA for the entire data set. SEM	5: leadership; people; policy and strategy; partnerships and resources; processes.	The proposed factor structure was supported. Interactions and causal relationships were found between both the 5 enablers and the goals factor, and among the enablers themselves.
Antonsen (2009)	Not specified	20	Norway. 415 (82.5%) respondents from an oil and gas platform	Not specified	5: managers’ prioritization of safety; safety communication; individual risk assessment; supportive environment; safety rules and procedures.	High divergence between the safety culture questionnaire results and two post-incident descriptions. Differences in four items between the platform under study and three other installations.
Mearns, Kirwan and Kennedy (2009)	Based on literature review and interviews with SMEs, items belonging to 13 constituents of safety culture (commitment to safety; resources for safety; responsibility for safety; involving air traffic controllers in safety; management involvement in safety; teaming for safety; reporting incidents/communicating problems; learning from incidents; blame & error tolerance/discipline and punishment; communication about procedural/system changes; trust within the organization; real working practices; and regulatory effectiveness) were identified.	From 80 to 59	Europe. 4 different samples from 4 different air navigation service providers (ANSP). Response rate over 30% in 3 of the 4 ANSPs	EFA for the entire data set in two samples. CFA in one sample	3 dimensions extracted from the CFA: prioritization; involvement; trust.	Face and content validity by a group of European ANSP safety managers. EFA and CFA could not replicate the proposed factor structure. One EFA provided a unifactorial solution; another EFA resulted in an 8-factor model, but the items that grouped together did not reflect a single specific factor. CFA showed a good fit for a 3-factor structure which represented 3 main emerging themes from the safety culture literature.

Filho, Andrade and Marinho (2010)	5 common dimensions of safety culture identified from literature review. Items for each of these dimensions were developed to identify Hudson's (2001) stages of maturity of an organization's safety culture.	102	Brazil. 23 (100%) safety managers from 23 petrochemical companies	Not applied. Dimensions identified from literature = questionnaire dimensions	5: Information; organization learning; involvement; communication; commitment.	High correlations between questionnaire scores and interview scores were found for each of the 5 dimensions. The 23 companies presented characteristics of different levels of safety culture maturity.
Wang and Liu (2012)	On the basis of literature review, items covering 18 dimensions of safety culture grouped in 4 categories (environment; organization; personal; psychology) were proposed.	96	Taiwan. 229 (88.1%) respondents from four railway companies	PCA with summary scores of the 18 safety culture dimensions	18 dimensions of culture were grouped in two categories: Organization and environment (management of change; risk management; performance measurement; procurement management; safety system; safety commitment; safety training; safety leadership; safety communication; safety encouragement and punishment; safety rule; contractor management; safety environment); psychology and person (safety knowledge; worker participation; safe behavior; safety awareness and attitude; health activities)	Face and content validity established by focus groups with the railway management and on-site employees, and reviews by 5 SMEs. Differences among positions were found in the 4 dimensions of safety culture initially proposed. Factor analyses did not support the proposed factor structure.

Frazier (2013)	SME on safety culture identified 4 safety culture dimensions (management concern for safety; peer support for safety; personal responsibility for safety; safety management systems) from the literature, and 92 items to cover them.	92	25574 respondents from 5 multinational organizations in five different industries (mining, chemical, healthcare, steel, agricultural)	EFA of the entire data set. CFA	4 first order and 12 second order factors: management concern for safety (supervisor concern; senior management concern; management work pressure); personal responsibility for safety (risk taking; supervisor/management blame; incident reporting behavior); peer support safety (caution others; respectful feedback); safety management systems (communication; training and rules; discipline and investigation; reward/recognition).	The data showed a good fit to the 4 safety culture dimensions identified from the literature.
López de Castro, Gracia, Peiró, Pietrantoni and Hernández (2013)	37 attributes clustered into 5 dimensions based on research findings, lessons learned about the root causes of organizational failures in safety management and safety culture, and the international collaboration of safety experts under the auspices of the IAEA.	37	Spain. 3 independent samples: 468 workers of a Spanish NPP (65.13%), 48 experts in organizational behavior (74%) and 290 students (100%).	Judgments. EFA and PCA of the entire data set. CFA	5: safety is a clearly recognized value; leadership for safety is clear; accountability for safety is clear; safety is integrated into all activities; safety is learning driven	The study suggests that several attributes may not be related to their corresponding dimensions. According to results, a one-dimensional structure fits the data better than the five dimensions proposed by the IAEA. The IAEA proposal, as it stands, seems to have rather moderate content validity and low face validity.

Note: In Antonsen (2009) and Frazier (2013), the authors of the study are not the same as the authors of the questionnaire.

Table 5

Most common assessed contents in safety culture questionnaires

Management / Leadership / Supervision (14)	Involvement (4)
Training / Learning (12)	Measures, Audit (4)
Communication (10)	Rules (4)
Risk (7)	Competence / Knowledge / Experience (4)
Support (7)	Responsibility (4)
Commitment (6)	Values (4)
Proactivity (6)	Empowerment (3)
Resources (5)	Behaviors (3)
Attitudes (5)	Personnel suitability (3)
Technology / Design (4)	Compliance (3)
Reporting (4)	Relations (3)
Trust (4)	Professionalism (2)
Job (4)	Safety values (2)
Rewards (4)	Contractors (2)
Procedures (4)	Emergency (2)

Note: Figures in parentheses represent the number of studies (out of 20) in which the corresponding theme appears once or more.

Comparing our review with those by Guldemund and Flin et al., we notice that 'management', 'training' and 'risk' are also among the five most common dimensions included in their reviews. However, 'communication' and 'support' were not highlighted as common themes in the Flin et al. and Guldenmund reviews. On the other hand, while their reviews highlight the safety management system (SMS) ('safety system' in Flin [2000] and 'safety arrangements' in Guldenmund [2000]) as a single and frequent dimension, our review does not. To us, SMS is too broad a concept to be considered as a single safety culture dimension. Moreover, there is still much debate about what the components of a good SMS are (e.g., safety policy, incentives for employee participation, training, communication, planning and control [Fernández-Muñiz et al., 2007]; safety officials, safety committees, permit to work systems, safety policies, and safety equipment [Flin, 2000]; policies, strategies, and procedures [Kirwan, 1998]). For these reasons, we have not grouped together the different contents that may belong to SMS. Furthermore, in our review we have separated 'training' from 'competence' and 'knowledge', as the latter two do not necessarily have to be a consequence of training. Flin et al. (2000), however, include these three dimensions under the theme of 'competence'. Finally, it is interesting that while 'work pressure' is a frequent dimension of their questionnaires, it only appears in one of the questionnaires in our review.

This wide variety in the dimensions of culture and climate questionnaires is partly due to the methodology used in their designs. Typically, in both culture and climate questionnaires, the authors identify a number of objects that are believed to affect safety outcomes, and they create items to measure the current perceptions or current attitudes of respondents toward those objects. In order to reduce the complexity and help to interpret the information provided by the numerous items included in a questionnaire, the items are usually grouped by themes or higher-level contents or dimensions of culture or climate. However, the typical use of reductionist approaches to identify these dimensions (e.g. factor analysis [FA]) without the guidance of solid theoretical models (Guldenmund, 2000) leads to limited consensus about the number and content of the dimensions of safety culture questionnaires.

The majority of the studies in our review apply tentative exploratory analyses without trying to elaborate on existing proposals. Only seven of them developed their questionnaires on the basis of theoretical models of safety culture or more general theoretical frameworks. Díaz-Cabrera et al. (2007) composed the questionnaire items based on the Competing Values Framework by Cameron and Quinn (1999); Grote and Kunzler (2000) presented a three-dimensional socio-technical model of safety culture that was used to developed their own questionnaire; Filho et al. (2010) and Gordon et al. (2007) created questionnaires to identify the stages of maturity of organizations' safety culture proposed by Hudson (2001) and Fleming (1999), respectively; Chinda and Mohamed's (2008) questionnaire had its origins in the European Foundation for Quality Management Model (EFQM); Kao et al. (2007) created a safety culture model and questionnaire based on the first IAEA safety culture model (1991); López de Castro et al. (2013) created a questionnaire using the 37 attributes of the second IAEA safety culture model (IAEA, 2006a).

Most of the studies in the present review reported differences in scores across different groups (e.g., hierarchical level, occupation, gender) as proof of the discriminative power of the items and dimensions of their scales. Some of the authors also made an effort to provide additional sources of evidence of validity. However, as Guldenmund (2000) claims in his review, only a few authors (Chinda and Mohamed, 2008; Håvold, 2005; Kao et al., 2007; Lee, 1998; Lee and Harrison, 2000]) validated their questionnaire scores against safety outcomes, which means that the usefulness of the majority of safety culture questionnaires remains untested.

4.3. Safety culture questionnaires based on models of organizational and safety culture

This section provides a further description of those safety culture questionnaires (mentioned at the end of Section 4.2.) whose items and/or dimensions have been drawn from models of organizational culture or from models of safety culture (Chinda and Mohamed's, 2008; Díaz-Cabrera et al., 2007; Filho et al., 2010; Gordon et al., 2007; Grote and Kunzler, 2000; Kao et al., 2007). The corresponding 'inspiring' safety culture or organizational culture models are also described.

Additionally, two questionnaires (and their corresponding culture models) not included in the content analysis of safety culture questionnaires in Section 4.2. are also outlined in the present section: a triangulation study by Schöbel et al. (2017), not included in section 4.2. because the items on the questionnaires they used are to be customized for the particular organization under study; and a safety culture questionnaire (The Safety Culture Enactment Questionnaire [SCEQ]) and its corresponding model of safety culture, both developed by our team (López de Castro et. al., 2017). This model and questionnaire were not included in Section 4.2. because "the dimensions of the SCEQ are not intended to be dimensions of safety culture per se, but rather dimensions of fundamental sets of actions of an NPP where the value of safety can be crystallized" (López de Castro et. al., 2017, p. 50).

4.3.1. The Culture Values and Practices Questionnaire (QCS) and the Competing Values Framework

The Competing Values Framework was created from research on key indicators of effective organizational performance. From these empirical studies, two major dimensions consistently emerged. One dimension distinguishes an emphasis on flexibility, discretion, and dynamism from an emphasis on stability, order, and control. A second dimension distinguishes an internal orientation with a focus on integration, collaboration, and unity from an external orientation with a focus on differentiation, competition, and rivalry (Cameron, 2009). Together, these dimensions form four quadrants representing organizational culture orientations that co-exist in an organization and represent opposite or competing assumptions of organizational life: human relations model or clan culture, open system model or adhocracy culture, internal process model or hierarchy culture, and rational goal model or market culture (Cameron and Quinn, 1999).

Díaz-Cabrera et al (2007) developed a safety culture questionnaire focused on organizational values and practices related to the safety management system. Based on a theoretical review, they identified a number of key safety culture dimensions and indicators related to the four cultural models of Cameron and Quinn’s (1999) framework. These safety culture dimensions reflect the organizational structure, policies, and practices of an organization that are directly involved in risk prevention. For Cabrera’s team, these components come from underlying patterns of shared meanings and beliefs, and they can be used as valid indicators in safety culture assessment.

The initial questionnaire was reviewed by a human resources expert group, administered in a pilot study in an aviation maintenance company, and finally, submitted to Principal Component Analysis. The result was a 44-item questionnaire grouped "in six factors for key organizational values and practice related to organizational safety culture" (p. 1205): company values, leadership styles, motivation patterns, training programs, downward communication, and use of accident and incident information.

Furthermore, Díaz-Cabrera et al. (2007) used cluster analyses and discriminant function analysis to explore the simultaneous presence of the four cultural orientations proposed by the Competing Values Framework toward safety: support, innovation, rules, and goals. However, the four cultural orientations were not obtained. The authors proposed that some characteristics of their work made it difficult to affirm the suitability of Cameron and Quinn's model for the study of safety culture: an inherent theoretical difficulty of adapting and extrapolating Cameron and Quinn's (1999) framework to safety is that "the organizational profile oriented toward goal achievement is characterized by prioritizing productivity objectives that can occasionally conflict with safety goals" (p. 1210). Moreover, the Likert-Type scales used by Díaz-Cabrera's team may not accentuate the differences between the cultural orientations, such as the ipsative response scales employed by Cameron and Quinn, where participants must share 100 points among the four alternatives describing each cultural orientation. Díaz-Cabrera's team decided to use Likert-Type scales in order to run more complex statistical analyses and encourage greater sample participation.

The questionnaire could not reflect the competing values framework as planned, but the results suggested that different safety culture orientations can coexist in a single organization. Díaz-Cabrera's team suggested that "a positive safety culture based on standard safety rules might co-exist with a cultural orientation towards developing human resources and innovation" (p. 1210).

Finally, Díaz-Cabrera's team found different safety culture profiles in companies operating in different sectors (gas companies, petrol refineries, aviation companies, transport companies, and breweries). The profiles obtained showed significant differences in three of the six dimensions of their questionnaire (values, training programs, and motivation patterns) among the companies assessed.

4.3.2. Socio-technical model and safety culture questionnaire

Grote and Künzler (2000) presented a socio-technical model of safety culture and a questionnaire, based on that model, which, along with interviews and work place observations, could support audits to analyze a company's safety management and safety culture. Grote and Künzler argue that:

"1. The proactive integration of safety into organizational structures and processes (proactiveness) and 2. the joint optimization of technology and work organization (socio-technical integration) need to be aimed at, taking into account 3. both material and immaterial characteristics of an organization (value consciousness)" (p. 133).

Grote and Künzler´s questionnaire included items related to material (visible) and immaterial (hidden) characteristics related to both safety process integration and socio-technical design. The questionnaire, developed primarily to carry out audits at petrochemical production sites, contained three sets of items:

- Operational safety: a total of 20 items for technical, organizational, and person-related safety measures; as well as for actual safety performance. This section tried to capture perceptions about formal safety management, as well as about safety enacted in daily operations. Five-point Likert-type scales were used for these items.
- Safety and design strategies: a total of 16 pairs of statements were included in the questionnaire, addressing strategies related to safety management and socio-technical design. The authors defined a ‘positive’ and ‘negative’ side based on assumptions contained in their safety culture model. Respondents needed to choose, on a five-point scale (2, 1, 0, 1, 2 with the two statements serving as anchors for the value 2 on either side), which value best described the way the respective issue was handled in their organization.
- Personal job needs: a total of 21 items addressing personal needs for good job performance, dealing with safety measures as well as issues of quality of job design and general training. For each item, participants had to indicate whether they needed more or less of that aspect to do their job well. Five-point Likert-type scales were also used for these items.

Grote and Künzler found differences in scores on the three sections of the questionnaire among the test sites, as well as between different groups of employees within sites (operations versus maintenance and management versus employees). They used expert evaluations of safety management based on interviews and plant visits as a criterion for testing concurrent validity. However, the authors did not intend to correlate results from either the questionnaire or the formal safety management audits with accident and incident data because their occurrence was too rare in the petrochemical companies under study.

4.3.3. Safety culture questionnaire drawing on the EFQM model

The EFQM Excellence Model, promoted by the European Foundation for Quality Management, is based on nine criteria. Five of them are ‘enablers’ and four are ‘results’. The ‘enabler’ criteria cover what an organization does and how it does it, i.e. the operation of the company. The five enablers proposed by the EFQM are: leadership; people; strategy; partnerships and resources; and processes, products and services. The ‘results’ criteria cover what an organization achieves, i.e. the organizational goals. The EFQM includes four results: customer results, people results, society results, and business results.

Chinda und Mohamed (2007) used the EFQM model to understand and improve safety culture in construction companies. They created a safety culture questionnaire that covered the five enablers of the EFQM model and a sixth dimension called ‘goals’, which amounted to the four ‘results’ criteria from the EFQM model. The items were designed to elicit respondents’ opinions about these six dimensions in the context of their current safety practices and performance. Five-point Likert-type scales were used.

By performing exploratory factor analyses (EFA) with the ‘enablers’ items, the authors identified a total of five underlying factors, which the authors labelled (in line with the EFQM model's enablers): leadership; people; policy and strategy; partnerships and resources; processes. These five dimensions included a total of 24 items. In addition, seven items were used to explain the 'goals' dimension (e.g., level of job satisfaction, safe work behavior, number of accidents and safety-related incidents, exceeded customers' expectations).

Structural equation modeling (SEM) supported the existence of a strong relationship between processes and goals, implying that "positive safety outcomes can only be achieved through the rigorous implementation of safety related processes, which appear to be directly related to people, and to policy and strategy, and not to partnerships and resources" (p. 127).

The six theoretical constructs mentioned (five enablers and a single set of goals) represented the basic elements of the proposed construction safety culture model by Chinda and Mohamed (2007).

4.3.4. The Safety Culture Survey (SCS) and Fleming´s safety culture maturity model

Fleming proposes that companies in the early stages of developing their safety culture need different improvement techniques from those companies with strong safety cultures. For this reason, a safety culture maturity model can be helpful to assist HROs in assessing their current level of safety culture maturity and in identifying the actions needed to improve their safety culture (Fleming, 1999; Fleming, 2001).

The safety culture maturity model is set out in a number of iterative stages. Organizations progress sequentially through the five levels by building on the acquired strengths and removing the existent weaknesses of the previous level. A brief description of these levels (Fleming, 1999; Fleming, 2001) is presented next:

- Level 1 - Emerging - safety guaranteed by technical and procedural solutions and compliance withregulations; safety is not a key business risk; accidents seen as unavoidable and part of the job; most frontline staff have no interest in safety.
- Level 2 - Managing - safety seen as a business risk; safety solely defined in terms of adherence to rules, procedures, and engineering controls; accidents seen as preventable; perception that most accidents are caused by unsafe behavior of front-line staff; senior managers are reactive in their involvement in health and safety.
- Level 3 - Involving - majority of staff involved in health and safety and accept personal responsibility for own health and safety; managers recognize a wide range of factors that cause accidents, and that root causes often originate from management decisions; safety performance actively monitored and data effectively used.
- Level 4 - Cooperating - managers and frontline staff recognize a wide range of factors that cause accidents; employees accept personal responsibility for their own and others' health and safety; all employees are valued and treated fairly, and a healthy lifestyle is promoted; proactive measures to prevent accidents are in place; non-work accidents are also monitored.
- Level 5 - Continuous improvement - prevention of all injuries or harm to employees (both at work and at home) as a core company value; no

feelings of complacency; organization always strives to find better ways to improve hazard control mechanisms; all employees share the belief that health and safety are crucial in their jobs and in the organization.

Gordon et al. (2007) created the Safety Culture Survey (SCS) based on the findings from five research groups (Fleming, 1999; Hudson, 2001; NATS, 2002; Nickelby, 2002; Sharp et al., 2002), with an special emphasis on Fleming's (1999) safety culture maturity model. The SCS aims to gather information about the attitudes of the workforce related to detecting and helping to implement key steps to improve and develop the existing safety culture. The 21 items, believed to described the safety culture of organizations (Gordon et al., 2007), were chosen and grouped in four safety culture dimensions for this purpose: management demonstration; planning and organizing for safety; communication, trust, and responsibility; measuring, auditing, and reviewing.

Gordon et al. (2007) also contrasted the application of the SCS and a SMS survey tool in an Air Traffic Management Research and Development Centre on the basis of five criteria: evaluation (overall assessment of maturity of safety), content validity, convergent validity, face validity, diagnosticity (usefulness of outcomes for improving safety), and usability.

The authors of the study concluded that approaching safety with both tools simultaneously (the SCS and the SMS survey tool) would bring the best results. However, in the words of Gordon et al. (2007), the contrast of the two survey tools "is not neatly scientific" (p. 693) because they were carried out with a difference of over a year, and the participants were different.

4.3.5. Safety culture questionnaire drawing on Hudson´s safety culture maturity model

A number of authors, like Fleming (1999), have proposed (safety) culture maturity models (e.g., Hudson, 2001; IAEA, 2002; Parker et al., 2006; Schein, 1992; Westrum, 1993). Hudson's (2001) model, based on the one originally developed by Westrum (1993), has been especially influential in HROs.

The developmental stages of Hudson's model, in Hudson's own words (2003, p. 9), are:

- Stage 1 - Pathological - safety is a problem caused by workers; the main drivers are the business and a desire not to get caught by the regulator.
- Stage 2 - Reactive - organizations start to take safety seriously but there is only action after incidents.
- Stage 3 - Calculative - safety is driven by management systems, with much collection of data; safety is still primarily driven by management and imposed rather than looked for by the workforce.
- Stage 4 - Proactive - with improved performance, the unexpected is a challenge; workforce involvement starts to move the initiative away from a purely top down approach.
- Stage 5 - Generative - there is active participation at all levels; safety is perceived to be an inherent part of the business; organizations are characterized by chronic unease as a counter to complacency.

Fihlo et al. (2010) created a safety culture questionnaire designed to measure aspects of organizational safety indicative of Hudson´s five levels of cultural maturity. Their safety culture framework, and resulting questionnaire, presented the following five dimensions chosen from a literature review of 19 safety culture studies: information, organizational learning, involvement, communication, and commitment. Fihlo' team described how each of their five dimensions is addressed in each of the five stages of the chosen safety culture maturity model.

The questionnaire contained 22 questions: 14 questions with five items and eight questions with four items, totaling 102 items. For each question, participants were asked to choose the item that best represented their company.

The questionnaire was completed by the safety managers of 23 different petrochemical companies who were interviewed by the researcher (asking the same questions as those on the questionnaire) one month later. The purpose was to compare the answers given to both (quantitative and qualitative) methods. The author found significant correlations of between .70 and .90, which indicated good alternate form reliability.

Results of the study indicated that the 23 companies had characteristics of different levels of safety culture maturity, with most scores at the proactive level. The results supported the idea that safety culture does not develop at the same pace in all companies and in all dimensions, even when companies come from the same sector and/or country (Fleming, 2001; Hudson and Willekes, 2000; IAEA, 2002).

4.3.6. Safety culture questionnaire and first IAEA safety culture model

Back in 1991, the IAEA started to deal with the concept of safety culture and proposed that:

> "Safety culture has two general components. The first is the necessary framework within an organization and is the responsibility of the management hierarchy. The second is the attitude of staff at all levels in responding to and benefiting from the framework. These components are dealt with under the headings of: requirements at policy level; requirements on managers; and response of individuals." (p. 5).

Figure 4 illustrates the major components of safety culture, as proposed by the IAEA in 1991:

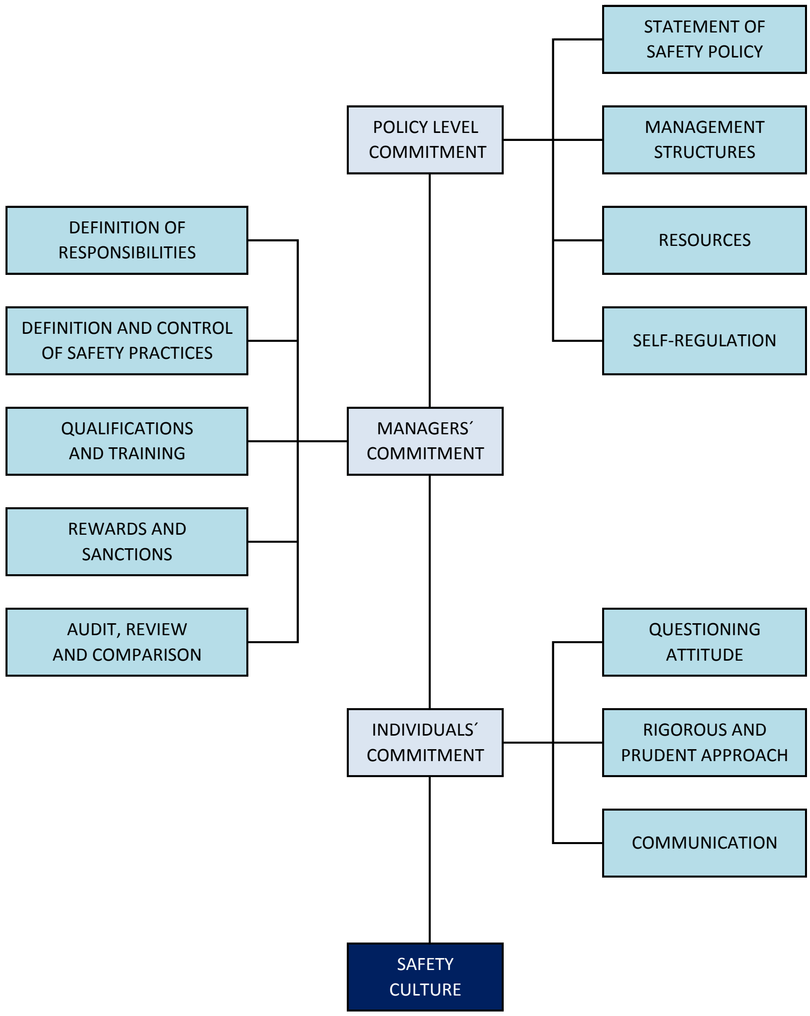

Fig. 4. First safety culture model of the IAEA (1991)

Kao et al. (2007) developed a safety culture questionnaire based on this 3-dimensional safety culture structure developed by the IAEA. Using SEM techniques and CFA, the authors proposed a model containing 3 higher-order dimensions and 8 lower-order dimensions:

- Organizations' commitment (equivalent to the policy level commitment of the IAEA's [1991] model): management system and organization; accident investigation and emergency.
- Managers' commitment: supervision and audit; commitment and support; reward, punishment and benefits.
- Individuals' commitment: attitude and behavior; communication and involvement; training and competence.

These dimensions were covered by 73 survey items, which were responded by five petrochemical companies, in order to reveal safety-related areas in need of the company's attention for improvement.

Differences in scores on the eight lower-order dimensions were investigated across different hierarchical levels and job occupations, as well as across companies. Moreover, support was found for the influence of companies' safety culture on safety performance, measured by the variables safety satisfaction and work risks.

4.3.7. Safety culture questionnaire and second IAEA safety culture model

In 2006, the IAEA presented a new model of safety culture that is still being used today for the common understanding and assessment of safety culture within nuclear power facilities. The model is composed of 37 attributes clustered into five dimensions, referred to as characteristics by the IAEA: safety is a clearly recognized value, leadership for safety is clear, accountability for safety is clear, safety is integrated into all activities, and safety is learning driven. The IAEA (2008) explains that “the attributes are short descriptions of a specific organizational performance or attitude in a nuclear facility, which, if fulfilled, would characterize this performance or attitude as belonging to a strong safety culture” (p. 8). More information about this model is provided in the first empirical study of the present thesis in Chapter VI.

Despite the relevance of the 2006 IAEA safety culture model for the nuclear industry, and its use as a framework for the understanding and assessment of safety culture, its dimensionality was never empirically tested before. Because of this, our team (López de Castro et al., 2013) presented three independent empirical studies to take the first steps to empirically validate this model, in particular the correspondence between the attributes and dimensions proposed by the IAEA. In the first study, we tested the face validity of the model on the basis of the opinions of a sample of students. In the second study, a sample of experts in organizational behavior was used to test the content validity of the model. For the third study, we developed a questionnaire based on the IAEA safety culture model, composed of 37 items that corresponded to the 37 attributes of the model. The answers of a sample of workers of an NPP to the questionnaire were analyzed to discover the extent to which the data replicate the theoretical five-dimensional model. The questionnaire itself, as well as the three complete studies, can also be found in Chapter VI.

4.3.8. Artifacts and gap questionnaires based on Schein's organizational culture model

Schöbel et al. (2017) presented two questionnaires based on Schein's (1985) organizational culture model, which is described in section 2.3. of this thesis. Like the assessment approach proposed by Grote and Künzler (2000), previously described, the Schöbel team's questionnaires are part of a wider triangulation assessment of safety culture. Schöbel et al.'s (2017) multi-method approach aimed to reach deeper levels of culture, and, at the same time, be useful for practitioners and transparent in producing meaningful results. Their study is first carried out in an NPP and then cross-validated in a second NPP.

The first questionnaire included 64 work practices (cultural artifacts) based on literature research, participant observations, and interviews with employees and supervisors from the NPP under analysis. Each of the work practices was assigned to one of four management domains (risk management, task management, management of technical resources, and management of human resources) further differentiated in ten facets. Afterwards, middle managers from the NPP rated each of the practices with regard to its implementation in daily work, which served to identify those work practices (plant-specific artifacts) that are most relevant to plant members in establishing safe and reliable plant performance. Seven-point Likert-type scales ranging from 1 (practice not applied) to 7 (practice fully applied) were used in this first questionnaire.

The relevant plant-specific safety practices identified were included in a second questionnaire, labelled the 'gap questionnaire', which was distributed to all staff members of the NPP. Participants gave two ratings to each relevant practice: to what extent they perceive the practice is actually implemented in the plant; and to what extent they think the practice should ideally be implemented in the plant. The aim was to contrast the ‘actual’ (level of artifacts) and ‘ideal’ ratings (level of espoused values) for each practice. Seven-point Likert-type scales were also used for this questionnaire. From the application of this second questionnaire, gap-practices (presenting an important difference between their actual and ideal ratings) and best practices (presenting high ratings on both their actual and ideal implementation) were identified and used in a third assessment step.

The authors assume that gap-practices and best practices provide hints about basic assumptions hold by the organizational members. For this reason, in a third and last assessment step, they were discussed in cultural dynamic interviews and group workshops. This goal of this last stage, called the ‘assumption analysis’, was to uncover some of the basic assumptions shared by the organization or by groups within it, facilitating organizational intervention strategies to improve the existing safety culture (Schöbel et al., 2017).

4.3.9. The Safety Culture Enactment Questionnaire (SCEQ) and three-dimensional model of safety culture

We believe that a high intensity and strong safety culture can only be present in a HRO when safety pervades ‘everything’ the HRO does, and the way all its employees constantly behave. Our team (López de Castro et al., 2017) developed a safety culture model, proposing that this ‘everything’ can be covered by three fundamental components of the functioning and operation of HROs: strategic decisions, human resources practices, and daily activities and behaviors. This way, the safety culture of an NPP or HRO will be mainly determined by the extent to which strategic and important decisions guarantee the priority of safety at all times (strategic level), human resources practices promote the safety of the plant (managerial level), and safety is the primary guide for all operating actions and behaviors (operational level). Next, we present a brief description extracted from López de Castro et al. (2017), of each of these components:

- *Strategic decisions ensuring safety:* "Safety culture manifests itself in the role safety plays in the strategic decisions made in NPPs. This dimension covers decisions that are carefully and thoughtfully made for the smooth running of the plant. It encompasses decisions about the operation of the plant and the conflicts between safety and other competing goals, and decisions about the allocation of resources and the establishment of procedures." (p. 47).
- *Human resources practices driving safety:* "The safety culture of an NPP manifests itself in the extent to which the HR practices are coherently articulated to guarantee high levels of safety performance. For this purpose, the organization must be able to bring in new workers (e.g. by means of appropriate recruitment and selection practices) who share the priority of safety and have the ability and willingness to work safely; it must continuously prepare the employees, especially in safety matters (e.g., through training and performance appraisals), and it must encourage and motivate them (e.g., through formal reward systems, such as goal

setting, promotions or salary, as well as informal rewards, such as recognition) to work safely under all conditions." (p. 47).

- *Daily activities and behaviors supporting safety:* "The extent to which safety is important for an NPP is reflected in the daily behaviors of every employee in the organization, the relationship with external agents (e.g., contractors and regulatory bodies), and the day-to-day operations (such as meetings or internal publications, e.g., Gracia and Peiró, 2010)." (p. 48).

A further detailed description of each of the three components is provided in Sections 7.1.4.1, 7.1.4.2. and 7.1.4.3. of the present thesis, respectively.

Each of the main hierarchical levels of an organization (top management, supervisory level, and operating core) plays a role in preserving and enhancing the safety of an NPP through all three fundamental components of its functioning and operation. However, each hierarchical level has different opportunities to enact the value of safety through each of these components:

Strategic decisions ensuring safety and hierarchical levels.

The strategic decisions of any organization are made by the strategic apex. The strategic management defines the processes and procedures through which the mission and shared goals are to be met. Top management decides how to administer and assign available resources in order to satisfy the needs and demands of stakeholders (users, investors, government, employees, etc.), while guaranteeing the safety of the plant. If any of these demands come into conflict, they will convey the priorities to be followed to the rest of the organization. In accordance with the content of this dimension, the top management has the greatest opportunities in the organization to enact the value of safety through the strategic decisions made. However, although the strategic plan and strategic decisions (and how the importance of safety is embedded on them) are developed in the top management level, middle level managers (supervisors) and even the rest of employees play an important role in their realization. Supervisors must act as transmission belts of the strategic vision and as sounding boards echoing the strategic decisions and how the value of safety can and must be embedded in them in practice. Middle management must take these decisions upon themselves and encourage the rest of the employees to act in accordance. Thus, safety should not only be a priority of the strategic decisions, but also of their realization by all members of the organization.

Human resources practices driving safety and hierarchical levels.

Supervisors are in charge of identifying the needs that must be met in order to achieve safe and quality work within their departments. They report on the need for new employees and attend to the training needs of their supervisees. Supervisors make sure that their teams fulfill their functions without compromising the safety of the plant, playing a central role in goal setting, performance appraisals, and the way rewards systems are implemented. In accordance with the content of this dimension, middle management (supervisors) have the greatest opportunities in the organization to enact the value of safety through the organizational HR practices. However, although HR policies and practices are mainly implemented at the supervisory level, they are designed and spread by the HR department and by top management. On the other hand, the employees of the operating core have also opportunities to enact the value of safety through specific HR practices, for example, employees who ask for additional training voluntarily in order to master their work and make less mistakes, or employees who raise the importance of not compromising the safety of their operations when establishing objectives with their supervisors.

Daily activities and behaviors supporting safety and hierarchical levels.

The performance of an NPP is shown in the daily work of employees from every functional area (operations, maintenance, technical support, etc.). In this regard, the ultimate safety of an NPP depends largely on what the operating core employees do and how they do it. On the other hand, the center stage that safety takes in meetings, bulletins, and other internal publications is intended to result in safer behaviors in the day-to-day running of the NPP. Based on the content of this dimension, the operating core of the organization has the greatest opportunities to enact the value of safety through the daily activities and behaviors displayed in the organization. However, top management and supervisors must set an example for the rest of the employees through their own daily behaviors and actions, and through their interactions with the other employees. It is clear that the operating core has greater access to the behaviors and actions displayed by their supervisors than to those of top management, who they interact with and see less frequently. But it is highly important for both top management and supervisors to consistently show their commitment to the value of safety through each of their behaviors, and actions because the extent to which safety is enacted, supported, prioritized, and rewarded in the day-to-day organizational functioning will inform organizational members about the actions expected from them (Schein, 1992).

This model of safety culture also highlights that the three dimensions are different from each other, but closely related. The safety culture of an NPP can be understood as evolving and being configured through top-down and bottom-up flows among the three dimensions of the present model. The Top-down flow represents the way strategic decisions determine HR practices, and both in turn influence the daily activities and behaviors of all the employees in the organization. As an example, deciding to preserve safety in refueling outages is reflected in not awarding financial rewards for working faster and under time pressure during outages, which leads to safer employee and contractor behaviors during the outage. The bottom-up flow refers to how daily activities and behaviors from employees determine appropriate HR practices, and both in turn influence the strategic decisions made in the NPP. As an example, employees are identified as working systematically and routinely without having a questioning attitude. This leads to the training of supervisors in participative leadership techniques (if the reason for the problem is that leaders do not stimulate participation and open communication), which in turn affects the way top management allocates existing resources (e.g., higher investment in training).

Fig. 5. Dimensions and flows of the safety culture model behind the SCEQ.

Based on this model, we developed the Safety Culture Enactment Questionnaire (SCEQ), a questionnaire designed to assess the degree to which safety is an enacted value in the day-to-day running of HROs and NPPs. The final goal of the SCEQ is to serve as a better predictor of safety performance than existing safety questionnaires that merely assess the endorsement of safety values. In Section 7.1.2. the concepts of enacted and espoused values are explained. In Section 7.1.3. three arguments are proposed to support the ability of the SCEQ in capturing the enactment of safety.

The 21 items on the SCEQ were based on a literature review, examination of safety culture questionnaires, our consulting experience in the nuclear industry, the "Analysis, Management and Intervention Guidelines in Organizations (AMIGO) model" (Peiró and Martínez-Tur, 2008), and focus group sessions.

Five-point Likert-type scales with responses ranging from 1 (not at all important) to 5 (very important) were used.

In our study, the questionnaire was completed by the employees of two Spanish NPPs in 2008 and 2014. As can be seen in Chapter VII, empirical evidence was obtained showing the validity of the SCEQ and supporting the dimensionality derived from the theory.

CAPÍTULO V.

OBJETIVOS DE LA TESIS Y METODOLOGÍA

En este capítulo se presentan los objetivos de la tesis y los motivos que nos llevaron a realizar cada uno de los tres estudios empíricos. Seguidamente, se describen las muestras utilizadas en los diferentes estudios y los procedimientos empleados a la hora de recoger los datos. Posteriormente, se detallan las variables consideradas y los instrumentos utilizados para su medición. Finalmente, se indican los análisis de datos realizados en los estudios.

Para simplificar la redacción de este capítulo y los siguientes, hablaremos del Estudio 1, Estudio 2 y Estudio 3, para referirnos a los tres estudios empíricos que conforman la presente tesis doctoral:

- Estudio 1: se investiga la validez empírica del modelo de cultura de seguridad de la Agencia Internacional de Energía Atómica (IAEA) y de un cuestionario de cultura de seguridad basado en el mismo.
- Estudio 2: se investiga la validez empírica del modelo de cultura de seguridad y cuestionario de cultura de seguridad (SCEQ) creados por nuestro equipo.
- Estudio 3: se investiga la adecuación de la utilización de herramientas de medición de cultura organizacional y de cultura de seguridad en la industria nuclear a través de la comparación del SCEQ y del Inventario de Cultura Organizacional (OCI).

5.1. Objetivos y justificación de los estudios realizados

La cultura de seguridad se ha identificado como causa directa de la gran mayoría de accidentes en Organizaciones de Alta Fiabilidad o High Reliability Organizations (HROs) (ver Apartado 3.1.). En consecuencia, la cultura de seguridad se ha convertido en una bandera para las HROs y para la industria nuclear en particular. Todas las centrales nucleares son conscientes de que garantizar la seguridad en la operación de sus centrales, pasa por contar con una cultura de seguridad que contribuya a la consecución de un desempeño de seguridad y unos resultados de seguridad óptimos.

Sin embargo, a pesar de haber nacido hace más de 30 años y del trabajo incesante de investigadores, profesionales y organismos reguladores, el concepto de cultura de seguridad y la forma de abordarlo, distan de ser claros. Prueba de ello es la disparidad mostrada entre las 40 definiciones de cultura de seguridad y entre los 20 cuestionarios para medirla, que se han descrito en las Apartados 3.3. y 4.2. de esta tesis doctoral.

El objetivo general de esta tesis es contribuir al desarrollo de una industria nuclear más segura a través de la clarificación del término de cultura de seguridad y, sobre todo, a través del avance en medidas de cultura de seguridad. Este objetivo general se desglosa en objetivos específicos teóricos y empíricos, los cuales se describen a continuación:

- Objetivos teóricos - clarificación del constructo de cultura de seguridad.
    - Presentar y analizar las definiciones más influyentes de cultura de seguridad.
    - Identificar los elementos centrales de la naturaleza de cultura de seguridad.
    - Ofrecer una definición propia de cultura de seguridad que aúne el acuerdo entre expertos sobre el concepto.

  - Presentar y analizar cuestionarios de cultura de seguridad de referencia en HROs.
  - Identificar las dimensiones en que la cultura de seguridad se ha operacionalizado con mayor frecuencia.
  - Clarificar la relación de cultura de seguridad con cultura organizacional y clima de seguridad.
- Objetivos empíricos - avance en medidas de cultura de seguridad.
  - Validar por primera vez en la industria nuclear el modelo de cultura de seguridad de la IAEA.
  - Crear y validar el SCEQ, un cuestionario de cultura de seguridad diseñado para medir la importancia real de la seguridad en la industria nuclear.
  - Crear y validar un modelo de cultura de seguridad que sirve de respaldo del SCEQ y de marco teórico para la comprensión de la cultura de seguridad.
  - Ofrecer evidencias sobre la capacidad de cuestionarios de cultura organizacional y de cultura de seguridad de predecir el desempeño de seguridad.
  - Validar el OCI en la industria nuclear española.
  - Investigar qué perfiles culturales del OCI son más propicios para promover la cultura de seguridad y para optimizar el desempeño de seguridad.

Los objetivos teóricos se han trabajado principalmente en la introducción de la tesis, mientras que los objetivos empíricos se pretenden conseguir a través de los tres estudios mencionados anteriormente (Estudio 1, Estudio 2 y Estudio 3). A continuación, se explican los motivos que nos animaron a alcanzar los objetivos propuestos, y se especifica cuáles de ellos se cubren a través de la introducción y de cada uno de los tres estudios empíricos.

5.1.1. Objetivos teóricos - clarificación del constructo de cultura de seguridad

En vistas de la carencia de una definición comúnmente aceptada de cultura de seguridad, una definición que ofrezca un marco común para su comprensión y a partir de la cual se puedan aunar los esfuerzos para su medición, gestión y optimización, decidimos recopilar y analizar las principales definiciones dadas hasta día de hoy al constructo, y elaborar una definición que reúna los elementos más comúnmente aceptados hasta día de hoy.

El análisis de estas definiciones nos permite obtener dos cosas, principalmente:

1) Identificar los elementos centrales de la naturaleza de cultura de seguridad destacados por los expertos en la materia y posteriormente cuantificar el grado de acuerdo sobre la existencia de dichos elementos.
2) Elaborar una definición de cultura de seguridad que reúna los elementos más comunes de las definiciones ofrecidas hasta ahora. Esta definición refleja en pocas palabras el acuerdo conseguido entre expertos en cultura de seguridad durante los últimos 30 años, y se ofrece como definición del concepto para las HROs.

Debido a la confusión y múltiples acercamientos a la dimensionalidad del constructo de cultura de seguridad, recopilamos y analizamos algunos de los cuestionarios de cultura de seguridad más conocidos en las HROs, e identificamos las dimensiones más comúnmente aceptadas en estos cuestionarios.

La finalidad fue, por tanto, extraer conclusiones sobre los contenidos de cultura de seguridad que cubren dichos cuestionarios. Este análisis nos permitió, entre otras cosas, cuantificar el grado de acuerdo sobre las dimensiones de cultura de seguridad más comúnmente referidas en los cuestionarios bajo estudio.

La confusión y distintos acercamientos existentes a la naturaleza y relación del constructo de cultura seguridad con otros términos pertenecientes a su red nomológica, nos animó a clarificar los conceptos de cultura organizacional y clima de seguridad, y la relación de estos dos con cultura de seguridad. Esto se aborda principalmente en la introducción teórica de la tesis (Apartados 3.2. y 3.4.) y a lo largo de los tres estudios empíricos presentados en esta tesis.

5.1.2. Objetivos empíricos - avance en medidas de cultura de seguridad

Las HROs necesitan, no sólo poder entender qué es exactamente una cultura de seguridad, sino también saber cómo capturar el estado de sus culturas de seguridad o el grado en que sus culturas organizacionales garantizan un desempeño y resultados de seguridad óptimos.

La cultura de seguridad se puede medir a través de herramientas cualitativas y cuantitativas (ver Apartado 4.1. para una explicación mayor sobre ambos acercamientos). Se reconoce que las herramientas cualitativas tienen el mayor potencial para capturar los elementos culturales más profundos e influyentes en la organización o en sus sub-grupos. Sin embargo, las herramientas cualitativas requieren altos costes económico-temporales que las organizaciones frecuentemente no están dispuestas a asumir. Además, una herramienta cualitativa no permite por sí misma acercarse a la cultura real de la organización, sino que requiere un trabajo de integración e interpretación de resultados muy complejo y no exento de ser contaminado por prejuicios y expectativas de los evaluadores.

Por otro lado, las herramientas cuantitativas proveen información sobre la cultura de la organización que se limita a los ítems escogidos sin permitir profundizar en los resultados obtenidos, a no ser que se empleen de forma conjunta con otras herramientas cualitativas. Sin embargo, las herramientas cuantitativas, como los cuestionarios de cultura de seguridad, ofrecen un gran número de ventajas, que es lo que los ha convertido en una estrategia muy frecuente de medición de cultura HROs y en la industria nuclear. La aplicación de cuestionarios es menos costosa en términos económicos y de implicación de los trabajadores, y permite obtener información de un gran número de trabajadores de todos los niveles jerárquicos y departamentos de la organización. Además, los resultados obtenidos se pueden comparar entre organizaciones del mismo sector (p.e., entre centrales nucleares) y ofrecen indicios a los investigadores de forma rápida sobre disfunciones en elementos organizacionales y de gestión (entre otros) que puedan suponer un peligro potencial para la seguridad de la organización.

Por lo argumentado anteriormente, parece claro que contar con cuestionarios que capten información relevante sobre la cultura de seguridad de la organización, es una obligación en la industria nuclear. Sin embargo, los cuestionarios de cultura de seguridad existentes no han permitido traspasar los niveles más superficiales de cultura y, a menudo, no han sido sustentados en modelos con respaldo empírico.

La detección de esta necesidad nos motivó a querer contribuir al avance en medidas de cultura de seguridad, que a su vez sirvan de base para gestionar y optimizar la cultura de seguridad en las HROs, y en las centrales nucleares en particular. Este objetivo se materializa de distinta forma a lo largo de los tres estudios empíricos que conforman esta tesis doctoral.

5.1.2.1. Estudio 1

Fundada en 1957, la Agencia Internacional de Energía Atómica (IAEA) pertenece a las organizaciones internacionales conexas al sistema de las Organización de las Naciones Unidas, siendo el organismo de referencia mundial en materia nuclear. En concreto, la IAEA establece normas de seguridad nuclear y protección ambiental, sirve de ayuda a los países miembros (167 a día de hoy) mediante actividades de cooperación técnica, y alienta el intercambio de información científica y técnica sobre la energía nuclear y sobre cómo garantizar la seguridad en la operación de las centrales nucleares.

Como se ha explicado anteriormente, fue la IAEA el organismo que acuñó el concepto de cultura de seguridad después de la catástrofe de Chernobyl en 1986. Desde ese momento, la IAEA ha trabajado sin cesar en el desarrollo teórico del concepto y en la creación de metodologías que permitan comprender, medir y desarrollar una cultura de seguridad que evite futuras catástrofes. Dentro de este marco, una de las contribuciones mayores de la IAEA ha sido la creación de un modelo de cultura de seguridad, el cual la misma IAEA etiqueta como 'esencial' para alcanzar una cultura de seguridad óptima (IAEA, 2006b). Este modelo está compuesto por 37 atributos, agrupados en 5 dimensiones, que todos los trabajadores de la industria nuclear deben comprender y tener en cuenta a la hora de preservar la seguridad nuclear (IAEA, 2009a). Este modelo ha satisfecho la urgente necesidad de la industria nuclear de comprender qué es cultura de seguridad, y qué aspectos se deben medir, monitorizar y optimizar para contar con una cultura de seguridad que asegure un desempeño y resultados de seguridad óptimos (en el Apartado 6.1.3. se pueden encontrar ejemplos del alcance y utilización de este modelo por organismos reguladores, y por la propia IAEA). Sin embargo, a pesar de la común aceptación y utilización del modelo de cultura de seguridad de la IAEA en la industria nuclear, este modelo no había sido previamente testado de forma empírica.

Ante esta situación, nuestro equipo tomo la responsabilidad de dar los primeros pasos en la validación empírica del modelo de cultura de seguridad de la IAEA. En concreto, nuestro Estudio 1 investiga la correspondencia empírica entre los 37 atributos y las 5 dimensiones de cultura de seguridad propuestas por la IAEA. Comprobar esta correspondencia es necesario para evitar que herramientas de medición basadas en este modelo puedan llevar a conclusiones erróneas sobre aquellos aspectos en la organización sobre los que se necesita actuar para asegurar la seguridad de la central nuclear.

El Estudio 1 completo se presenta en el Capítulo VI y a su vez puede encontrarse en la revista Accident Analysis & Prevention, Volumen 60, Noviembre 2013, páginas 231–244, bajo el título: “Testing the validity of the International Atomic Energy Agency (IAEA) safety culture model”.

5.1.2.2. Estudio 2

Como se ha explicado en el Apartado 2.3., la mayor parte de los investigadores y expertos en cultura organizacional, entienden que ésta está compuesta por distintos elementos que se pueden ordenar por el grado en que son accesibles, tangibles y modificables. La propuesta más aceptada y utilizada a la hora de estudiar la cultura de las organizaciones ha sido de largo la ofrecida por Schein (1985), quien clasifica estos elementos culturales en tres niveles: asunciones básicas profundas que conforman el corazón de la cultura organizacional y de las que los trabajadores generalmente no son conscientes; valores expuestos, ideales o racionalizaciones, sobre cómo los trabajadores entienden que su organización debería de ser y debería comportarse; y artefactos o productos tangibles de la organización, que son resultado de los niveles culturales más profundos.

Es aceptado que cada uno de estos tres niveles puede captarse a través de distintas metodologías. En un extremo, los artefactos pueden captarse a través de observaciones, incluso sin ser necesario la ayuda de los integrantes de la organización bajo estudio. En el otro extremo, capturar las asunciones básicas de los trabajadores de una organización demanda la utilización de combinaciones de herramientas cualitativas y procesos de interpretación complejos. Y en el medio se encuentran los cuestionarios, la herramienta de medición de cultura más utilizada en las HROs, que normalmente se han centrado en recabar información sobre los artefactos de la organización y, en ocasiones, sobre la cultura reflejada en los valores expuestos.

A pesar de la popularidad de los cuestionarios de cultura de seguridad en la industria nuclear, Wilpert y Schobel (2007) indican que no es claro el grado en que los valores expuestos determinan el comportamiento último de los trabajadores. La medición de los valores expuestos a través de cuestionarios podría ser útil siempre y cuando los valores expuestos estuviesen alineados con los valores en acción. Sin embargo, hay suficiente evidencia, proveniente de investigaciones de incidentes y desastres organizacionales, de que la puesta en acción de los valores expuestos raramente ocurre (Waring, 2015, p. 261). Como Schein (1992) indica, son los valores en acción, los que en el día a día se respaldan, se priorizan y por los que se recompensa y se da reconocimiento a los trabajadores, los que informan a los miembros de la organización de las acciones que se espera de ellos. En resumen, para poder entender la cultura de una organización y tener más probabilidades de predecir su futuro desempeño, no basta con capturar los valores expuestos en la organización.

Debido a lo planteado anteriormente, la necesidad de tener en cuenta los valores en acción a la hora de estudiar la cultura de una organización, ha sido enfatizada por muchos autores (Branch y Olson, 2011; Schein, 1992; Siehl y Martin, 1990; Waring, 2015; Zohar y Hofmann, 2012). Sin embargo, de acuerdo con nuestro conocimiento del sector nuclear, no existen cuestionarios de cultura de seguridad en la industria nuclear (y tampoco en otras HROs) que permitan captar los valores en acción. La detección de la necesidad de cubrir esta carencia, fue lo que motivo la realización del Estudio 2 de la presente tesis doctoral.

Nuestro objetivo central fue por tanto crear y validar un cuestionario que pudiese captar el nivel de los valores en acción en HROs. En concreto, nos propusimos crear y validar un cuestionario diseñado para medir el grado en que la seguridad es un valor en acción o puesto en práctica (y no un valor expuesto o teórico) en HROs. Este cuestionario se bautizó como el Safety Culture Enactment Questionnaire (SCEQ), que podría traducirse como el Cuestionario de Cultura de Seguridad en Acción. El SCEQ está enmarcado en un modelo teórico de cultura de seguridad, creado por nuestro equipo de investigación, que cubre tres componentes fundamentales del funcionamiento y operación de cualquier organización: decisiones estratégicas, prácticas de gestión de recursos humanos, y comportamientos y actividades del día a día. El Estudio 2 tuvo también como objetivo la validación del modelo de forma paralela a la validación del SCEQ.

El Estudio 2 completo se presenta en el Capítulo VII y a su vez puede encontrarse en la revista Accident Analysis & Prevention, Volumen 103, Junio 2017, páginas 44–55, bajo el título: “The Safety Culture Enactment Questionnaire (SCEQ): Theoretical model and empirical validation”.

5.1.2.3. Estudio 3

A la hora de abordar el estudio de cultura de seguridad caben dos enfoques. El primero aborda el estudio directo e inmediato de la cultura de seguridad. Como se viene explicando a lo largo de esta tesis, éste es el enfoque que se ha utilizado normalmente en HROs y en particular en la industria nuclear. El segundo enfoque plantea que se puede obtener información sobre la cultura de seguridad a través del estudio general de la cultura organizacional. Dentro del primer enfoque (directo) encontramos un gran número de cuestionarios, etiquetados por sus autores como cuestionarios de cultura de seguridad, que han sido utilizados en la industria nuclear. Por su parte, el segundo enfoque (distal) ha tenido poca relevancia dentro de la industria nuclear, encontrándose prácticamente ningún cuestionario de cultura organizacional aplicado en centrales nucleares.

A pesar de la existencia de ambos enfoques, prácticamente no hay estudios que ofrezcan evidencias empíricas para decantarse por la utilización de cuestionarios de cultura organizacional o de cultura de seguridad en la industria nuclear. Aún menos se encuentran estudios metodológicamente sólidos que comparen ambos enfoques en términos de su poder para predecir el desempeño de seguridad y/o los resultados de seguridad de una organización.

Ante esta situación, nuestro equipo se propuso arrojar luz sobre esta cuestión a través del estudio comparativo de nuestro cuestionario de cultura de seguridad SCEQ y del OCI. En particular, nos propusimos estudiar el poder de ambas herramientas para predecir el desempeño de seguridad en una central nuclear.

Por otro lado, este tercer estudio de la tesis tuvo los objetivos de validar el OCI en la industria nuclear española, y de obtener nuevas evidencias para la validación del SCEQ en la industria nuclear española y del modelo en que éste se sustenta.

Finalmente, comprendiendo la aplicación del OCI en la industria nuclear desde un enfoque distal, se entiende que las dimensiones de cultura organizacional que abarca el OCI, a pesar de no hacer referencia directa a la seguridad, sí que están relacionadas con ella. En este contexto, nos propusimos también investigar qué perfiles culturales son más propicios para fomentar la cultura de seguridad y optimizar el desempeño de seguridad en las HROs.

El Estudio 3 completo se presenta en el Capítulo VIII, y está en la fase final de preparación para ser sometido a una revista científica bajo el título: “Organizational culture or safety culture assessment?”.

5.2. Muestras, participantes y procedimientos de recogida de datos

En la realización de los tres estudios empíricos de la presente tesis, se utilizaron cinco muestras diferentes. A continuación se describe cada muestra, así como el procedimiento de recogida de datos empleado. Al final del apartado se resume de forma esquemática qué muestras se utilizaron en cada uno de los tres estudios (Tabla 6).

5.2.1. Muestra de estudiantes (2010)

En el Estudio 1 se utilizó una muestra de estudiantes (recogida en 2010) para estudiar la validez aparente del modelo. La muestra contó con 290 estudiantes de la Universidad de Valencia (110 estudiantes de psicología, 96 de relaciones laborales y 84 de turismo). Todos los estudiantes a los que se les entregó el ejercicio, lo completaron, por lo que se obtuvo una tasa de respuesta del 100%. La literatura recomienda evaluar la validez aparente de modelos, cuestionarios o herramientas de medición en general, mediante personas no entrenadas para el propósito y sin conocimientos previos de la herramienta a evaluar (Anastasi, 1976; Cronbach, 1984; Sartori, 2010). En palabras de Litwin, “jueces no entrenados, como tu hermana, novio o compañero de squash” (1995, p. 35). Por este motivo, se decidió contar con una muestra de estudiantes (personas sin conocimientos de cultura de seguridad de la industria nuclear) para este propósito.

Los participantes recibieron dos documentos: uno con los 37 atributos del modelo de cultura de seguridad de la IAEA; y otro con las cinco dimensiones a las que, según la IAEA, pertenecen los atributos. El primer documento incluía además las instrucciones sobre la tarea, que consistía en determinar a cuál de las cinco categorías (A, B, C, D y E, donde cada letra correspondía a una dimensión) pertenecía cada uno de los 37 enunciados. Los atributos y dimensiones fueron presentados en español, para lo que previamente fueron traducidos desde el inglés al español por dos traductores certificados a través técnicas de traducción inversa o *back-translation*.

Durante la administración del cuestionario, los investigadores estuvieron presentes para clarificar posibles dudas que pudiesen surgir. Se enfatizó la importancia del proyecto para contribuir al desarrollo de la seguridad en la industria nuclear. La participación fue voluntaria y anónima.

Para ver más detalles sobre la muestra, motivo de su elección, así como sobre el desarrollo y administración de la herramienta, se recomienda visitar el Apartado 6.2.1. de esta tesis.

5.2.2. Muestra de expertos en comportamiento organizacional (2010)

En el Estudio 1 se empleo también una muestra de expertos en comportamiento organizacional de la Universidad de Valencia (España). La muestra fue recogida en 2010. En total participaron 48 expertos de los 65 que fueron invitados a formar parte del estudio, lo que supuso una tasa de respuesta del 74%. En esta ocasión el objetivo fue estudiar la validez de contenido del modelo de cultura de seguridad de la IAEA. En concreto la muestra estuvo compuesta por 24 doctores del departamento de Psicología Social, siete doctorandos del programa Europeo de Psicología del Trabajo, de las Organizaciones y de los Recursos Humanos (WOP-P), y 17 estudiantes del Master Erasmus Mundus WOP-P. Para evaluar la validez de contenido de modelos, cuestionarios o herramientas de medición en general, la literatura recomienda que personas expertas en el tema bajo estudio juzguen la relevancia y representatividad del dominio de contenido estudiado (Sireci, 1998). Los participantes de la muestra elegida eran expertos en los contenidos incluidos en el modelo de la IAEA (p.e., liderazgo, aprendizaje organizacional, gestión organizacional), pero no eran expertos en la industria nuclear ni en HROs, lo cual evitaba que sus respuestas pudiesen estar sesgadas por conocimientos previos del modelo de la IAEA o de otros modelos de cultura de seguridad utilizados en el sector nuclear.

Los 48 expertos recibieron las mismas instrucciones y documentos que los 290 estudiantes de la muestra explicada en el apartado anterior. Sin embargo, los expertos fueron contactados por email debido a las dificultades de contactar con muchos de ellos en persona. Se hizo énfasis en que los expertos debían contactar con los investigadores en caso de dudas o dificultades a la hora de realizar el ejercicio. Algunos expertos destacaron la complejidad de la tarea, percibiendo solapamiento y ambigüedad en algunas dimensiones.

De la misma forma que en la muestra de estudiantes, se enfatizó la importancia del proyecto para contribuir al desarrollo de la seguridad en la industria nuclear, y la participación fue voluntaria y anónima.

Para ver más detalles sobre esta muestra, motivo de su elección, así como sobre el desarrollo y administración de la herramienta, se recomienda visitar el Apartado 6.2.2. de la presente tesis.

5.2.3. Muestras de trabajadores del sector nuclear (2008, 2011, 2014)

En los tres estudios empíricos de la presente tesis, se emplearon muestras con empleados de dos centrales nucleares españolas pertenecientes a la misma organización, así como de sus servicios centrales. Todos los niveles de responsabilidad y áreas funcionales posibles fueron registrados. El procedimiento mediante el cual se llevó a cabo la recogida de datos en 2008, 2011 y 2014, fue idéntico. La organización bajo estudio instó (por correo interno) a la participación voluntaria de todos los trabajadores en sesiones grupales dispuestas cada hora durante tres días. En dichas sesiones, se presentó el objetivo de la evaluación, se señaló la importancia de la participación en el estudio y se enfatizó que el tratamiento de los datos sería totalmente confidencial, por lo que el anonimato estaba garantizado. En todas y cada una de estas sesiones se siguió dicho procedimiento. Una vez los participantes presentes fueron informados a este respecto, cumplimentaron de forma individual una batería de cuestionarios diseñada para evaluar diferentes aspectos organizacionales relacionados con la seguridad. Cada uno de los cuestionarios de la batería contó con sus correspondientes instrucciones de cumplimentación. Debido al sistema de trabajo por turnos utilizado en la organización bajo estudio, se dejaron en sobre cerrado el número de cuestionarios correspondientes a los trabajadores de los turnos que no pudieron presentarse. En estos casos, una persona de contacto de la propia organización entregó el cuestionario, igualmente explicando a los participantes la importancia de su colaboración y la confidencialidad de las respuestas. De ésta forma, los participantes respondieron al cuestionario durante el horario laboral, en la mayoría de los casos en presencia del investigador responsable. Con ello, las dudas que pudieran surgir durante el proceso fueron resueltas inmediatamente.

A continuación se resume la inclusión de cada una de estas tres muestras en los estudios empíricos de la presente tesis. En concreto se detalla el número de participantes, tasa de respuesta obtenida y número de cuestionarios utilizados en los análisis estadísticos correspondientes a cada estudio.

Muestra sector nuclear 2008

566 trabajadores de las dos centrales nucleares pertenecientes a la misma organización completaron la batería de cuestionarios. El tamaño total de la organización en 2008 era de 760 trabajadores, por lo que se obtuvo una tasa de respuesta del 74.47%. Esta muestra fue utilizada en el Estudio 2 y en el Estudio 3 de la tesis, como se indica en la Tabla 6.

En el caso del Estudio 2, no se incluyeron en los análisis los cuestionarios de aquellos participantes que no habían respondido a más de tres de los 24 ítems iniciales del SCEQ, lo que resultó en la utilización de 533 cuestionarios. En el caso del Estudio 3, los 566 participantes que completaron la batería de cuestionarios fueron incluidos en los análisis estadísticos correspondientes.

Muestra sector nuclear 2011

En esta ocasión 495 trabajadores de las dos centrales nucleares completaron la batería de cuestionarios correspondiente. El tamaño total de la organización en

2011 era también de 760 trabajadores, por lo que se obtuvo una tasa de respuesta del 65.13%. Esta muestra fue utilizada en el Estudio 1 y en el Estudio 3, como se indica en la Tabla 6.

En el caso del Estudio 1, no se incluyeron en los análisis los cuestionarios de aquellos participantes que no habían respondido a más de tres de los 37 ítems del cuestionario correspondiente al modelo de IAEA, lo que dio lugar a la utilización de 468 cuestionarios. En el caso del Estudio 3, los 495 participantes que completaron la batería de cuestionarios fueron incluidos en los análisis estadísticos correspondientes.

Muestra sector nuclear 2014

Tres años más tarde, 617 trabajadores de las dos centrales nucleares completaron de nuevo un batería de cuestionarios. El tamaño total de la organización en 2014 fue de 806 empleados, por lo que la tasa de respuesta, un 76.55%, mejoró con respecto a las dos ocasiones anteriores. Esta muestra fue utilizada únicamente en el Estudio 2 de la tesis, como se indica en la Tabla 6.

Tampoco en esta ocasión se incluyeron en los análisis los cuestionarios de aquellos participantes que no habían respondido a más de tres de los 21 ítems finales del SCEQ, lo que dio lugar a la utilización de 598 cuestionarios.

Tabla 6

Resumen de las muestras utilizadas en los estudios empíricos de la presente tesis doctoral

Participantes y recogida de datos	Manuscrito
Estudiantes universitarios (2010)	Estudio 1 Testando la validez del modelo de cultura de seguridad de la Agencia Internacional de energía Atómica **Testing the validity of the International Atomic Energy Agency (IAEA) safety culture model**
Expertos en comportamiento organizacional (2010)	Estudio 1 Testando la validez del modelo de cultura de seguridad de la Agencia Internacional de energía Atómica **Testing the validity of the International Atomic Energy Agency (IAEA) safety culture model**
Empleados de central nuclear (2008)	Estudio 2 El cuestionario de cultura de seguridad en acción (SCEQ): modelo teórico y validación empírica **The Safety Culture Enactment Questionnaire (SCEQ): Theoretical model and empirical validation** Estudio 3 ¿Medición de cultura organizacional o de cultura de seguridad? **Organizational culture or safety culture assessment?**
Empleados de central nuclear (2011)	Estudio 1 Testando la validez del modelo de cultura de seguridad de la Agencia Internacional de energía Atómica **Testing the validity of the International Atomic Energy Agency (IAEA) safety culture model**
	Estudio 3 ¿Medición de cultura organizacional o de cultura de seguridad? **Organizational culture or safety culture assessment?**
Empleados de central nuclear (2014)	Estudio 2 El cuestionario de cultura de seguridad en acción (SCEQ): modelo teórico y validación empírica **The Safety Culture Enactment Questionnaire (SCEQ): Theoretical model and empirical validation**

Nota: el nombre original de los estudios se destaca en negrita

5.3. Variables e instrumentos de medida

A continuación se describen las variables utilizadas en esta tesis, así como los instrumentos de medida empleados para su operacionalización. Al final del apartado se incluye la Tabla 7, donde se resume la utilización de las variables en los estudios empíricos de la presente tesis. Complementariamente, en el anexo se presentan las escalas utilizadas para medir cada una de las variables.

5.3.1. Cultura de seguridad (safety culture)

Para medir cultura de seguridad en el Estudio 1 se utilizó el modelo de cultura de seguridad de la IAEA (IAEA, 2006a). Por un lado, se presentó un ejercicio que incluyó las cinco dimensiones y 37 atributos de cultura de seguridad propuestos por la IAEA, en el que los participantes tuvieron que asignar cada uno de los atributos a una de las dimensiones. Por otro lado, se creó un cuestionario que incluía 37 ítems, correspondientes a los 37 atributos del modelo, y en el que los participantes tuvieron que reportar la medida en que cada uno de estos atributos estaba presente en su organización. Para este cuestionario se utilizo una escala de respuesta tipo Likert (1-Muy en desacuerdo/ 5- Muy de acuerdo). Algunos ejemplos de los ítems (atributos del modelo de la IAEA) son “la dirección fomenta la participación activa del personal en la mejora de la seguridad”, “la confianza impregna la organización” y “una actitud cuestionadora predomina en todos los niveles de la organización”.

5.3.2. Cultura de seguridad en acción (enacted safety culture)

La cultura de seguridad fue evaluada en los Estudios 2 y 3 mediante el Safety Culture Enactment Questionnaire (SCEQ), creado por nuestro equipo (López de

Castro y cols., 2017). El SCEQ estuvo inicialmente formado por 24 ítems, a través de los cuales los participantes tuvieron que reportar el peso fundamental y la importancia práctica en el día a día de la seguridad en su empresa. El cuestionario incluyó una escala de respuesta tipo Likert (1-Nada/ 5- Mucho). Algunos ejemplos de los ítems en que se refleja la importancia y peso fundamental de la seguridad son “en el comportamiento diario de la alta dirección”, “en la contratación del personal” y “a la hora de adjudicar recursos (tiempo, equipos, personal, dinero)”.

5.3.3. Cultura organizacional (organizational culture)

La cultura organizacional fue evaluada en el Estudio 3 mediante la versión original del Inventario de Cultura Organizacional (Organizational Culture Inventory [OCI]) de Human Synergistics International (Cooke y Lafferty, 1987). Este cuestionario está formado por 120 ítems que recaban información sobre los comportamientos que los trabajadores consideran que se espera de ellos y de otros trabajadores para encajar y satisfacer las expectativas (“fit in and meet expectations”) de su organización. De esta forma, los participantes tuvieron que reportar en qué medida se espera que la gente lleve a cabo ciertos comportamientos. El cuestionario incluyó una escala de respuesta tipo Likert (1-En ninguna medida/ 5-En muy gran medida). Algunos ejemplos de ítems son “motive a los demás con la amabilidad”, “asuma tareas que constituyan un reto” y “esté de acuerdo con todo el mundo”.

5.3.4. Clima de seguridad organizacional (organizational-level safety climate)

El clima de seguridad a nivel organizacional se evaluó en los Estudios 2 y 3 mediante el cuestionario original de Zohar y Luria (2005) de “Clima de seguridad organizacional” ("Organizational-level Safety Climate"). Este cuestionario está formado por 16 ítems con una escala de respuesta tipo Likert (1- Muy en desacuerdo/ 5- Muy de acuerdo). Los participantes fueron instados a contestar en qué medida estaban de acuerdo con afirmaciones tales como “continuamente se pone empeño en mejorar los niveles de seguridad en cada departamento”, “se corrige rápidamente cualquier riesgo para la seguridad (incluso si es costoso)” o “se considera la seguridad cuando se establece la programación y los plazos de los trabajos”.

5.3.5. Clima de seguridad grupal (group-level safety climate)

El clima de seguridad a nivel de unidad de trabajo se evaluó en el Estudio 3 mediante una adaptación española del cuestionario original de Clima de Seguridad Grupal ("Group-level Safety Climate") de Zohar y Luria (2005). La escala original de Zohar y Luria incluía una serie de interacciones entre supervisores y miembros del equipo que servían para medir percepciones sobre cómo las prácticas de los supervisores reflejaban la prioridad de la seguridad frente a la productividad en la organización. La adaptación de Latorre, Gracia, Tomás y Peiró (2013) utilizó 15 de los 16 ítems originales añadiendo algunas modificaciones. En concreto, en ocho ítems el referente de las percepciones de los participantes pasó de ser el supervisor o jefe a ser el grupo de trabajo. De esta forma los participantes respondieron en qué medida estaban de acuerdo con una serie de afirmaciones (ítems) referidas a su unidad de trabajo. Se empleó una escala de respuesta tipo Likert (1- Muy en desacuerdo/ 5- Muy de acuerdo). Algunos ejemplos de los ítems son “frecuentemente se recuerdan los riesgos que existen en nuestro trabajo”, “nuestro jefe se asegura de que seguimos todas las normas de seguridad (no sólo las más importantes)” y “se siguen las reglas de seguridad incluso cuando el trabajo se retrasa respecto a la planificación”.

5.3.6. Satisfacción con la seguridad (safety satisfaction)

Para medir la satisfacción con la seguridad en los Estudios 2 y 3 se utilizó el Cuestionario de Satisfacción con la Seguridad (“Safety Satisfaction Questionnaire [SSQ]”), el cual fue desarrollado por nuestro equipo. El cuestionario constó de seis ítems, a través de los cuales los participantes tuvieron que reportar cuán satisfechos estaban con la seguridad de su organización. El SSQ incluyó una escala de respuesta tipo Likert (1-Muy insatisfecho/ 5- Muy satisfecho). Algunos ejemplos de los ítems son “la seguridad en el funcionamiento u operación de la planta” ó “la eficacia de las acciones correctivas”.

5.3.7. Satisfacción con el trabajo (job satisfaction)

La satisfacción con el trabajo se midió en los Estudios 2 y 3 mediante los siguientes tres ítems: “¿cuán satisfecho está con su trabajo?”, “¿cuán satisfecho está con el equipo en el que trabaja?” y “¿cuán satisfecho está con su empresa?”. Se empleó una escala de respuesta tipo Likert (1- Muy insatisfecho/ 5- Muy satisfecho).

5.3.8. Ambigüedad de rol (role ambiguity)

Para medir ambigüedad de rol en el Estudio 1 se utilizaron cuatro ítems de la escala original de ambigüedad de rol de Rizzo, House y Lirtzman (1970). El cuestionario incluyó una escala de respuesta tipo Likert (1-Muy en desacuerdo/ 5-Muy de acuerdo) en la que los participantes indicaron su grado de acuerdo con los cuatro enunciados. Algunos ejemplos de estos enunciados son "sé exactamente lo que se espera de mi en mi trabajo" y "sé cuáles son mis responsabilidades en mi trabajo".

5.3.9. Confianza (trust)

Para medir confianza en el Estudio 1, se utilizaron cuatro ítems desarrollados por nuestro equipo. Los participantes tuvieron que evaluar el grado de confianza que tenían en su jefe de equipo, en los miembros de su equipo, en otras unidades de trabajo de la organización, y en el equipo de dirección. Un ejemplo de un ítem es "confío en los compañeros de mi unidad". Se empleo una escala de respuesta tipo Likert (1- Muy en desacuerdo/ 5- Muy de acuerdo).

5.3.10. Cumplimiento de la seguridad (safety compliance)

El cumplimiento de la seguridad se midió en el Estudio 3 con la escala original de Cumplimiento de la Seguridad ("Safety compliance") de Neal y Griffin (2006), formada por 3 ítems. Los participantes tuvieron que indicar en una escala de respuesta tipo Likert (1-Muy en desacuerdo/ 5- Muy de acuerdo) su grado de acuerdo con las siguientes afirmaciones: "uso todo el equipo de seguridad necesario para hacer mi trabajo", "uso los procedimientos correctos de seguridad para llevar a cabo mi trabajo", y "aseguro los niveles más altos de seguridad cuando realizo mi trabajo".

5.3.11. Participación en seguridad (safety participation)

La participación en seguridad se midió en el Estudio 3 mediante la escala original Participación en Seguridad ("Safety participation") de Neal y Griffin (2006), compuesta por 3 ítems. Los participantes señalaron en una escala de respuesta tipo Likert (1-Muy en desacuerdo/ 5- Muy de acuerdo) su grado de acuerdo con las siguientes afirmaciones: "promuevo el programa de seguridad dentro de la organización", "hago un esfuerzo extra para mejorar la seguridad del lugar de trabajo", y "voluntariamente realizo tareas o actividades que ayudan a mejorar la seguridad en el trabajo".

5.3.12. Conductas arriesgadas (risky behaviours)

Las conductas arriesgadas de los trabajadores se midieron en los Estudios 2 y 3 mediante el cuestionario original de Conductas Arriesgadas ("Risky behaviors") de Mearns, Flin, Gordon y Fleming (2001). El cuestionario original está formado por doce ítems, pero nuestros estudios no tuvieron en cuenta dos ítems de la escala original porque no se consideraron apropiados para el sector nuclear. Por lo tanto, la escala utilizada se compuso de diez ítems con un rango de respuesta (1-Nunca/ 5- Muy a menudo). Los participantes tuvieron que marcar la frecuencia con la que se llevaban a cabo diversas conductas. Algunos ejemplos de dichas conductas son "para poder ser más eficaz en mi trabajo, tengo que saltarme algunos procedimientos que no son esenciales", "para lograr los objetivos, tengo que saltarme ciertas reglas que no son críticas para la seguridad" y "algunas situaciones en mi trabajo me impiden trabajar siguiendo los procedimientos y normativas en seguridad".

Tabla 7
Utilización de variables en los tres estudios empíricos de la presente tesis

	Estudio 1	Estudio 2	Estudio 3
Cultura de seguridad	X		
Cultura de seguridad en acción		X	X
Cultura organizacional			X
Clima de seguridad organizacional		X	X
Clima de seguridad grupal			X
Satisfacción con la seguridad		X	X
Satisfacción con el trabajo		X	X
Ambigüedad de rol	X		
Confianza	X		
Cumplimiento de la seguridad			X
Participación en seguridad			X
Conductas arriesgadas		X	X

Nota: La variable "Cultura de seguridad 1 (IAEA)" tomó como referencia el modelo de cultura de seguridad de la IAEA. La variable "Cultura de seguridad 2 (SCEQ)" tomó como referencia el cuestionario SCEQ.

5.4. Análisis de datos

Los tres estudios incluidos en la presente tesis tienen como objetivo central la validación de tres cuestionarios, que a su vez contribuya a la validación de los modelos teóricos en que estos cuestionarios se sustentan.

Es ampliamente aceptado que los dos requisitos más importantes de una herramienta de medida (p.e., un cuestionario) son la fiabilidad y la validez. La fiabilidad se refiere al grado en que las puntuaciones del cuestionario no son afectadas por errores de medición, es decir, la fiabilidad se preocupa de la precisión de la herramienta. Se dice que un cuestionario es 'fiable' en la medida en que las diferencias obtenidas entre las puntuaciones individuales son debidas a diferencias reales en el constructo bajo estudio. Por otro lado, la validez se refiere al grado en que las puntuaciones del cuestionario ofrecen información sobre el constructo bajo estudio, es decir, la validez se preocupa del significado. Se dice que un cuestionario es 'válido' en tanto en cuanto mida el constructo o constructos que pretende medir.

La validación empírica de un cuestionario reside por tanto en la fuerza de las evidencias encontradas para apoyar la fiabilidad y validez de sus resultados. De acuerdo con esto, los análisis estadísticos realizados en los tres estudios se han centrado en recoger evidencias que permitan validar o no validar empíricamente los cuestionarios y modelos presentados.

5.4.1. Análisis descriptivos

En los tres estudios que componen la presente tesis doctoral se han realizado una serie de análisis descriptivos preliminares. De esta forma se calculó la media, desviación típica, asimetría y curtosis, de las respuestas dadas por los trabajadores de las centrales nucleares a cada uno de los ítems pertenecientes a los cuestionarios estudiados (cuestionario basado en el modelo de la IAEA, cuestionario SCEQ y cuestionario OCI).

Por otro lado, se realizaron análisis descriptivos con los ítems de las variables externas utilizadas en los Estudios 2 y 3 (clima de seguridad organizacional, clima de seguridad grupal, satisfacción con la seguridad, satisfacción con el trabajo, cumplimiento de la seguridad, participación en seguridad y conductas arriesgadas). Los análisis de desviaciones típicas permitieron estudiar el poder discriminante de los ítems, mientras que los análisis de asimetría y curtosis permitieron analizar la existencia de normalidad en la distribución de los datos muestrales correspondientes a cada uno de los estudios. Los criterios utilizados para asumir un ajuste razonable a la distribución normal fueron que los valores absolutos medios en la asimetría presentada por los ítems fuesen inferiores a 1 (Boomsma, 1983) y que casi todos los ítems presentasen una asimetría y curtosis univariantes entre -1 y +1 (Muthén y Kaplan, 1985).

Adicionalmente, se llevaron a cabo análisis descriptivos para investigar cómo las muestras de estudiantes y de expertos en comportamiento organizacional en el Estudio 1 determinaron la correspondencia entre cada uno de los 37 atributos del modelo de la IAEA y sus 5 dimensiones. Para ello se calcularon los porcentajes de respuestas correctas por persona, de respuestas correctas por dimensión, y de participantes que asignaron cada uno de los atributos de forma correcta. Una respuesta fue calificada como 'correcta' cuando el participante asignó un atributo a la dimensión a la que, de acuerdo a la IAEA, pertenece.

5.4.2. Evidencias de fiabilidad

A lo largo de los tres estudios se hicieron distintos análisis de fiabilidad. Por un lado, mediante el coeficiente alfa de Cronbach, se comprobó la consistencia interna de cada una de las dimensiones y sub-dimensiones propuestas por los cuestionarios bajo estudio, así como la consistencia interna de otras escalas utilizadas en los Estudios 2 y 3 (clima de seguridad organizacional, clima de seguridad grupal, satisfacción con la seguridad, satisfacción con el trabajo, cumplimiento de la seguridad, participación en seguridad y conductas arriesgadas). Adicionalmente, se empleo el índice de fiabilidad compuesta para estudiar la consistencia interna de las dimensiones del SCEQ en el Estudio 2. En la presente tesis se aceptan los valores superiores a .70 como indicadores de una consistencia interna aceptable medidos por el coeficiente alfa de Cronbach (Nunnally, 1978) y por el índice de fiabilidad compuesta (Hair, Anderson, Tatham and Black, 1998; Raykov, 2001).

Por otro lado, en los Estudios 2 y 3 se calcularon los coeficientes de homogeneidad corregidos de cada uno de los ítems de los tres cuestionarios bajo estudio (cuestionario basado en el modelo de la IAEA, cuestionario SCEQ y cuestionario OCI) a través de análisis de correlaciones ítem-escala corregidas. El criterio de aceptación utilizado en este caso es que las correlaciones ítem-escala corregidas sean mayores de .30 (Fitzpatrick y cols., 1998; Nunnally y Bernstein, 1994) y menores que .90 (Fitzpatrick y cols., 1998). Un valor de correlación alto es indicador de que el ítem mide el mismo constructo que el resto de ítems de su escala. Sin embargo, una correlación demasiado alta (>.90) es una señal de redundancia con otros ítems de la escala. Estos análisis de fiabilidad permiten evaluar cuánto mejoraría (o empeoraría) la fiabilidad de una escala si se excluyera un determinado ítem.

5.4.3. Evidencias de validez

Para recoger evidencias de validez de las puntuaciones de los tres cuestionarios bajo estudio (cuestionario basado en el modelo de la IAEA, cuestionario SCEQ y cuestionario OCI) se hicieron distintos análisis, que a continuación se detallan.

5.4.3.1. Evidencias de validez basadas en la estructura interna

En los tres estudios de la tesis se examinó el grado en que los ítems de los cuestionarios bajo estudio mostraron cargas factoriales altas y significativas en sus factores (dimensiones) correspondientes. A lo largo de la tesis se aceptaron como satisfactorias las saturaciones iguales o superiores a .40, y se consideró que un ítem satura fuertemente en su factor correspondiente si la saturación es igual o mayor que .60 (Hair y cols., 1998).

En lo que se refiere a los análisis factoriales empleados, en los tres estudios se ha investigado la estructura interna de los cuestionarios evaluados a través de análisis factorial confirmatorio (AFC). En el Estudio 1 se ha empleado también análisis de componentes principales (ACP), y análisis factorial exploratorio (AFE). Y en el Estudio 2 se ha utilizado AFE. A continuación se detallan los análisis factoriales realizados en cada estudio.

Estructura interna del cuestionario basado en el modelo de la IAEA (Estudio 1)

En el Estudio 1 se realizó en primer lugar un AFC mediante el programa LISREL 8.80 (Jöreskog y Sörbom, 2006). Para estimar los parámetros del modelo de cultura de seguridad de cinco factores propuesto por la IAEA, se analizaron las correlaciones policóricas a través del método de estimación de máxima verosimilitud robusto o ‘robust maximum likelihood’ (RML).

Con el objetivo de evaluar el ajuste del modelo de cinco factores propuesto por la IAEA, se consideraron los siguientes índices de bondad de ajuste: NNFI (non-normed fit index), CFI (comparative fit index), RMSEA (root mean square error of approximation) y SRMR (standarized root mean square residual). El criterio utilizado en esta tesis para considerar que un modelo presenta un ajuste satisfactorio atendiendo a los índices NNFI y el CFI es el de obtener valores superiores o iguales a .90 (Batista-Foquet y Coenders, 2000; Jöreskog y Sörbom, 2006; Marsh, Hau y Grayson, 2005). Para considerar un buen ajuste, los valores deberían ser mayores de .95 (Hu y Bentler, 1999). Por su parte, para interpretar los índices RMSEA y SRMR, los valores menores que .08 se han considerado indicativos de un ajuste aceptable al modelo (Byon y Zhang, 2010; Hu y Bentler, 1999), siendo mejor el ajuste cuanto menores sean los valores.

Sin embargo, a pesar del ajuste satisfactorio del modelo de cinco dimensiones propuesto por la IAEA, las altas correlaciones encontradas entre las cinco dimensiones del modelo ($r_{xy} > .85$) sugerían que un modelo unidimensional podría ser más adecuado para representar los 37 atributos (ítems) del modelo de la IAEA.

Por este motivo se decidió investigar el ajuste de un modelo unidimensional y compararlo con el ajuste del modelo de cinco dimensiones. Para comparar el ajuste entre ambos modelos, se tuvieron en cuenta varios criterios basados en la comparación de los índices de bondad de ajuste (índices de ajuste incrementales). De este modo, siguiendo las recomendaciones de Cheung y Rensvold (2002) y

Widaman (1985), las diferencias inferiores a .01 entre los valores de los índices NNFI y CFI fueron consideradas como indicación de diferencias triviales entre modelos. Asimismo, seguimos la recomendación de Chen (2007), quien sugiere que cuando el incremento de los valores del índice RMSEA es menor que .015, las diferencias entre los modelos son triviales, pudiendo optar por el modelo más parsimonioso.

Finalmente, a pesar de que el AFC apoyó la estructura unidimensional del modelo de la IAEA, se decidió explorar la estructura interna del modelo sin las restricciones impuestas por AFCs por dos motivos: 1) las respuestas de las otras dos muestras utilizadas en este Estudio (estudiantes y expertos en comportamiento organizacional) sugerían que algunos de los atributos del modelo (ítems) sí podrían estar relacionados con las dimensiones a las que teóricamente pertenecen; 2) los resultados de los AFCs sugerían que algunas de las correlaciones entre dimensiones del modelo parecían empíricamente discriminables.

Para ello se exploró la estructura interna del modelo de la IAEA a través de ACPs con rotación oblimin, sin establecer el número de factores a priori. De acuerdo con el criterio comúnmente aceptado de Kaiser o 'Kaiser Criterion', se retuvieron aquellos factores que presentaron un Eigenvalue igual o mayor que 1. Se ofrecieron resultados teniendo en cuenta tanto las saturaciones factoriales por encima de .30 (recomendado por Spector, 1992) como las saturaciones por encima de .40 (recomendado por Hair y cols., 1995). Se aceptó un número mínimo de tres ítems por factor (Brown, 2006; Tabachnick y Fidell, 2001). Adicionalmente, debido a que el criterio de Kaiser puede sobreestimar el número de factores a retener (Costello y Osborne, 2005; Kline, 1994; Lance, Butts y Michels, 2006;

Zwick y Velicer 1986), se repitieron los ACPs forzando el número de factores a dos, tres o cuatro.

La razón de escoger ACP en vez de AFE, fue para controlar la posibilidad de que cultura de seguridad fuese un constructo formativo multidimensional en vez de un constructo reflectivo multidimensional (una diferenciación entre ambos tipos de constructos se ofrece en el Apartado 6.2.3.4.). En todo caso, finalmente se investigó también si una solución factorial más acorde con la propuesta por la IAEA podía emerger a través de AFEs.

Adicionalmente, en el Estudio 1 se decidió controlar la posibilidad de que las altas correlaciones entre las cinco dimensiones del cuestionario (basado en el modelo de cultura de seguridad de la IAEA) no se debieran, al menos parcialmente, a que todos los ítems habían sido asignados a las dimensiones a través de los mismos participantes. Para ello se empleo el método Harman de un solo factor o 'Harman's single factor test', realizando un AFE con constructos claramente distintos para determinar si la presencia de varianza del método común resulta en un único factor o en un factor que cuente con la mayoría de las varianzas (Podsakoff, MacKenzie, Lee y Podsakoff, 2003). Para descartar esta posibilidad, se empleo el método de Harman de un solo factor mediante un AFE que incluyó los 37 ítems del cuestionario de cultura seguridad, cuatro ítems del cuestionario de confianza y cuatro ítems del cuestionario de ambigüedad de rol.

Estructura interna del cuestionario SCEQ (Estudio 2)

En el Estudio 2, en primer lugar se llevo a cabo un AFE con las respuestas dadas al SCEQ por los trabajadores de dos centrales nucleares (pertenecientes a la misma organización), en 2008. El AFE se realizó mediante el método de estimación de mínimos cuadrados no ponderados o 'unweighted least square' (ULS) aplicando el criterio de rotación oblicua o 'oblique rotation criterion' (Lloret-Segura y cols., 2014; Sass y Schmitt, 2010). Como paso previo a los análisis factoriales, se evaluó si los datos eran adecuados para realizarlos. Para ello se utilizaron dos indicadores del grado de asociación entre variables: la prueba de esfericidad de Bartlett o 'Bartlett test of sphericity', y la medida de adecuación de la muestra KMO o 'Kaiser-Meyer-Olkin' (KMO). En la prueba de Bartlett se consideró que el resultado del test debería de ser estadísticamente significativo ($p < .05$). Por su parte, se consideró que los resultados del modelo factorial serían excelentes si el índice KMO estuviese comprendido entre .90 y 1; mientras que los resultados serían buenos, si estuviese comprendido entre .80 y .90 (Kaiser, 1974).

Al igual que en el Estudio 1, en el AFE llevado a cabo en el Estudio 2, se retuvieron también aquellos factores que presentaron un Eigenvalue igual o mayor que 1, se tuvieron en cuenta saturaciones factoriales por encima de .40 y se aceptó un número mínimo de tres ítems por factor. En base a los resultados del AFE y su interpretación teórica, se eliminaron tres ítems de los 24 ítems que inicialmente componían el SCEQ.

Para confirmar la estructura interna del SCEQ, se llevaron a cabo AFCs con las respuestas dadas al SCEQ por los trabajadores de las centrales nucleares seis años más tarde (muestra de 2014) mediante el programa Mplus (Muthén y Muthén, 1998-2010). Se utilizó el método de estimación de Mínimos Cuadrados Ponderados Robustos o 'robust weighted least squares' (WLSMV). Se estudiaron y compararon los ajustes del modelo tridimensional del SCEQ hipotetizado (decisiones estratégicas, prácticas de gestión de recursos humanos, y comportamientos y actividades del día a día ó más en concreto ‘strategic decisions ensuring safety’, ‘human resources practices driving safety’ y ‘daily activities and behaviors supporting safety’), y de un modelo unidimensional donde los 21 ítems del SCEQ medían una misma dimensión.

Para evaluar el ajuste de ambos modelos, se consideraron los índices de bondad de ajuste NNFI (también llamado TLI, Tucker-Lewis Index), CFI y RMSEA. Los criterios seguidos para considerar que un modelo presenta un ajuste satisfactorio atendiendo a estos índices fueron los mismos que los seguidos en los AFCs del Estudio 1. Del mismo modo, la comparación del modelo tridimensional y unidimensional del SCEQ siguió los mismos criterios y recomendaciones que los utilizados en la comparación del ajuste de modelos en el Estudio 1.

Estructura interna de los cuestionarios SCEQ y OCI (Estudio 3)

Para analizar la estructura interna del OCI propuesta por sus autores, se llevaron a cabo AFCs con las respuestas dadas al OCI por los trabajadores de dos centrales nucleares (pertenecientes a la misma organización) en 2008 mediante el programa Lisrel 8.80 (Jöreskog y Sörbom, 2006). Se utilizó el método de estimación de máxima verosimilitud (ML) y la matriz de correlaciones de Pearson como input para los análisis.

En concreto se estudiaron y compararon los ajustes de los siguientes tres modelos: 1) un modelo unifactorial donde los 120 ítems del OCI representaban una misma dimensión; 2) un modelo de tres factores (con 40 ítems cada uno) que representaban las tres dimensiones o estilos culturales del OCI (estilo ‘constructivo, estilo ‘Pasivo/defensivo, y estilo ‘Agresivo/defensivo); 3) un modelo de doce factores (con 10 ítems cada uno) que representaban los doce sub-dimensiones o normas culturales del OCI.

Por otro lado, para profundizar aún más en la estructura interna del OCI, mediante AFCs se compararon también modelos alternativos que tuvieron en cuenta los ítems de cada uno de los estilos culturales por separado. De esta forma se comparó un modelo unifactorial donde los ítems del estilo ‘constructivo’ representaban una misma dimensión con un modelo de cuatro factores que representaban las cuatro sub-dimensiones o normas culturales del estilo ‘constructivo’; un modelo unifactorial donde los ítems del estilo ‘pasivo/defensivo’ representaban una misma dimensión con un modelo de cuatro factores que representaban las cuatro sub-dimensiones o normas culturales del estilo ‘pasivo/defensivo’; y un modelo unifactorial donde los ítems del estilo ‘agresivo/defensivo’ representaban una misma dimensión con un modelo de cuatro factores que representaban las cuatro sub-dimensiones o normas culturales del estilo ‘agresivo/defensivo’.

Para evaluar el ajuste de cada uno de los modelos probados, se consideraron los índices de bondad de ajuste NNFI, CFI y RMSEA. Los criterios seguidos para considerar que un modelo presenta un ajuste satisfactorio atendiendo a estos índices fueron los mismos que los seguidos en los AFCs de los Estudios 1 y 2. Del mismo modo, las comparaciones entre modelos siguieron los mismos criterios y recomendaciones que los utilizados en las comparaciones del ajuste de modelos en los Estudios 1 y 2.

5.4.3.2. Evidencias de validez basadas en las relaciones con otras variables

El estudio de las relaciones entre la medida obtenida por el cuestionario (en este caso el SCEQ y el OCI) y variables externas (las siete variables utilizadas), conocida como el aspecto externo de la validez por Loevinger (1957), o como amplitud nomotética por Embretson (1983), es probablemente el tipo de evidencia más utilizado en el proceso de validación de cuestionarios (Elosua Oliden, 2003). Esta fuente de información se nutre de evidencias que relacionan la puntuación con algún criterio que se espera pronostique el cuestionario, con otros cuestionarios que hipotéticamente midan el mismo constructo, constructos relacionados o constructos diferentes (AERA, APA y NCME, 1999). Los resultados de estos análisis servirían para evaluar el grado en que las relaciones hipotetizadas son consistentes con la interpretación propuesta, y obtener así evidencias de validez del cuestionario estudiado.

Relaciones con variables externas

Como parte del trabajo de validación del cuestionario de cultura de seguridad SCEQ y del cuestionario de cultura organizacional OCI, en los Estudios 2 y 3 se analizaron las relaciones de estos dos cuestionarios con diferentes variables externas que miden constructos teórica y empíricamente asociados con cultura de seguridad y cultura organizacional, y conceptualizados en la literatura como consecuentes de cultura de seguridad. Por otro lado, se analizó la relación entre cultura de seguridad y cultura organizacional.

En concreto, en el Estudio 2 se calcularon coeficientes de correlación de Pearson entre cada una de las dimensiones del SCEQ (muestra de 2014) y las variables externas clima de seguridad organizacional, satisfacción con la seguridad, satisfacción con el trabajo y conductas arriesgadas (muestra de 2014).

Adicionalmente, en el Estudio 2 recogimos evidencias de validez discriminante entre el cuestionario de cultura de seguridad SCEQ y la adaptación española del cuestionario de clima de seguridad de Zohar y Luria (2005). Esto se realizó de dos formas: 1) se estudió si existían diferencias significativas entre las correlaciones de cada par de dimensiones del SCEQ y la correlación de cada una de estas dimensiones con el SCEQ. Si las correlaciones entre dos dimensiones del SCEQ fuesen significativamente mayores que las correlaciones entre cada una de esas dimensiones y el clima de seguridad, se obtendrían evidencias adicionales de validez del SCEQ; 2) se realizaron AFCs testando distintos modelos que incluían los ítems del SCEQ y los ítems del cuestionario de clima de seguridad. A través del ajuste y comparación entre los modelos estudiados, se quiso también respaldar que el SCEQ y el cuestionario de clima de seguridad medían constructos distintos.

En el Estudio 3 se presentó un estudio transversal y un estudio longitudinal. En el estudio transversal se calcularon coeficientes de correlación de Pearson entre cada una de las tres dimensiones del SCEQ (muestra de 2008) y las variables externas clima de seguridad organizacional, clima de seguridad grupal, satisfacción con la seguridad y satisfacción con el trabajo (muestra 2011). En el estudio longitudinal, se calcularon coeficientes de correlación de Pearson entre cada una de las tres dimensiones del SCEQ (muestra 2008) y las variables externas cumplimiento de la seguridad, participación en seguridad y conductas arriesgadas (muestra 2011). Del mismo modo se calcularon las correlaciones entre cada una de las tres dimensiones y doce sub-dimensiones del OCI (2008) y las variables anteriormente mencionadas (muestras 2008 y 2011). Finalmente se estudió empíricamente la relación entre cultura de seguridad y cultura organizacional mediante coeficientes de correlación de Pearson entre las dimensiones del SCEQ, y las dimensiones y sub-dimensiones del OCI.

Predicción de variables externas

En el Estudio 3 se llevaron a cabo análisis de regresión múltiple con el programa SPSS 22 para investigar el grado en que la cultura de seguridad (medido por las dimensiones del SCEQ en 2008) y la cultura organizacional (medido por las dimensiones y sub-dimensiones el OCI en 2008) podrían predecir el desempeño de seguridad (medido en 2011 por los cuestionarios de cumplimiento de la seguridad, participación en seguridad y conductas arriesgadas) de las centrales nucleares estudiadas. Para evitar problemas de colinealidad, se estandarizaron las variables independientes.

Los coeficientes de determinación (R^2) obtenidos en los análisis de regresión múltiple expresaron la proporción de varianza de cada uno de los tres criterios de desempeño de seguridad que explicaban las dimensiones del SCEQ y las dimensiones del OCI.

Posteriormente se incluyeron las dimensiones del SCEQ y las dimensiones del OCI en un modelo de regresión jerárquica para investigar el grado en que el desempeño de seguridad se podría predecir empleando herramientas de medición de cultura de seguridad y de cultura organizacional por separado o conjuntamente. En este caso, los cambios en R^2 de modelos consecutivos permitieron estudiar la proporción de varianza de cada uno de los tres criterios de desempeño de seguridad que se podía explicar teniendo en cuenta las respuestas de los participantes al SCEQ y al OCI de forma separada y conjunta.

Relaciones entre las dimensiones del cuestionario

La evidencia de validez convergente y discriminante se enmarca dentro de las evidencias de validez basadas en las relaciones con otras variables (AERA, APA y NCME, 1999). Siguiendo este criterio, incluimos en este apartado los análisis realizados para recoger evidencias de validez discriminante de las dimensiones de los cuestionarios estudiados (cuestionario basado en el modelo de la IAEA, cuestionario SCEQ y cuestionario OCI). Debido a que estos análisis se ciñen a las relaciones entre las dimensiones de los propios cuestionarios, esta información podría haberse incluido también en el apartado anterior (5.4.3.1), referido a las evidencias basadas en la estructura interna.

En concreto, se calcularon coeficientes de correlación de Pearson para estudiar la correlación presentada por cada dimensión de cada uno de los tres cuestionarios bajo estudio con el resto de las dimensiones del cuestionario al que pertenecen. La presente tesis toma el criterio comúnmente aceptado de Kline (2005), que establece que dos dimensiones son discriminantes cuando las correlaciones entre éstas son menores de .85. El cumplimiento de este criterio (r_{xy}< .85) apoyaría que las dimensiones de los cuestionarios estudiados en esta tesis miden aspectos relacionados pero distintos del mismo constructo (cultura de seguridad en el caso del SCEQ y del cuestionario de la IAEA, y cultura organizacional en el caso del OCI).

5.4.3.3. Evidencias de validez basadas en diferencias inter-grupos

En el Estudio 2 se compararon las respuestas dadas a cada una de las tres dimensiones del SCEQ por el equipo de alta dirección y por el resto de empleados de las centrales nucleares. A través de pruebas t o 'T-Tests' se estudió si el SCEQ tenía la capacidad de discriminar entre las valoraciones que distintos grupos jerárquicos daban al grado en que la seguridad era un valor en acción en su organización. Este gap en la percepción y valoración de la seguridad en la organización se ha observado frecuentemente en la literatura (Huang, Robertson, Lee, Rineer, Murphy, Garabet y Dainoff, 2014).

CHAPTER VI.

TESTING THE DIMENSIONALITY OF THE INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA) SAFETY CULTURE MODEL: FACE, CONTENT AND FACTORIAL VALIDITY

Abstract

This paper takes the first steps to empirically validate the widely used model of safety culture of the International Atomic Energy Agency (IAEA), composed of five dimensions, further specified by 37 attributes. To do so, three independent and complementary studies are presented. First, 290 students serve to collect evidence about the face validity of the model. Second, 48 experts in organizational behavior judge its content validity. And third, 468 workers in a Spanish nuclear power plant help to reveal how closely the theoretical five-dimensional model can be replicated. Our findings suggest that several attributes of the model may not be related to their corresponding dimensions. According to our results, a one-dimensional structure fits the data better than the five dimensions proposed by the IAEA. Moreover, the IAEA model, as it stands, seems to have rather moderate content validity and low face validity. Practical implications for researchers and practitioners are included.

Keywords: Empirical validation;HRO; nuclear industry;nuclear power plant; safety culture; safety performance

6.1. Introduction

In 1986 the Chernobyl catastrophe led to the emergence of ʽsafety cultureʼ as a new concept in high reliability organizations (HRO) in general and in the nuclear industry in particular. Experts at the International Atomic Energy Agency (IAEA) analyzed the disaster and came to the conclusion that the occurrences could not just be attributed to human error, the technology, or even the socio-technical system. The identified cause was a group of organizational and management factors which they labeled as safety culture. The report was published by the IAEA (1986) as Safety Series No. 75-INSAG-1. Since the appearance of this term, all of the hazard industries have adopted it as their banner in the efforts to promote safety in their installations and operations (Wilpert and Schöbel, 2007).

During the last 25 years, the IAEA has continuously worked toward the conceptualization and theoretical development of safety culture and the creation of specific methodologies and tools for the assessment and development of strong safety cultures. One of the most remarkable contributions of the IAEA has been its five-dimensional model of safety culture. This model has clearly influenced a sector – largely composed of technical professionals, such as engineers, physicists and chemists – eager to know exactly what that important concept called safety culture was, what they should do to assess it, and how they could build strong safety cultures capable of avoiding future catastrophes. As a result, the IAEA model has become widely used in the nuclear industry as the main guide to safety culture.

Despite the relevance of the IAEA model to nuclear safety outcomes, its validity has never been empirically tested. This will be the aim of the present study and our main contribution to the advancement of safety in the nuclear industry. In order to achieve this goal, three studies are presented. The first study tests the face validity of the model on the basis of the opinions of a sample of non-experts in organizational behavior with no previous experience in the nuclear industry. In the second study, a sample of experts in organizational behavior is used to test the content validity of the model. Finally, the third study examines the factorial structure of a questionnaire based on the model in a sample of workers in a Spanish nuclear power plant (NPP).

6.1.1. Conceptualization of safety culture

Safety culture presents a great diversity of meanings and connotations due to the broad dimensionality of the concept. It has sometimes been explained in the form of intuitive slogans (e.g. “do the right thing even when nobody is watching” or “the way we do things around here”). Nevertheless, the understanding, assessment and improvement of the safety culture have typically been based on the way it has been formally defined.

Safety culture has been defined by the IAEA (1991) as “that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance” (p. 1). This was the first definition of safety culture and one of the most influential in the field. The IAEA definition “was carefully composed to emphasize that safety culture is attitudinal as well as structural, relates both to organizations and individuals" (IAEA, 1991, p. 1). Therefore, the IAEA (1991) highlights two general components of safety culture: "the first is the necessary framework within an organization and is the responsibility of the management hierarchy. The second is the attitude of staff at all levels in responding to and benefiting from the framework" (p. 5).

The definition of safety culture of the IAEA has stimulated researchers' interest in the topic, but it is not exempt from criticism. Wilpert (1991; cited in Wilpert, 2001) referred to the ˈcharacteristicsˈ term in the definition as being rather vague. On the other hand, he warned that this definition leaves out safety-related behavior, which is important because, as he reminds us, attitudes and actions do not always correlate strongly. In our view, another critical issue is that cultures are 'shared' by individuals and groups pertaining to the same country, society, organization, etc.

Later, the IAEA (1998a) adds that the ˈcharacteristicsˈ and ˈattitudesˈ referred to in its definition should be commonly held (addressing the shared issue) and relatively stable. Furthermore, in an effort to extend its own definition to other contents, the IAEA (1998a) clarifies that "safety culture is also an amalgamation of values, standards, morals and norms of acceptable behavior. Therefore, safety culture has to be inherent in the thoughts and actions of all the individuals at every level in an organization" (p. 4).

The theoretical and practical development of safety culture has been closely related to the development of the term "safety climate". In this context, it is important to mention the theoretical distinction between these two constructs.

While safety culture is believed to encompass stable shared basic assumptions, beliefs, values and norms regarding safety at work, safety climate is presented as shared perceptions of safety at a given point in time. Specifically, safety climate generally includes day-to-day perceptions towards the working environment, working practices, organizational policies, and management (Yule, 2003). Safety climate is viewed as a manifestation or "snapshot" of safety culture (Flin et al, 2000); it is more transient and less stable, and reflects somewhat the current-state of the underlying safety culture (Mearns et al., 2001; Mearns et al., 2003). Because of this, many authors rely on climate studies to capture the state of HRO´s safety cultures, and these terms have been often used interchangeably (Cox and Flin, 1998; Rollenhagen, 2010) although it is important to define each construct precisely and use them accordingly.

6.1.2. Dimensions of safety culture

Safety culture comprises a variety of contents that are indistinctively called indicators, principles, traits, characteristics, components, dimensions, attributes or a combination of these (e.g., the Institute of Nuclear Power Operations [INPO] and the World Association of Nuclear Operators [WANO] refer to principles; the Health and Safety Executive [HSE], to indicators; the Nuclear Regulatory Commission [NRC], to components; and the IAEA, to characteristics). Following the psychometric terminology and reflecting the assumed multidimensional nature of safety culture, we will use the term *dimension* when referring to each of these contents. When a dimension is composed of smaller sub-contents, these will be referred as *attributes* of that specific dimension.

The existing conceptualizations, models and assessment tools for safety culture reflect a lack of consensus on the dimensions that comprise the safety culture construct. There is an overlap between the identified dimensions as well as a lack of conceptual clarity. The dimensionality of safety culture, as reported by Guldenmund (2000), ranges from 2 to 19 dimensions, with little coincidence in their labels. The labels given to these dimensions vary considerably from author to author, even when they try to refer to the same safety culture contents. Several reasons lie behind the existing multitude of safety culture dimensions and the lack agreement between them, for instance:

- The numerous definitions of safety culture, which show little consensus about the operationalization of the construct.

- The variety in authors' professional and academic backgrounds (e.g., psychology, sociology, engineering, economics, etc.), their idiosyncratic writing styles, and the paradigms their work is influenced by (e.g., constructivism, positivism, relativism, etc.).

- The use of empirical atheoretical approaches to identify the dimensions of safety culture (e.g. factor analysis [FA], principal components analysis [PCA], etc.) without the guidance of solid theoretical models, leaves researchers considerable freedom to label their dimensions. For a detailed explanation of this point, the reader is directed to Guldenmund (2000).

- Different industries (e.g., nuclear, petrochemical, aviation, mining, construction, etc.) often address distinct organizational and management aspects having an impact on safety outcomes.

The labeling of dimensions requires special caution, as quite often labels have a life of their own beyond what the items making up these dimensions operationally measure. This is especially true when assessment tools are used by practitioners. If a label does not adequately capture and summarize the content of its corresponding attributes, it can be confusing and misleading in practice.

A number of safety culture reviews have attempted to identify the commonly accepted dimensions of safety culture (see Table 8). According to Sorensen (2002), most investigators agree that the dimensions of safety culture are: good organizational communication; good organizational learning; senior management commitment to safety; and a working environment that rewards indentifying safety issues. He also noted that some investigations have included a dimension related to management and organizational factors, such as a participative management leadership style. Wiegmann et al. (2004) concluded in their review that safety culture includes five dimensions: organizational commitment; management involvement; employee empowerment; reward systems; and reporting systems. The Health and Safety Executive (HSE, 2005), after reviewing the literature surrounding safety culture, identified the following five dimensions: safety leadership; two-way communication; employee involvement; learning culture; and attitudes towards blame (a just culture). Meanwhile, Choudhry et al. (2007) take the view that safety culture comprises five dimensions: management commitment to safety; management concerns for the workforce; mutual trust and credibility between management and employees; workforce empowerment; and continuous monitoring, corrective action, review of system and continual improvements to reflect the safety at the work site.

In addition to the common themes identified in existing reviews of safety culture, nuclear organizations and regulators have contributed to the development of the safety culture dimensionality (see Table 8). The INPO (2004) and the WANO (2006) consider that strong safety cultures are composed of eight different dimensions: everyone is personally responsible for nuclear safety; leaders demonstrate commitment to safety; trust permeates the organization; decision-making reflects safety first; nuclear technology is recognized as special and unique; a questioning attitude is cultivated; organizational learning is embraced; and nuclear safety undergoes constant examination. The NRC (2011) recently finalized its new safety culture policy statement as the result of a three-year project with extensive public participation and numerous workshops and meetings. The policy statement concluded that a positive safety culture has the following nine dimensions: leadership safety values and actions; problem identification and resolution; personal accountability; work processes; continuous learning; environment for raising concerns; effective safety communication; respectful work environment; and a questioning attitude. The IAEA (2006c) has identified five main safety culture dimensions based on "research findings, lessons learned regarding the root causes of organizational failures in safety management and safety culture, and the international collaboration of safety experts under the auspices of the IAEA" (p. 35). The dimensions proposed by the IAEA are: safety is a clearly recognized value; leadership for safety is clear; accountability for safety is clear; safety is integrated into all activities; and safety is learning driven.

Table 8

Common themes or dimensions of safety culture identified by safety culture reviews, regulators and nuclear organizations

Sorensen (2002)	Good organizational communication
	Good organizational learning
	Senior management commitment to safety
	Working environment that rewards identifying safety issues
	Participative management leadership style
Wiegmann et al. (2004)	Organizational commitment
	Management involvement
	Employee empowerment
	Reward systems
	Reporting systems
INPO (2004) / WANO (2006)	Everyone is personally responsible for nuclear safety
	Leaders demonstrate commitment to safety
	Trust permeates the organization
	Decision-making reflects safety first
	Nuclear technology is recognized as special and unique
	A questioning attitude is cultivated
	Organizational learning is embraced
	Nuclear safety undergoes constant examination
HSE (2005)	Leadership
	Two-way communication
	Employee involvement
	Learning culture
	Just culture
IAEA (2006a,b)	Safety is a clearly recognized value
	Leadership for safety is clear
	Accountability for safety is clear
	Safety is integrated into all activities
	Safety is learning driven

Choudhry et al. (2007)	Management commitment to safety Management concerns for the workforce Mutual trust and credibility between management and employees Workforce empowerment Continuous monitoring, corrective action, review of system and continual improvements to reflect the safety at the work site
NRC (2011)	Leadership safety values and actions Problem identification and resolution Personal accountability Work processes Continuous learning Environment for raising concerns Effective safety communication Respectful work environment Questioning attitude

The authors of the present paper are especially interested in the dimensions proposed by the IAEA because they are widely accepted and used in the nuclear industry. For this reason, the IAEA model was compared to the dimensions suggested in the other six studies mentioned above. Two of the dimensions of the IAEA model – “safety is a clearly recognized value”, and “safety is integrated into all activities” – could not be clearly related to any of the dimensions proposed by these studies. At first glance, the labels of these two dimensions seemed very general and wide in scope. Therefore, covering the content of these dimensions would probably require a large number of attributes. The IAEA’s dimension “leadership for safety is clear” is consistent with the HSE’s “safety leadership”, as both generally highlight that leadership is a key element for safety. The dimensions “participative management leadership style” (reported by Sorensen), “leadership safety values and actions” (NRC) and “leaders demonstrate commitment to safety” (INPO/WANO) cover distinct aspects of the IAEA’s “leadership for safety is clear”, and as such they could be understood as attributes of it. The IAEA’s dimension “accountability for safety is clear” corresponds fairly well to the NRC’s dimension “personal accountability” and to the INPO/WANO’s “everyone is personally responsible for nuclear safety”. Finally, the IAEA’s dimension “safety is learning driven” shows the closest match to the studies to which it was compared. In this regard, the reviews by Sorensen (“good organizational learning”), the HSE (“learning culture”), the INPO/WANO (“organizational learning is embraced”) and the NRC (continuous learning”) agree with the IAEA that learning is fundamental to preserving the safety of HROs. Moreover, the NRC and the INPO/WANO include a “questioning attitude” as a dimension of safety culture, which could also be understood as an attribute of the IAEA’s “safety is learning driven”.

The dimensions of the IAEA model are covered by 37 attributes, which are presented in the next section. Some of these attributes have similar labels to the dimensions proposed by other authors. An analysis of these correspondences is not included in this paper; nevertheless, two examples are given to show the existing confusion between dimensions and attributes of safety culture. Sorensen, Choudhry, and the INPO/WANO include a dimension of safety culture referring to management commitment to safety. The IAEA captures this element in the attribute “commitment to safety is evident at all levels of management”, which belongs to the IAEA’s dimension “leadership for safety is clear”. As a second example, Sorensen, Weigmann, the HSE and the NRC believe that one dimension of safety culture should highlight the existence of report systems for safety issues and an environment for raising concerns without fear of retaliation. This idea is reflected in the IAEA's attribute "open reporting of deviations and errors is encouraged", which is part of the IAEA's dimension "safety is learning driven".

6.1.3. The IAEA five-dimensional safety culture model

The IAEA has created a model for the common understanding and assessment of safety culture within nuclear power facilities. The model, described in detail in Table 9, is identified in Safety Guide No. GS-G-3.1 (IAEA, 2006a) as essential for achieving a strong safety culture. It is composed of 37 attributes clustered into five dimensions, referred to as characteristics by the IAEA, and mentioned in section 1.2.: safety is a clearly recognized value; leadership for safety is clear; accountability for safety is clear; safety is integrated into all activities; and safety is learning driven. The IAEA (2008a) explains that "the attributes are short descriptions of a specific organizational performance or attitude in a nuclear facility, which, if fulfilled, would characterize this performance or attitude as belonging to a strong safety culture" (p. 8). The characteristics and attributes are general enough to reflect the reality of distinct types of nuclear facilities (NPPs, research reactors, fuel cycle facilities, etc.).

Table 9
The IAEA five-dimensional safety culture model

Dimension		Attribute
A - Safety is a clearly recognized value	A1	The high priority given to safety is shown in documentation, communications and decision making
	A2	Safety is a primary consideration in the allocation of resources
	A3	The strategic business importance of safety is reflected in the business plan
	A4	Individuals are convinced that safety and production go hand in hand
	A5	A proactive and long term approach to safety issues is shown in decision making
	A6	Safety conscious behavior is socially accepted and supported (both formally and informally).
B - Leadership for safety is clear	B1	Senior management is clearly committed to safety
	B2	Commitment to safety is evident at all levels of management
	B3	There is visible leadership showing the involvement of management in safety related activities
	B4	Leadership skills are systematically developed
	B5	Management ensures that there are sufficient competent individuals
	B6	Management seeks the active involvement of individuals in improving safety
	B7	Safety implications are considered in change management processes
	B8	Management shows a continual effort to strive for openness and good communication throughout the organization
	B9	Management has the ability to resolve conflicts as necessary
	B10	Relationships between managers and individuals are built on trust
C - Accountability for safety is clear	C1	An appropriate relationship with the regulatory body exists that ensures that the accountability for safety remains with the licensee
	C2	Roles and responsibilities are clearly defined and understood
	C3	There is a high level of compliance with regulations and procedures
	C4	Management delegates responsibility with appropriate authority to enable clear accountabilities to be established
	C5	‘Ownership’ for safety is evident at all organizational levels and for all individuals

D - Safety is integrated into all activities	D1	Trust permeates the organization
	D2	Consideration of all types of safety, including industrial safety and environmental safety, and of security is evident
	D3	The quality of documentation and procedures is good
	D4	The quality of processes, from planning to implementation and review, is good
	D5	Individuals have the necessary knowledge and understanding of the work processes
	D6	Factors affecting work motivation and job satisfaction are considered
	D7	Good working conditions exist with regard to time pressures, workload and stress
	D8	There is cross-functional and interdisciplinary cooperation and teamwork
	D9	Housekeeping and material conditions reflect commitment to excellence
E - Safety is learning driven	E1	A questioning attitude prevails at all organizational levels
	E2	Open reporting of deviations and errors is encouraged
	E3	Internal and external assessments, including self-assessments, are used
	E4	Organizational experience and operating experience (both internal and external to the facility) are used
	E5	Learning is facilitated through the ability to recognize and diagnose deviations, to formulate and implement solutions and to monitor the effects of corrective actions
	E6	Safety performance indicators are tracked, trended, evaluated and acted upon
	E7	There is systematic development of individual competences

The IAEA highlights that all individuals must have a common understanding of the characteristics and attributes of this model; consequently, training should be regularly provided to make sure that the model is understood and acted upon (IAEA, 2009a). At the management level, importance is given to the monitoring and reinforcement of attributes, and to the detection of early signs of decline in these attributes (IAEA, 2006a). The IAEA recommends that safety culture assessments take the characteristics and attributes of its model into account. This recommendation is applicable to independent assessments, such as internal audits, external audits, surveillance and reviews, checks and inspections, as well as to self-assessments (IAEA, 2006a). The IAEA (2009a) specifies that "these characteristics and attributes should all be covered when developing interview questions, items for inclusion in a questionnaire or issues for discussion in focus groups" (p. 89). As an example, the IAEA has developed a triangulated methodology to assess safety culture based on this model. This methodology, called SCART (Safety Culture Assessment Review Team), includes interviews, observations and documentation reviews. SCART is aimed to identify strengths and areas for improvement in nuclear facilities in relation to the dimensions and attributes of the IAEA model.

Although the IAEA's role is purely advisory, its model of safety culture is becoming a reference for regulatory bodies. As an example, the Norwegian Radiation Protection Authority (NRPA) and the Department of Nuclear Safety and Security of the IAEA are working together with the Bulgarian Nuclear Safety Agency (BNRA) and the National Commission for Nuclear Activities Control (CNCAN) towards the development and implementation of several projects to promote nuclear safety in Bulgaria and Romania (IAEA website). These projects aim to enhance the ability of the BNRA and CNCAN to assess the safety culture of their licensees on the basis of the IAEA safety culture model and the SCART methodology (Rolina, 2011). Another example comes from the Ministry of Education, Science and Technology (MEST) in South Korea, which encourages NPPs to improve their methodologies for safety culture self-assessment by taking the IAEA safety culture model into consideration (MEST, 2010). An increasing number of well-known organizations are recognizing the importance of the model (e.g. the Belgian Nuclear Research Centre [BNRC] [Xu et al., 2011], and the Forum for Nuclear Cooperation in Asia [FNCA] [FNCA website]). On the other hand, SCART missions are being carried out in different nuclear organizations, such as the Pebble Bed Modular Reactor (Pty) Limited in South Africa (IAEA, 2006d), Santa María de Garoña in Spain (IAEA, 2007), and Laguna Verde in Mexico (IAEA, 2009b).

6.1.4. Need for empirical testing of the IAEA five-dimensional safety culture model

The five dimensions and 37 attributes of the IAEA safety culture model serve to understand what safety culture is and what organizational aspects should be assessed, monitored and acted upon in order to ensure safer nuclear facilities. In this sense, the work of the IAEA has been commendable and highly useful for the nuclear industry. However, and to our knowledge, the validity of the IAEA model and of the measurement instruments based on the model have not been empirically tested yet.

The course of action in science is that a model must be empirically validated before it can be applied to practical settings. Empirical validation ideally takes place before the application of a model but, if not, during or after its application. In any case, this validation is not only desirable but also necessary in order to ensure a rigorous professional performance in solving organizational problems. The scientist-practitioner model (Briner and Rousseau, 2011; Jones and Mehr, 2007; Trierweiler and Stricker, 1998) is a good example of the way professionals who are scientifically rigorous in developing and implementing solutions must act to maximize success when facing practical problems. However, on some occasions the need for urgent and efficient solutions to practical problems justifies professionals putting supposedly ‘good’ models into practice, even though these models do not have sufficient empirical support. This is the case of the nuclear industry, where the pressing need for cultures that can guarantee the safety of nuclear facilities has led to the extended use of the IAEA safety culture model. In our opinion, this model has contributed to fulfilling the need stated by the nuclear industry; however, a model that has the potential to change nuclear safety outcomes should have sufficient empirical support.

The empirical validation of the IAEA model is necessary in order to maximize its practical usefulness for the nuclear industry. The validation of an assessment instrument, such as the one directly derived from the IAEA model and the 37 attributes included in this model to capture the five dimensions proposed, requires accumulating evidence that supports the adequacy, meaning and usefulness of inferences that can be drawn from this instrument. In this context, if there was a lack of empirical correspondence between the IAEA’s attributes and the dimensions proposed by the model, the scores on the dimensions obtained from safety culture assessments could lead to misleading inferences. Therefore, we believe that testing the correspondence between the attributes and dimensions is of paramount importance and contributes to obtaining evidence about the validity of the IAEA model. As a result, we agreed to accept this challenge by working on three independent empirical studies designed to study the face, content and factorial validity of the IAEA model.

6.2. Method

6.2.1. First study – testing face validity

6.2.1.1. Purpose of the study

Research using new, changed or previously unexamined scale items should, at a minimum, be judged on its face validity (Hardesty and Bearden, 2004). Face validity refers to the extent to which a measure reflects what it is intended to measure (Nunnally and Bernstein, 1994). It is not about what the model actually measures but about what it superficially appears to measure. Improving the face validity of a model, a test or a measurement instrument in general will not ensure the improvement of its construct validity; however, face validity is a requirement for a measurement instrument to function effectively in practical situations (Anastasi, 1976).

The purpose of this first study is to test the face validity of the IAEA safety culture model, by investigating to what extent the attributes of the model appear to reflect what they are supposed to measure, that is, whether or not the 37 attributes of the model appear to be valid in our sample.

Hypothesis 1. The attributes of the model will appear to measure what they are intended to measure, showing evidence of face validity.

6.2.1.2. Development of the survey

The IAEA safety culture model was converted into a survey form. Attributes and dimensions were separated into two different documents that make up the survey. The first document included the instructions for completing the exercise and the model's 37 attributes mixed randomly and numbered from 1 to 37. The second document included the five dimensions of the model labeled from A to E. The labeling of attributes with numbers and dimensions with letters was done to avoid biased answers based on potential cognitive associations between numbers or letters. It is worth noting that this second document included the labels (e.g. accountability for safety is clear) and not the descriptions of the dimensions. The reasons behind this choice were twofold. First, the descriptions given by the IAEA (2009a) overlapped with the attributes of the model. Using the descriptions instead of the labels could have biased the answers of our participants who, as will be explained in section 2.1.4., were asked to match the attributes to the dimensions of the model. Second, the descriptions of the dimensions provide additional and rich information about the IAEA model. However, when putting a model into practice, researchers and practitioners quite often only consider the labels of dimensions, and for this reason the adequacy and accuracy of these labels must be ensured.

The next step was to translate the survey into Spanish, since it was the native language of the target sample. The back-translation technique was chosen, as it is the best approach to preserve the functional and conceptual equivalence of words and sentences. Back-translation is the translation of a survey instrument that has already been translated into a foreign language back to the original language. Two certified translators performed this task. The forward-translation, English into Spanish, was done by one of them, whereas the other one carried out the back-translation, Spanish into English. Afterwards, the two translators met to analyze any divergence on the forward-translated, the original and the back-translated surveys. As a result, they agreed by consensus on a translation that accurately reflected the intent of the wording in the original language.

6.2.1.3. Sampling procedure

Face validity has typically been tested by participants who do not have prior knowledge about the construct under study. A model, a test or a measurement instrument has face validity when it appears valid to non-experts (Sartori, 2010), lay persons (Cronbach, 1984), untrained observers (Anastasi, 1976), or in the words of Litwin (1995), "untrained judges such as your sister, boyfriend or squash partner" (p. 35). In this sense, a number of studies in organizational management have favored the use of students to assess the face validity of their models or measurement instruments (Chaudhry et al., 2011; Cockrell and Stone, 2010; Holden and Jackson, 1979; Key, 1997; Porter, Angle and Allen, 2003; Torres-Harding, Siers and Olson, 2011; VandeWalle, 1997; Verbeke, 2000). The opinions provided by these students have helped researchers to decide what items on their proposed instruments they should retain or eliminate.

For all these reasons, we decided to test the face validity of the IAEA model with a sample of graduate students. Participants were untrained judges for this study, as they were not knowledgeable about safety culture. Furthermore, they were not familiar with the IAEA safety culture model and had never worked within the nuclear industry. All surveys were completed and returned to the researchers; therefore, a response rate of 100% was obtained. Any survey showing systematic response patterns or having more than 3 unanswered items was dropped from the data set. As a result, 290 out of the 297 surveys returned were accepted for data analyses (N=290). The final sample was composed of 110 students of psychology, 96 of labor relations and 84 of tourism. The students averaged 24 years of age ranging from 18 to 55. 72% of students were female, and 80% had previous work experience.

6.2.1.4. Survey administration

The survey was administered by the authors of the current study. This condition assured that any doubts when filling out the survey could be resolved by the researchers, who were always present during the administration. No help was provided in terms of clarifying the meaning of attributes and dimensions, but only about the manner in which the survey should be completed.

Each of the participants was provided with written instructions that explained the purpose of the study and the way the survey should be completed. Participants received the 37 attributes and the five dimensions on two different documents, and their task was to place each of the attributes in the dimension to which they believed it belonged. For this purpose, they were asked to write A, B, C, D or E – letters representing the five dimensions – next to each of the attributes. Participants were encouraged not to leave any attribute without a response.

Participation and making an effort to do their best were reinforced by telling the participants that they were contributing to the development of nuclear safety, an indispensable goal for all of us. Voluntary participation and anonymity were emphasized. No names or identifying information were required on the survey, only some socio-demographic data, which included gender, age and whether or not the participant had previous work experience.

Reactions of a few students included questions about hard-to-understand statements.

6.2.1.5. Analyses and results

For simplicity, a *correct answer* is scored when a participant successfully classifies an attribute in the dimension it belongs to according to the IAEA. *Incorrect answers* reflect an inappropriate classification of attributes into dimensions.

To get a global view of the face validity of the model, the average of *correct answers* per participant was calculated. Descriptive analyses indicated that the students were able to correctly allocate an average of 13 attributes – ranging from 3 to 22 – out of 37 to their corresponding dimensions. In the participants' opinions, 35.51% of the attributes appeared to measure the dimensions that, according to the IAEA, they were supposed to measure.

The next step was to explore the face validity of each of the dimensions of the model. To do so, we analyzed participants' *correct answers* for each of the dimensions of the model. The percentage of *correct answers* given by the students was 36.4% in dimension A, 44.7% in B, 28.6% in C, 25.8% in D, and 38.6% in E.

Finally, face validity was checked for each of the 37 attributes of the model. To do this, the percentage of participants assigning each of the attributes to each of the five dimensions of the model was calculated. A great variance was found in the results, ranging from 8% of participants placing attribute B7 in its corresponding dimension ("leadership for safety is clear") to 78.9% of participants placing attribute B3 in its corresponding dimension ("leadership for safety is clear”). Further details on the allocation of the attributes can be seen in Table 10.

We followed two different criteria to assess the face validity of the attributes of the model. The first and less restrictive criterion considered an attribute to have enough face validity when the percentage of students allocating it to its corresponding dimension was higher than the percentages of students allocating it to each of the four remaining dimensions. The second and more restrictive criterion accepted every attribute that was allocated to its corresponding dimension by at least half of the students. Under less restrictive conditions, 21 attributes were accepted: 4 attributes supposed to belong to dimension A (A1, A2, A3 and A4); 7 to dimension B (B1, B3, B4, B5, B8, B9 and B10); 2 to dimension C (C1 and C2); 3 to dimension D (D4, D7 and D8); and 5 to dimension E (E2, E3, E4, E5 and E7). The less restrictive criterion indicated that 43% of the attributes of the model did not show enough face validity. When the answers of the students were analyzed according to the more restrictive criterion, only 6 attributes could be accepted as being face valid: A2, B3, B4, B8, B9 and E5. In other words, according to more than half of the students, 84% of the attributes of the model do not appear to reflect what they are intended to measure.

6.2.1.6. Conclusions

Taking the validity of the model at face value, it seems that most of the model’s attributes and dimensions may be problematic. Moreover, most of its components (attributes and dimensions) do not appear to be valid to the untrained eye.

6.2.2. Second study – testing content validity

6.2.2.1. Purpose of the study

The demonstration of content validity is a fundamental requirement of all assessment instruments because, among other reasons, by maximizing content validity the predictive validity of the instrument will be enhanced (Sireci, 1998). As Haynes, Richard and Kubany (1995) point out, most definitions of content validity refer to the degree to which elements of an assessment instrument are relevant to and representative of the targeted construct for a particular assessment purpose. While the relevance aspect refers to the appropriateness of its items, that is, the degree to which the instrument contains items reflecting the facets or dimensions of the targeted construct, the representativeness refers to the coverage of the intended construct, that is, the extent to which the content of the items is sampled representatively from the universe of content being measured. These two characteristics of content validity have been highlighted by Fitzpatrick (1983) as domain relevance and domain sampling, and by Anastasi (1986) as content relevance and content coverage.

The purpose of this second study is to shed light on the content validity of the IAEA safety culture model. We tested the relevance of the 37 attributes of the model to the five dimensions of safety culture identified by the IAEA.

Hypothesis 2. The attributes of the model will be relevant to the dimensions to which they are supposed to belong, showing evidence of content validity.

6.2.2.2. Development of the survey

For this second study, researchers used the same survey as in the first study in this paper. The development of the survey was explained in detail in section 2.1.2.

6.2.2.3. Sampling procedure

The evaluation of content validity is dependent on knowledge about the underlying constructs being measured (Holden and Jackson, 1979). A model, test or measurement instrument has content validity when a group of subject matter experts (SMEs) rate its items high with regard to their relevance to and representativeness of the content domain tested (Sireci, 1998). Therefore, content validity has to be assessed by experts in the constructs under study.

Following this requirement, the second study of this paper counted with 48 experts in organizational behavior, who were highly knowledgeable about organizational culture, leadership, organizational learning, management, values, roles, etc., and all the main constructs that the IAEA model and its attributes revolve around. The participants were industrial and organizational psychologists not specialized in safety culture or the nuclear industry. Of them, 24 were PhD holders working in the department of social psychology, 7 were undertaking doctoral research within the European Work, Organizational and Personnel Psychology Program – WOP-P – and 17 were completing the Erasmus Mundus Master in WOP-P. Furthermore, most of the participants teach these topics in degree, master and doctoral courses, and have published articles on these topics in scientific journals. Participants were between 23 and 58 years old, with an average of 35 years. 63% percent of the experts were female and 98% had worked before.

6.2.2.4. Survey administration

In this study participants were contacted via e-mail. They were provided with the same instructions and survey received by the students in the first study. The experts were strongly encouraged to ask for any necessary clarification before or while completing the survey. As in the first study, voluntary participation and anonymity were emphasized.

The response rate obtained was 74%. In this second study, all 48 returned surveys were found to be usable after determining the percentage of missing data and the absence of systematic response patterns.

Feedback received from some experts highlighted the complexity of the survey due to the ambiguous and apparently overlapping dimensions.

6.2.2.5. Analyses and results

To offer a general approach to the content validity of the model, the experts' answers were analyzed at a global level. The average of *correct answers* per participant was 17,ranging from 9 to 27; that is, according to the experts, more than half of the attributes of the model (53.49%) were not relevant to the dimensions to which they should belong.

When analyzing the experts' answers at a dimensional level, noticeable differences in the content validity of the dimensions were found. The percentage of *correct answers* given by the experts was 47.6% in dimension A, 60.8% in B, 35.8% in C, 37.7% in D, and 44% in E. This means that according to the judgment of experts, more than half of the attributes of dimensions A, C, D and E were not appropriate or relevant to the dimensions they were supposed to measure. Dimensions C and D seemed to be especially problematic, while, according to participants' answers, dimension B offered the highest content validity.

This last analysis further examined the content validity of the IAEA model by testing the relevance of each attribute to each of the five dimensions of the model. The degree to which an attribute was relevant to the dimension to which it belongs according to the IAEA was determined by the percentage of participants who assigned this attribute to that dimension. Table 11 shows that results ranged from 2.1% of participants allocating attribute E1 to its corresponding dimension ("safety is learning driven") to 95.8% of participants allocating attribute B3 to its corresponding dimension ("leadership for safety is clear").

Researchers proposed two criteria to determine whether an attribute was relevant enough to the dimension to which it was supposed to belong. The first and less restrictive criterion considered an attribute to be relevant when the percentage of experts allocating it to its corresponding dimension was higher than the percentages of experts allocating it to each of the four remaining dimensions. The second and more restrictive criterion accepted every attribute that was allocated to its corresponding dimension by at least half of the experts. Results under less restrictive conditions indicated that 28 attributes were relevant enough to their corresponding dimensions: 5 attributes that were supposed to measure dimension A (A1, A2, A3, A4 and A6); 9, dimension B (B1, B2, B3, B4, B5, B6, B8, B9 and B10); 3, dimension C (C1, C2 and C3); 7, dimension D (D2, D3, D4, D6, D7, D8 and D9); and 4, dimension E (E2, E4, E5 and E7). This means that under the less restrictive criterion, one-fourth of the attributes of the model were not relevant indicators of the dimensions they were supposed to measure. When the participants' answers were analyzed using the more restrictive criterion, 17 attributes were considered relevant enough to their corresponding dimensions: A2, A3, A4, B1, B3, B4, B5, B6, B8, B9, B10, C1, C2, D4, D7, E5 and E7. In other words, according to the judgment of more than half of the experts, 46% of the attributes of the model are not good indicators of the dimensions they are supposed to measure.

Table 10

Testing the face validity of the model of safety culture of the IAEA - Percentage of students allocating each of the attributes in each of the dimensions of the model.

	Dimension						
Att.	A	B	C	D	E	NRC	RC
A1	**42,6**	12,1	18,3	17	10	X	
A2	**50,9**	7,3	14,9	23,5	3,5	X	X
A3	**34,5**	13,4	19,3	23,1	9,7	X	
A4	**37,6**	3,8	13,8	30,3	14,5	X	
A5	**22,2**	22,9	29,5	12,5	12,8		
A6	**31,1**	6,2	19,7	11,4	31,5		
B1	27,2	**41,4**	19	8,3	4,1	X	
B2	21,4	**24,8**	24,8	24,1	4,8		
B3	5,2	**78,9**	8	4,8	3,1	X	X
B4	7,6	**63,7**	5,5	8,3	14,9	X	X
B5	10,3	**44,8**	26,6	7,2	11	X	
B6	12,8	**27,6**	13,4	11,4	34,8		
B7	26,6	**8**	21,1	26,3	18		
B8	9,3	**53,6**	14,2	10	12,8	X	X
B9	5,2	**71,7**	15,2	4,5	3,4	X	X

Table 11

Testing the content validity of the model of safety culture of the IAEA - Percentage of experts in organizational behavior allocating each of the attributes in each of the dimensions of the model.

	Dimension						
Att.	A	B	C	D	E	NRC	RC
A1	**45,8**	6,3	16,7	25	6,3	X	
A2	**64,6**	6,3	8,3	18,8	2,1	X	X
A3	**62,5**	6,3	6,3	22,9	2,1	X	X
A4	**54,2**	2,1	10,4	27,1	6,3	X	X
A5	**25**	27,1	25	16,7	6,3		
A6	**33,3**	4,2	18,8	25	18,8	X	
B1	18,8	**70,8**	10,4	0	0	X	X
B2	18,8	**37,5**	27,1	16,7	0	X	
B3	0	**95,8**	0	0	4,2	X	X
B4	0	**60,4**	0	2,1	37,5	X	X
B5	12,5	**54,2**	16,7	4,2	12,5	X	X
B6	10,4	**62,5**	8,3	6,3	12,5	X	X
B7	18,8	**10,4**	12,5	43,8	14,6		
B8	12,5	**72,9**	6,3	4,2	4,2	X	X
B9	2,1	**93,8**	2,1	2,1	0	X	X

B10	16,6	**33,1**	18,3	14,8	17,2	X	
C1	23,5	28,7	**37,4**	7,3	3,1	X	
C2	18,7	11,4	**34,6**	21,1	14,2	X	
C3	34,5	6,2	**33,8**	19	6,6		
C4	4,2	60,9	**23,2**	6,6	5,2		
C5	29,7	5,2	**14,1**	42,1	9		
D1	33	9,7	24	**18,4**	14,9		
D2	40,7	6,6	15,9	**31**	5,9		
D3	25,4	7,7	28,6	**23**	15,3		
D4	23,4	9	20	**36,9**	10,7	X	
D5	11	4,5	13,8	**9,7**	61		
D6	21,4	13,1	24,5	**23,1**	17,9		
D7	21,7	5,9	26,9	**32,4**	13,1	X	
D8	10	21	21,7	**32,4**	14,8	X	
D9	27,9	4,8	31,4	**25,5**	10,3		
E1	12,9	34,8	21,3	15,7	**15,3**		
E2	15,2	10	20,8	16,6	**37,4**	X	
E3	17,3	6,6	26,6	13,8	**35,6**	X	
E4	20,8	8,7	18,8	20,8	**30,9**	X	
E5	4,5	4,8	7,6	6,9	**76,1**	X	X
E6	24,7	5,6	28,5	14,9	**26,4**		
E7	5,5	8,7	23,9	12,5	**49,5**	X	

Note: marks in columns RC and NRC indicate attributes showing face validity under the restrictive and non-restrictive conditions respectively.
Percentages of respondents allocating attributes to its corresponding dimension are shown in bold.
Att. denotes attributes.

B10	22,9	**50**	12,5	10,4	4,2	X	X
C1	20,8	6,3	**56,3**	12,5	4,2	X	X
C2	10,4	14,6	**50**	16,7	8,3	X	X
C3	20,8	0	**45,8**	31,3	2,1	X	
C4	2,1	77,1	**12,5**	8,3	0		
C5	35,4	0	**18,8**	43,8	2,1		
D1	37,8	6,7	13,3	**35,6**	6,7		
D2	37,5	2,1	10,4	**45,8**	4,2	X	
D3	17	2,1	27,7	**38,3**	14,9	X	
D4	14,6	8,3	18,8	**54,2**	4,2	X	X
D5	4,2	0	8,3	**10,4**	77,1		
D6	20,8	16,7	22,9	**33,3**	6,3	X	
D7	14,6	8,3	16,7	**56,3**	4,2	X	X
D8	20,8	14,6	18,8	**31,3**	14,6	X	
D9	29,2	0	31,3	**37,5**	2,1	X	
E1	22,9	12,5	29,2	33,3	**2,1**		
E2	20,8	12,5	25	12,5	**29,2**	X	
E3	10,4	0	33,3	27,1	**29,2**		
E4	14,6	0	14,6	25	**45,8**	X	
E5	4,2	0	0	4,2	**91,7**	X	X
E6	12,5	2,1	41,7	22,9	**20,8**		
E7	2,1	4,2	0	4,2	**89,6**	X	X

Note: marks in columns RC and NRC indicate attributes showing content validity under restrictive and non-restrictive conditions respectively.
Percentages of respondents allocating attributes to its corresponding dimension are shown in bold.
Att. denotes attributes.

Because both face and content validity are essential requirements of assessment instruments, it was agreed that those attributes satisfying face and content validity analyses could be more adequate for the current IAEA proposal. Under the less restrictive criterion, 20 attributes out of 37 should be kept: A1, A2, A3, A4, B1, B3, B4, B5, B8, B9, B10, C1, C2, D4, D7, D8, E2, E4, E5 and E7; while under more restrictive conditions, only 6 should be maintained: A2, B3, B4, B8, B9 and E5. It is worth noting that these attributes are the same ones accepted in the face validity study (with the exception of attribute E3, which under more restrictive conditions showed face validity but did not show content validity). Our studies suggest, therefore, that attributes with face validity have content validity as well, which is logical, since an attribute that appears to measure a dimension (face validity) would be expected to be relevant to that dimension (content validity).

6.2.2.6. Conclusions

Regardless of the way the answers have been analyzed – at a global, dimensional, or attribute level – experts' judgments dubiously support the IAEA proposal. At the most specific levels, many of the attributes and dimensions do not seem content valid to the experts. However, it is important to remember that the focus of this study is on the relevance aspect of content validity and not on the representativeness one. On the whole, the judgment of a sample of experts in organizational behavior suggests that the content validity of the IAEA model is rather moderate.

As a conclusion of the first two studies, taking into account the opinion of both students and experts, it seems that the IAEA safety culture model could be substantially improved.

6.2.3. Third study – testing the factorial structure

6.2.3.1. Purpose of the study

Investigating the internal structure of theoretical constructs is essential to social science research because the misspecification of dimensions can lead to incorrect and, consequently, misleading empirical results. The extent to which the relationships between the components of an assessment instrument are consistent with the definition of the construct constitutes relevant evidence of the validity of the instrument, which in turn contributes to the validation of the underlying construct (AERA, APA and NCME, 1999).

The purpose of this study is to test whether the five-dimensional safety culture model specified by the IAEA adequately represents the attributes that reflect, according to the IAEA, the attitudes and behaviors that are indicators of strong safety cultures. In order to attain this goal, the IAEA safety culture model was converted into a questionnaire containing 37 items corresponding to the 37 attributes of the model.

Specifically, apart from evaluating the fit of the five-factor model to the data, convergent and discriminant validity were assessed. Convergent validity was evaluated by examining the extent to which items correlate strongly with the dimensions they represent and show high and statistically significant factor loadings in the corresponding factors (Byon and Zhang, 2010). Discriminant validity was assessed by testing the hypothesis that the correlations among the IAEA factors differ significantly from unity (i.e., are not correlated perfectly) and are empirically discriminable (Floyd and Widaman, 1995).

Hypothesis 3. The five-factor structure of the model, operationalized through the proposed attributes, will be confirmed by the data, showing evidence of factorial validity.

6.2.3.2. Sampling procedure

We received a completed questionnaire from 495 workers from one Spanish nuclear power plant (NPP). The total size of the company was 760 employees. Thus, we obtained a response rate of 65.13%. The data were collected in 2011. In order to guarantee the quality of the data, those questionnaires with more than three unanswered items were dropped from the data set, resulting in a final sample of 468 participants. The sample included all responsibility levels and functional areas in the nuclear facility. 47% of participants had completed university studies. 3% of participants were under 30 years old; 18% were between 30 and 45; and 79% were older than 45.

6.2.3.3. Survey administration

The questionnaire was administered by the researchers, who stayed at the NPP for three days to collect data. This condition assured that any doubts when filling out the questionnaire could be immediately resolved. This questionnaire was part of a battery of questionnaires, aimed to address different topics related to safety culture and safety climate, that each participant was asked to complete. The administration of the battery took place during work time, and participants needed around 30 minutes to complete the entire battery. They were provided with instructions explaining the purpose of the study and the way the questionnaire should be completed. Participants' task was to rate on a five-point Likert-type scale to what extent they agreed with 37 statements related to their organization. These statements were the 37 attributes of the IAEA model. Since the target sample was native Spanish speakers, researchers created the questionnaire using the back-translated version of the model mentioned in the first two studies of this paper.

Participants were encouraged to answer sincerely and take as much time as they needed to accurately complete the questionnaire. Voluntary participation, confidentiality and anonymity were emphasized.

Cronbach's alpha values for the five dimensions of the model were as follows: .87 for the dimension "safety is a clearly recognized value", .92 for "leadership for safety is clear", .83 for "accountability for safety is clear", .89 for "safety is integrated into all activities", and .84 for "safety is learning driven". Cronbach's alpha for all the items included in the five dimensions was .97.

6.2.3.4. Analyses

Confirmatory analyses

Confirmatory factor analyses (CFA) were performed using the Linear Structural Relationship (LISREL) program, version 8.8. (Jöreskog and Sörbom, 2006).To estimate the parameters of the five-factor model, polychoric correlations were analyzed by means of the robust maximum likelihood (RML) estimation method. The reasons for choosing this method were twofold: First, considering the size of our sample (N=468), this method is preferable to other specific methods for ordinal variables, such as weighted least squares (WLS), because it does not require inverting the asymptotic covariance matrix; Second, RML is a commonly accepted estimation technique for the ordinal nature of the variables under study (Hoyle and Panter, 1995), and it is more suitable than maximum likelihood when the assumption of multivariate normality does not hold (Brown, 2006; Mels, 2003), as is the case in our sample. When RML is used, standard errors and goodness-of-fit indices are corrected for non-normality.

Exploratory analyses

The structure of the IAEA was also explored by means of principal component analysis (PCA), with oblimin rotation, without establishing the number of factors a priori. The reason for carrying out a PCA instead of an exploratory factor analysis (EFA) was that PCA provides a mathematical representation of the construct in terms of the measured variables without imposing the directionality of the effects from the construct to the items (Jarvis, MacKenzie and Podsakoff, 2003). This allows us to control for the possibility that safety culture is a formative multidimensional construct instead of a reflective multidimensional construct. Typically, constructs are viewed as reflective, since responses to the indicators are thought to be caused by the latent variable that is measured (i.e., because there is a strong safety culture, open reporting of deviations and errors is encouraged). In this case, EFA or principal axis is the best option (Jarvis et al., 2003). The indicators are expected to be highly correlated, but dropping one indicator from the measurement model is not expected to alter the empirical meaning of the construct (Podsakoff et al., 2003). However, in some occasions indicators are viewed as causing rather than being caused by the latent variable. In these cases, the constructs are formative instead of reflective, in such a way that changes in the indicators determine changes in the value of the latent variable (i.e. because open reporting of deviations and errors is encouraged in the organization, a strong safety culture emerges) (see Jarvis et al., 2003; Podsakoff et al., 2003). In this case, the principal component model is more adequate.

6.2.3.5. Results

Confirmatory analyses

Fit indices provide information about how well the proposed model empirically fits the driving theory. The chi-square ($\chi 2$) value is the traditional measure for evaluating overall model fit (Hooper, Coughlan and Mullen, 2008). However, because chi-square value is sensitive to sample size, the use of other indices is recommended. Values of NNFI and CFI greater than .95 are presently recognized as indicative of good fit (Hu and Bentler, 1999). Values of RMSEA and SMR under .08 indicate an acceptable fit (Byon and Zhang, 2010; Hu and Bentler, 1999), with lower values indicating better fit.

The five-factor CFA revealed that the goodness-of-fit of the model proposed by the IAEA (5 dimensions with 37 corresponding attributes) did show satisfactory fit (Satorra-Bentler scaled $\chi 2$ = 1901.23, df = 619, $p < .01$; NNFI = .985; CFI = .986; RMSEA = .071; and SRMR = .055).

Regarding convergent validity of the attributes reflected in the items, results indicated that the items converged well enough, since the standardized factor loadings for the five-factor structure proposed by the IAEA were statistically significant (p<.01) and high enough according to the standards. As a rule of thumb, an item loads high if the corresponding factor loading is above .60, and it does not load high enough if the corresponding factor loading is below .40 (Hair et al., 1998). Our results showed that for the five-factor model all the factor loadings, with the exception of items E1 and E7, were larger than .60 (see Table 12), ranging from.45 and .55 (for items E1 and E7, respectively) to .92 (for item A1), thus supporting convergent validity.

Table 12

Factor loadings and squared multiple correlations for CFA for the IAEA safety culture model (5 dimensions with 37 corresponding attributes)

Item variable	Standardized factor loading	SMC (R2)	Item variable	Standardized factor loading	SMC (R2)
A1	.92 (.01)	.85	C4	.76 (.03)	.58
A2	.87 (.02)	.76	C5	.82 (.03)	.67
A3	.74 (.04)	.55	D1	.77 (.03)	.59
A4	.73 (.04)	.53	D2	.84 (.02)	.70
A5	.75 (.04)	.56	D3	.67 (.03)	.45
A6	.85 (.03)	.73	D4	.81 (.03)	.66
B1	.87 (.02)	.76	D5	.70 (.04)	.49
B2	.85 (.02)	.73	D6	.76 (.03)	.58
B3	.85 (.02)	.72	D7	.66 (.04)	.44
B4	.72 (.03)	.52	D8	.70 (.03)	.49
B5	.70 (.03)	.49	D9	.72 (.03)	.52
B6	.84 (.02)	.71	E1	.55 (.05)	.30
B7	.78 (.03)	.61	E2	.83 (.03)	.69
B8	.81 (.02)	.66	E3	.64 (.03)	.41
B9	.80 (.03)	.65	E4	.85 (.02)	.72
B10	.74 (.03)	.55	E5	.83 (.02)	.69
C1	.76 (.03)	.58	E6	.81 (.02)	.66
C2	.73 (.03)	.53	E7	.45 (.05)	.20
C3	.78 (.03)	.60			

However, results on the discriminant validity of the five dimensions proposed by the IAEA were not satisfactory. The correlation coefficients among the five dimensions of the IAEA model were extremely high, ranging between .90 and 1 (see Table 13). Half of them (correlations between dimensions C and A, dimensions C and B, dimensions D and C, dimensions E and C and dimensions E and D) were not empirically discriminable as the correlations did not significantly differ from 1 ($p>.05$). The remaining correlations, although significantly lower than one, were too large from a practical point of view, following the criterion of Kline (2005), who stated that discriminant validity can be established when inter-factor correlations are below .85.

The large correlations among the 5 dimensions of the IAEA model suggested that a one-factor model could be more suitable to represent the IAEA's attributes. To evaluate this possibility, we fit a one-factor model and compared the results to the five-factor model. In fact, this is an advantage of applying CFA as it allows testing different conceptualizations of the data, or competing models, and helps researchers to retain the best fitting model (Noar, 2003). The results showed that the one-factor model provided a satisfactory fit to data (Satorra-Bentler scaled $\chi2$ = 2052.76, df = 629, $p< .01$; NNFI = .984; CFI = .985; RMSEA = .074; and SRMR = .055).

The one-factor model was compared to the five-factor model proposed by the IAEA, both in terms of statistical and practical significance. Focusing on statistical significance, and considering that Satorra (2000) showed that the difference between two nested models in Satorra-Bentler scaled chi-square for overall model fit (which is applicable when using RML methods of estimation) does not yield the correct Satorra-Bentler scaled difference, we applied the correction proposed by Satorra and Bentler (2001). Focusing on practical significance (i.e., substantive differences between models), it is widely accepted that differences in NNFI and CFI lower than .01 indicate irrelevant differences between models (Cheung and Rensvold, 2002; Widaman, 1985). In addition, Chen (2007) also suggests that significant differences not larger than .015 in RMSEA would suggest negligible practical differences.

Table 13

Descriptive statistics and intercorrelations among the five dimensions of the IAEA model

	M	SD	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Dim.1 - safety is a clearly recognized value	4.06	.83	-				
Dim.2 - leadership for safety is clear	3.80	.92	.90	-			
Dim.3 - accountability for safety is clear	4.04	.84	.98	.99	-		
Dim.4 - safety is integrated into all activities	3.84	.86	.94	.96	1	-	
Dim.5 - safety is learning driven	3.78	.88	.95	.95	1	.98	-

Note. all correlations are significant at $p< .05$

The results of the comparison showed significant differences between the two models (corrected Satorra-Bentler scaled $\chi 2$ difference=147.19; df=10; p<.01). However, the differences in NNFI, CFI and RMSEA between the five and one-factor models (.001, .001 and -.004) suggest that, although statistically significant, the differences are irrelevant from a practical point of view (see Table 14). These results indicate that, pursuing the parsimony principle, the one-factor model will represent the empirical data better than the five-factor model, bringing into question the adequacy of the attributes to assess the safety culture model as proposed by the IAEA.

Table 14
Goodness of fit indices for the IAEA safety culture model

Model	χ^2	χ^2/gl	NNFI	CFI	RMSEA	SRMR
Original	1901.23	3.07	.985	.986	.070	.055
Unidimensional	2052.76	3.26	.984	.985	.074	.055

Note. NNFI = non-normed fit index; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standarized root mean square residual. 'Original' refers to the factor structure proposed by the IAEA (37 attributes and 5 dimensions); 'Unidimensional' refers to a one-factor structure based on the model of the IAEA (37 attributes and 1 dimension).

Despite these results, we decided to explore the internal structure of the IAEA model without the restrictions imposed by a confirmatory analysis approach for two reasons. On the one hand, the first two studies in this paper suggested that a number of attributes of the model were related to the dimensions which, according to the IAEA, they belong to. This indicated that, although far from the IAEA proposal, some of the attributes of the model may be grouped under the same dimensions. On the other hand, as reported in the previous CFA, some of the inter-factor correlations seem to be empirically discriminable.

Exploratory analyses

The PCA of the 37-item safety culture model produced five factors with Eigenvalues greater than 1 (Kaiser Criterion), which accounted for 64% of the total variance. The way the attributes were grouped by the PCA was very different from the IAEA proposal (see Table 15). Several points that did not support the adequacy of this structure to represent the safety culture construct. First, 50% of the total variance explained was accounted for by the first factor, and the scree plot clearly suggested retaining only one factor (see Figure 6). Second, when trying to label the five factors that met the Kaiser rule, researchers found difficulties in conceptually interpreting each of these factors. For example, attributes A1, A6, C1, C2, D3, D5, E2 and E4, which seem to be grouped under the same factor, refer to quite distinct aspects of safety culture that cannot easily be included under the same label (items C1 and C2 refer to accountabilities and responsibilities; A6 and E2 refer to safety behaviors; D3 and D5 refer to conditions to act safely; and A1 could be understood as a mixture of conditions for safety and safety behaviors). Third, some of the items showed low loadings on all of the factors (i.e. <.40) (e.g. B3, B6, D1, D2, D4, D8, D9, E4 and E5), and several items cross-loaded on more than one factor (i.e. cross-loadings ≥.30) (e.g. A1, A2, A3, A6, B6, B7, B9, C1, C2, C3, C4, D1, D2, D4, D7, D8, E4, E5 and E6). All factor loadings can also be checked in Table 15. Fourth, some factors did not contain the recommended minimum of three items per factor (Brown, 2006; Tabachnick and Fidell, 2001). When the minimum value to consider that an item loads on any given factor was .30 to .35 (as recommended by Spector, 1992), the third factor contained just three items (D8, E1 and E7), and the fourth factor only two (E3 and E4). But when the cut-off point was .40 (as recommended by Hair et al., 1998), the third factor contained two items (E1 and E7), and the fourth factor only one (E3).

Table 15
PCA results for the 37 attributes of the IAEA model

	Factor				
Attribute	I	II	III	IV	V
B1	**.79**	.06	.09	-.01	.01
C5	**.71**	.08	.07	.09	.14
C3	**.66**	-.11	.09	.10	**.31**
B2	**.62**	.16	.06	.00	.13
A5	**.56**	.18	.20	-.05	-.05
A3	**.52**	-.02	.13	**-.37**	-.03
E6	**.51**	.14	-.02	**-.32**	.08
B7	**.49**	**.35**	-.04	-.21	-.05
A4	**.45**	.11	.09	-.15	.10
A2	**.45**	.06	.11	-.01	**.34**
D2	**.38**	-.04	.06	**-.38**	**.32**
D1	**.38**	**.30**	.16	.24	.26
D4	**.37**	**.34**	-.14	-.15	.24
D9	**.32**	.23	.02	.01	.28
B8	.13	**.75**	.03	-.01	.03
B5	.12	**.73**	-.16	-.06	.04
B4	.04	**.65**	.25	-.23	-.19
B9	**.35**	**.64**	.05	.04	-.09
D6	-.18	**.62**	.22	-.16	.24
B10	.16	**.48**	.21	.26	.25
D7	.03	**.44**	.04	.11	**.36**
C4	-.14	**.43**	.25	-.18	**.36**
B6	**.38**	**.39**	.09	-.22	-.01
B3	.16	**.35**	.17	-.27	.20
E5	.07	**.32**	.18	**-.30**	.27
E7	-.09	-.02	**.87**	-.09	-.09
E1	.13	-.12	**.87**	.05	.01
D8	**.31**	**.31**	**.36**	.19	.07
E3	-.05	.10	.19	**-.62**	.17
E4	.28	.14	.01	**-.35**	**.34**
D3	.07	-.03	-.05	-.09	**.70**
D5	.08	-.03	.05	-.07	**.66**
C2	-.12	**.39**	.13	.06	**.57**
A1	**.40**	-.04	.05	-.14	**.50**
C1	.21	.03	-.01	**-.32**	**.45**
A6	**.30**	-.02	.21	-.12	**.45**
E2	.25	.22	.04	-.04	**.45**
% Variance explained	50.44	4.56	3.38	3.13	2.74

Note. factor loadings ≥ .30 are indicated in bold, and variables have been sorted by loadings on each factor.

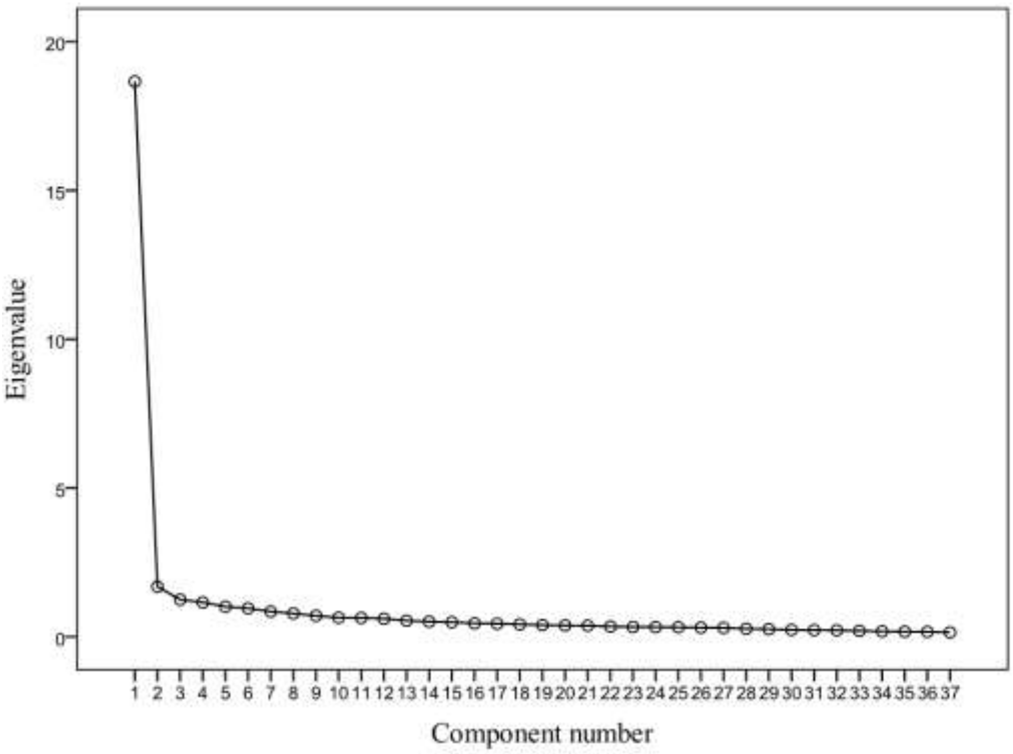

Figure 6. Scree plot of Eigenvalues from the IAEA safety culture model

Although the reasons for choosing PCA have been explained (see section 2.3.4.2.), the authors decided to perform an exploratory factor analysis (EFA) to see if a “better” factorial solution could emerge. The EFA also resulted in the retention of five factors, which showed the same problems as the PCA in terms of explained variance, interpretability and factor loadings.

Finally, because the use of the Kaiser criterion alone may overestimate the number of factors to retain (Costello and Osborne 2005; Kline, 1994; Lance et al., 2006; Zwick and Velicer, 1986), PCAs were carried out forcing the number of factors to two, three, and four. Of these options, only the two-factor solution seemed to be interpretable, but the authors could not support this solution because one of the factors accounted for 50% out of the 55% total variance explained.

6.2.3.6. Conclusions

Factor analyses (CFA, PCA and EFA) of the answers given by a sample of workers from a NPP to a questionnaire based on the IAEA model failed to support the dimensionality of this model. Results from these analyses could not support any alternative multidimensional structure either. Moreover, it seems that the IAEA's attributes may be better understood as being part of one unique dimension, namely safety culture.

6.3. Discussion

This is the first time that the validity of the IAEA model and the psychometric properties of the attributes that underpin the model have been investigated. Results from three independent but complementary studies could not support the correspondence between the IAEA's attributes and the dimensions proposed by the model; consequently, substantial evidence to support the validity of this model was not found. Our findings suggest that most of the attributes of the IAEA model may not be related to the dimensions to which they are supposed to belong; that is, most of the attributes included in the IAEA model may not be measuring the dimensions they are intended to measure. Furthermore, according to our results, the IAEA safety culture model, as it stands, could have a one-dimensional structure instead of the five dimensions the IAEA proposes. We believe that the conclusions from the three empirical studies included in this paper provide a useful addition to the discourse on safety culture, as they open the door for the improvement of a widely-used model that has the potential to change nuclear safety outcomes.

We consider two possible explanations for our results. First, the five dimensions of the IAEA model may not appropriately reflect the essence of safety culture. In this scenario, the attributes of the model could be good indicators of the construct of safety culture, even though they were not related to the dimensions the IAEA proposes. This could either mean that, as our results suggest, the attributes of the model are part of a one-dimensional construct (supposedly safety culture), or that other dimensions, distinct from those proposed by the IAEA, may need to be included in the model. Nevertheless, this last option seems less likely, as our results could not support any factorial solution apart from a one-dimensional structure. Second, the five dimensions of the IAEA model may appropriately reflect the essence of safety culture, but some of the attributes may not be adequate to assess these dimensions. In this case, the dimensions of the model should be kept, and the inclusion of better indicators (attributes) of these dimensions should be considered. All in all, it seems reasonable to think that our studies were not able to empirically reproduce the IAEA model due to a combination of these two explanations (non-adequacy of some dimensions and non-adequacy of some attributes). For example, it seems at first glance that some attributes of the model may overlap (e.g. “relationships between managers and individuals are built on trust” and “trust permeates the organization”). We also noted in section 1.2. that two dimensions of the model (“safety is a clearly recognized value”, and “safety is integrated into all activities”) may be too general and wide in scope. As these two broad dimensions could cover many of the attributes of the model, they may have contributed to the overlap among the five dimensions (i.e., inter-factor correlations between .90 and 1) and the one-dimensional structure supported by our results. Discovering the reasons behind the weak correspondence between attributes and IAEA's dimensions is essential to understanding how the proposed model could be evaluated and improved. To help with this purpose, the IAEA is encouraged to share additional information regarding the origin and development of the model. Were the attributes developed first? If so, how were they grouped and under which criteria were the dimensions labeled? Or on the contrary, were the dimensions developed first? If so, how were they identified and further operationalized through the attributes?

This paper is especially relevant to the IAEA, organizations using the IAEA model for self-assessment purposes, regulators currently using this model to determine policies and guidelines affecting the functioning of nuclear facilities (NPP, research reactors, fuel cycle facilities, etc), and those scholars and practitioners interested in this model of safety culture. Two practical implications of our results are discussed next. First, the IAEA provides detailed instructions about how to use the attributes when assessing safety culture (IAEA, 2008a), but it does not clarify the role of the dimensions in safety culture assessments. The IAEA also proposes that each attribute corresponds to one specific dimension of its model, but it does not specify either how the relation between attributes and their corresponding dimensions should be addressed in practice. This lack of specificity and guidance may lead to different interpretations about how to use the model in theory and in practice, how it should be empirically tested, etc. Authors such as Taylor (2010) note that the strength of a particular dimension of the IAEA model should be judged by assessing the degree of presence of the dimension's attributes. However, our findings suggest that the current attributes of the model should not be grouped into higher-level dimensions. For example, if attributes C1, C2, C3, C4 and C5 receive high scores on a safety culture assessment, one cannot conclude that “accountability for safety is clear” (label of dimension C) in the organization. But beyond the lack of guidance, another point must be noted. In practice, practitioners often only consider the interpretations suggested by higher-level dimensions, instead of the information derived from the scores of individual items, for several reasons (saving time, more intuitive approach, etc). Consequently, not only clear guidance on the use of the models must be provided, but the attributes must also be true indicators of the dimensions to which they supposedly belong and be grouped together in practice as well as in theory. Second, our studies suggest that the face validity of the IAEA safety culture model, as it stands, is low. The extent to which a safety culture model is face valid has practical implications for the nuclear industry. A model with low face validity will not make clear what it is intended to cover and what its purpose is. If the workers of a NPP find the IAEA model hard to understand and not very intuitive, they will have difficulty internalizing it. And if workers do not assimilate the model, they cannot be expected to contribute to the type of culture described by the model. The contribution and involvement of all workers in safety-related issues is in itself a characteristic of a strong safety culture (Filho et al., 2010; IAEA, 1999; Reason, 1997).

A number of possible limitations of our study are highlighted. First, although sections 2.1.3. and 2.2.3. explained why we chose a sample of students to test the face validity of the IAEA model and a sample of experts in organizational behavior to test its content validity, we acknowledge that using samples of a different nature could have provided relevant and perhaps distinct results from those we have obtained. On the one hand, although face validity is often assessed by participants who are not knowledgeable about the constructs under study (e.g., students), it is worth noting that the purpose of testing face validity is to ensure that the measure is self evident to the people who use the assessment instrument, in the case of the IAEA model, employees in the nuclear industry. Nevertheless, we decided not to include a sample of this type because nuclear power workers are typically exposed to the model, which they see in courses, seminars/congresses, posters around the nuclear plant, etc. On the other hand, it would have been interesting to test the content validity of the IAEA model with a sample of experts in safety culture in the nuclear industry. However, we did not include such a sample because their answers could have been biased by their previous knowledge about the IAEA model or other models and instruments used in the nuclear industry that have been influenced by the IAEA model. Second, the fact that a few students reported confusion about the meaning of attributes and dimensions could have contributed to the variability in their allocation of attributes into dimensions. If the students had problems understanding the content of the model, it could be expected that some of their answers would be arbitrary, which in turn could have contributed to the observed low face validity of the model. However, the sample of experts in the content validity study also showed a low performance in the allocation of attributes into dimensions. In this case, the difficulties in the sorting task could not be due to a lack of understanding of the contents of the model. Therefore, it seems reasonable to reject the lack of knowledge of some students as an alternative explanation for the results of the face validity study. Third, NPPs are highly-regulated work environments in which audits, control processes and safety measurements are part of workers' routines. The questionnaire we used for the third study of this paper not only served to test the factorial validity of the IAEA model, but it was also used, together with other questionnaires, to inform the members of the NPP about the state of their safety culture. This could have been a reason for participants to complete the questionnaire in a socially desirable manner. Such a tendency toward high ratings could have contributed to the one-dimensional structure of the model supported by our results. This could have been especially applicable in a 'blame culture', where members do not feel free to report mistakes and try to give the best picture of their work and the functioning of organizational policies, processes and practices. However, we tried to avoid social desirability bias by guaranteeing the anonymity and confidentiality of participants' answers. On the other hand, a strong awareness in the nuclear industry that their plants must be managed under 'no blame' principles should be enough to encourage workers to express their opinions openly and honestly. Fourth, the attributes of the model were not designed to be used as items on a questionnaire. A number of these attributes are double and triple barreled, and as such, respondents can agree with one part of the item but perhaps not with the other. We acknowledge that including these attributes in the questionnaire of the third study is a limitation of this paper; however, if we had rephrased them, the conclusions of this study would have been seriously biased. We kept all the attributes unaltered because the purpose of our study was not to create a safety culture questionnaire, but rather to test whether our participants' answers to the attributes could replicate the five-dimensional structure proposed by the IAEA. Despite this, three reasons support that the results of the third study have not been compromised by the "barreled" items: we could not find significant differences between the number of missing values of "barreled" and "non-barreled" items; none of the attributes increased the Alpha value of its corresponding dimension when it was removed; and none of the participants verbally expressed difficulties in understanding or responding to any of the "barreled" items. Nevertheless, we advise the nuclear industry to carefully review and adapt the attributes (e.g., some attributes could be divided and rephrased as separate items) if they are to be included as part of a questionnaire. Fifth, the fact that all the items across the five dimensions were rated by the same raters could explain, at least partially, the high correlations and lack of empirical discriminability among the five dimensions of the IAEA model as assessed by the corresponding attributes. To control for this possibility, we performed Harman's single factor test, which requires taking measures of clearly different traits and loading all the measures into an exploratory factor analysis under the assumption that the presence of common method variance will result in either a single factor or a general factor accounting for the majority of the covariance among measures (Podsakoff et al., 2003). In our case, even if the EFA of the IAEA's attributes resulted in five factors, we factor analyzed the responses of two additional scales (role ambiguity and trust). The analyses of the three scales, which had all been collected at the same time, resulted in a six-factor model that explained 58% of the variance. Interestingly, all the role ambiguity items (specifically four items with an alpha coefficient of .81) loaded on the same factor, and all the trust items (specifically four items with an alpha coefficient of .77) loaded on the same factor. None of the safety culture items had factor loadings larger than .40 on the factors that comprised the items on the role ambiguity and trust scales. These results reduce the likelihood that the high correlations observed among the five dimensions of the IAEA model could be mainly attributed to a response bias or common method effects. Finally, the sixth issue to be considered is related to the use of questionnaires for safety culture assessments. The third study explored the dimensional structure of the IAEA model through the answers given by a sample of nuclear workers to a questionnaire based on this model. With this quantitative technique, we measured to what extent participants perceived that 37 specific organizational performance aspects or attitudes were being fulfilled in their NPP. Perceptions, as well as thought processes, feelings and behaviors, are usually determined by the deepest and usually unconscious levels of culture (Schein, 2004), but it is believed that these underlying levels of culture can only be reached by ethnographic approaches, including intensive and extensive observations and employee interviews (Schein, 1991). Therefore, with this questionnaire we may have measured safety climate perceptions. However, if these perceptions are determined by the underlying safety culture of the organization, participants' answers should, to a certain degree, reflect the existing safety culture in their organization. Safety climate perceptions are a window to the underlying safety culture assumptions. Furthermore, the use of questionnaires for the assessment of safety culture is widely spread (Antonsen, 2009).

We encourage the nuclear community to contribute to the improvement and empirical validation of the IAEA model. The empirical studies presented in this paper could be replicated to determine whether our results are consistent across different samples and NPPs. We would also like to suggest the IAEA to perform factorial analyses of the scores they obtained on each of the attributes in their SCART missions, as this information may be crucial for understanding the dimensionality of their model. We are not aware that the validity of the SCART methodology has been investigated, and doing so could help to find evidence supporting the validity of the IAEA model. Organizations that have used the SCART methodology on their own (or any other assessment instrument based on the IAEA model) are also encouraged to test the validity of these instruments. As has been shown, the validity of the IAEA model can also be tested by means of assessment procedures simpler than SCART, such as the one we have presented in the third study of this paper. It is worth noting that the IAEA has created specific indicators of safety culture for each of the attributes of the model (IAEA, 2009a). In the present paper we decided to test the IAEA model through its 37 attributes; however, using these indicators could have provided additional information about the internal structure of the IAEA model. Further studies should also try to replicate the model with the indicators of safety culture, keeping in mind that some of them, as in the case of the attributes, are double or triple barreled. Finally, to gain more evidence about the validity of the model, an additional study is suggested. We have been concerned with the extent to which each of the attributes of the model is relevant to the dimension to which it is supposed to belong. This has been referred to as the relevance aspect of content validity. However, exploring the other side of the coin, the representativeness aspect of content validity, could also help to improve the model. Researchers are encouraged to test whether the attributes of the model are representative of the safety culture construct, in other words, whether the entire domain of the safety culture construct can be reproduced by the 37 attributes included in the IAEA model and, if higher-level dimensions exist within the construct, whether the attributes are proportional to them.

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CHAPTER VII.

THE SAFETY CULTURE ENACTMENT QUESTIONNAIRE (SCEQ): THEORETICAL MODEL AND EMPIRICAL VALIDATION

Abstract

This paper presents the Safety Culture Enactment Questionnaire (SCEQ), designed to assess the degree to which safety is an enacted value in the day-to-day running of nuclear power plants (NPPs). The SCEQ is based on a theoretical safety culture model that is manifested in three fundamental components of the functioning and operation of any organization: strategic decisions, human resources practices, and daily activities and behaviors. The extent to which the importance of safety is enacted in each of these three components provides information about the pervasiveness of the safety culture in the NPP. To validate the SCEQ and the model on which it is based, two separate studies were carried out with data collection in 2008 and 2014, respectively. In Study 1, the SCEQ was administered to the employees of two Spanish NPPs (N=533) belonging to the same company. Participants in Study 2 included 598 employees from the same NPPs, who completed the SCEQ and other questionnaires measuring different safety culture outcomes (safety climate, safety satisfaction, job satisfaction and risky behaviors). Study 1 comprised item formulation and examination of the factorial structure and reliability of the SCEQ. Study 2 tested internal consistency and provided evidence of factorial validity, validity based on relationships with other variables, and discriminant validity between the SCEQ and safety climate. Exploratory Factor Analysis (EFA) carried out in Study 1 revealed a three-factor solution corresponding to the three components of the theoretical model. Reliability analyses showed strong internal consistency for the three scales of the SCEQ, and each of the 21 items on the questionnaire contributed to the homogeneity of its theoretically developed scale. Confirmatory Factor Analysis

(CFA) carried out in Study 2 supported the internal structure of the SCEQ; internal consistency of the scales was also supported. Furthermore, the three scales of the SCEQ showed the expected correlation patterns with the measured safety culture outcomes. Finally, results provided evidence of discriminant validity between the SCEQ and safety climate. We conclude that the SCEQ is a valid, reliable instrument supported by a theoretical framework, and it is useful to measure the enactment of safety culture in NPPs.

Keywords: Empirical validation; enacted values; nuclear industry; nuclear power plant; safety culture model; safety culture questionnaire

7.1. INTRODUCTION

For the past 30 years, scientists and practitioners have continuously worked toward the creation of specific models, methodologies, and tools for the assessment of safety cultures. However, most culture studies have relied too heavily on the organization's espoused values (i.e., what should be done), instead of capturing what is actually enacted. Thus, many tools may be skewed toward the "declared" culture, rather than identifying "culture in action" (Siehl and Martin, 1990). In particular, questionnaires to assess safety culture have not yet been successful in grasping information about safety values (Guldenmund, 2000) and capturing the enactment of safety. In addition, most safety culture questionnaires created for High Reliability Organizations (HROs) are not supported by solid theoretical frameworks. Due to these shortcomings, even though questionnaires have been the main strategy for safety culture assessment (Antonsen, 2009; Gadd und Collins, 2002; Guldenmund, 2000), none of them has been widely used and accepted to capture and assess the enactment safety culture in the nuclear industry. Thus, there is rather limited guidance about how to assess safety culture (benefiting from the inherent advantages of questionnaires) in order to ensure safety in nuclear power plants.

This paper presents the SCEQ, a safety culture questionnaire developed to overcome these weaknesses. On the one hand, the SCEQ was designed to assess the degree to which the safety value is enacted in the operations of nuclear facilities and other HRO. On the other hand, the SCEQ is based on a safety culture model that measures its manifestation in three fundamental components of the functioning and operation of any NPP or HRO.

The paper aims to empirically validate the SCEQ and the dimensionality of the model on which it is based. The authors expect that the SCEQ will serve the nuclear industry and other High Reliability industries in the difficult but unavoidable quest to assess safety culture enactment.

7.1.1. What is safety culture?

The culture of an organization is composed of a specific set of elements that guide the ultimate behavior of its members toward the attainment of specific organizational goals. These cultural elements are hierarchically ordered from deeper and more intangible layers to more superficial and visible ones (Deal and Kennedy, 1982; Detert et al., 2000; Furnham and Gunter, 1993; Hofstede, 1991; Lundberg, 1990; Rousseau, 1990; Schein, 1985). Schein's (1985) three-layer model provides a widely-accepted framework to understand these cultural elements. At the organizational surface, the layer of artifacts is found. Artifacts are the most tangible and overt manifestations of culture, and they include everything that can be seen, heard and felt in an organization. Typical artifacts include physical environment, language, myths, stories, observable rituals, emotional displays, observable behaviors, and, in general, any kind of visible product of organizational members. At the second layer, one can find the espoused values, norms, philosophies and organizational rules that reflect what this organization would ideally like to be. This level can be expressed in public declarations during meetings or ceremonies, written documents describing the organization's mission and strategy, leaders' messages, etc. The third and deepest layer is composed of basic beliefs and assumptions shared by the members of the organization. These assumptions, often implicit, are deeply rooted in the history of the organization, as they have demonstrated to be useful for organizational survival and development. Therefore, to a greater extent than artifacts and espoused values, these underlying assumptions tell the members of an organization how to act, perceive, think, and feel about events and things if they are to be successful.

In general terms, most scholars refer to safety culture as a focused aspect (Richter and Koch, 2004), sub-element (Kennedy and Kirwan, 1998), sub-facet (Cooper, 2000; Mohamed, 2003) or subset (Clarke, 1999; IAEA, 1998a; Reiman and Rollenhagen, 2014; Sorensen, 2002) of organizational culture that alludes to organizational and/or worker features related to health and safety. In this line, and using Schein's model as a reference framework, an NPP has a high and strong safety culture (see González-Romá and Peiró, 2014) when its cultural elements (i.e., basic assumptions and values held by its workers and visible artifacts) result in safety management and performance behaviors designed to guarantee the safety of workers, the public, and the environment. Therefore, safety culture is present to the extent to which safety is the most important value in an NPP and, this is demonstrated through the enactment of this value in the behaviors its members do. As the International Atomic Energy Agency (IAEA) and the Institute of Nuclear Power Operations (INPO) conclude, in a safety culture, safety is the enduring overriding priority, always emphasized over any competing organizational goal (e.g. production, innovation, etc.) (IAEA, 1991; INPO, 2004), and a clearly recognized value (IAEA, 2006a).

7.1.2. Espoused vs. enacted values

Values refer to what is desirable (Kohn and Schooler, 1983; Rokeach, 1973; Schwartz, 1994; Williams, 1979). They are enduring convictions (Rokeach, 1973) and tendencies to prefer certain states of affairs to others (Hofstede, 1980) in trying to achieve our goals (e.g. cooperation vs. competition or flexibility vs. rigidity). In the nuclear industry, safety (vs. risk) can be considered an instrumental value (see Rokeach [1973] for an explanation of terminal and instrumental values) to achieve organizational goals (i.e., the necessary level of production without putting workers and the society at risk).

However, in some circumstances (e.g. financial rewards for producing more energy in an NPP), the enduring convictions or preferred tendencies of a specific group (e.g. safety) may be questioned. Members do not always behave according to the values that "in theory" are preferred and shared by their organizations. This distinction has been addressed in the literature as espoused theories vs. theories in use (Argyris and Schon, 1974); espoused rules vs. real rules (Shapiro, 1995); or espoused values vs. enacted values (Simons, 2002). Espoused values reflect what the organization articulates as essential, the managerial philosophy, and its aspirations, whereas the real, in use, or enacted values are the decision rules that guide employees' ultimate behavior in real situations and settings.

In the organizational context, the study of espoused vs. enacted values has mainly been addressed from two perspectives: 1) From an employee-leader approach, the concept of "behavioral integrity" is used (Simons, 2002). Behavioral integrity is defined as "the perceived pattern of alignment between an actor's words and deeds" (Simons, 2002, p. 19). It refers therefore to the congruence between the leader's espoused and enacted values, the famous "walk the talk". 2) From an organizational approach, the concept of "organizational authenticity" is adopted (Cording, Harrison, Hoskisson and Jonsen, 2014; Freeman and Auster, 2011; Liedtka, 2008). Organizational authenticity is defined as the consistency between an organization´s espoused values and the practices it carries out (Cording et al., 2014). It refers therefore to the alignment between the actions taken by an organization and the values it openly espouses.

From both the employee-leader and organizational approaches, the main interest in studying espoused and enacted values lies on how they determine individual and collective behaviors and organizational outcomes (e.g., organizational productivity [Cording et al., 2014], corporate growth [Neumann, 2005], confusion and dissatisfaction [Patankar et al., 2012], employee performance [Schuh and Miller, 2006], commitment [Branch and Olson, 2011], and the underreporting of near misses and first aid injuries [Lauver, Trank and Le, 2011]. Thus, if values determine and guide behaviors, measuring the varying degrees to which organizational values are enacted can provide information about the likelihood of future safety performance and employee behaviors in NPPs (e.g., if safety is a central value of an NPP, it can be expected that their workers will do everything possible to avoid risky behaviors).

However, is not clear to what extent espoused values determine employees' behaviors (Wilpert and Schobel, 2007). It could be argued that measuring espoused values would be useful when espoused and enacted values are aligned. Unfortunately, the values espoused by managers and leaders are not always coherent with the values that guide their priorities and behaviors (Argyris and Schon, 1978; Simons, 2002; Zohar and Hofmann, 2012). Specifically, there is "sufficient evidence from inquiry reports into major hazard incidents and disasters that idealized enactment rarely occurs" (Waring, 2015, p. 261). As Schein (1992) points out, the enacted values, the ones that are supported, prioritized and rewarded in the day-to-day organizational functioning, inform members about the actions expected from them. In summary, it seems that to understand an organization and predict its future performance, it is not enough to merely capture the culture reflected in its espoused values.

7.1.3. Capturing the enactment of safety culture

The need to take the level of enacted values into account when studying organizations has been widely highlighted (Branch and Olson, 2011; Schein, 1992; Siehl and Martin, 1990; Waring, 2015; Zohar and Hofmann, 2012), as they "offer more valid information regarding deep-layer assumptions and values than their espoused counterparts" (Zohar and Hofmann, 2012, p. 661). However, how can we reach beyond the level of espoused values?

The different layers of culture call for distinct research methods. Artifacts are easy to observe and, consequently, can be directly registered without the help of organizational members' reports. However, it is very difficult to understand the real meaning of artifacts and the cultural aspects that lie behind them without conducting a deeper cultural analysis. Next, one can try to capture and analyze the values of an organization. The espoused values are relatively easy for organizational members to articulate and, thus, can be captured by written surveys and questionnaires (Guldenmund 2007; Schein, 1992; Wilpert and Schobel, 2007) that have been adequately designed for this purpose. Access to the basic assumptions is the most difficult aspect of analyzing a particular culture. Because basic assumptions are taken for granted and ingrained, organizational members who hold them are often not aware of them (Schein, 1985).Therefore, basic assumptions cannot be reached by directly asking employees about them. The deepest cultural level can only be revealed through a combination of novel qualitative methodological approaches (Schein, 1985; Wilpert and Schobel, 2007) and time-consuming objective processes of data integration, deciphering, and interpretation (Schein, 1985).

Each of these levels provides valuable and complementary information with which to understand the particular culture of an organization. However, most attempts to assess safety culture have used questionnaires (Antonsen, 2009; Gadd und Collins, 2002; Guldenmund, 2000), typically oriented toward the espoused values layer (Guldenmund, 2007), and avoiding the difficulties and costs involved in the study of basic assumptions and the limited information provided by cultural artifacts.

Questionnaires offer advantages over qualitative approaches. They do not require excessive time and economic resources, they allow access to many organizational members from all hierarchical levels of the NPP, and they provide data that can be easily coded, analyzed and benchmarked. As a result, questionnaires allow the safety culture of NPPs to be assessed more frequently (e.g., annually) and systematically than other methods. Frequent monitoring in NPPs is extremely important for the early detection of declining and weakening safety cultures (IAEA, 2006a), allowing time to take remedial action before minimum acceptable safety levels are challenged (IAEA, 2003). Systematic monitoring through the comparison of quantified results at different times makes it possible to detect trends (Hale, 2009; Håvold, 2005; IAEA, 2003) and evaluate the evolution of safety culture. For these reasons, in spite of the merits of qualitative methods, a questionnaire on safety culture is a valuable resource for the nuclear industry. "The challenge is, of course, to develop a questionnaire that yields just enough relevant and valid information – the trusted 'wet finger' to find out from which way the wind blows – to decide whether and possibly where any corrective measures or actions are opportune" (Guldenmund 2007, p. 724).

We took on this challenge by creating a questionnaire that could capture the level of enacted values in HRO. However, the SCEQ does not intend to assess all the possible values enacted in an organization. As it is a safety culture questionnaire, the focus is on the real importance of safety in practice. More specifically, the SCEQ is designed to assess the degree to which safety is an enacted value within NPPs and HROs.

How can a questionnaire encourage respondents to report the degree to which safety is an enacted value, and not just an espoused value? Howell, Kirk-Brown and Cooper (2012) propose that "assessing the degree to which employees believe that a particular value is enacted within their organization requires employees to be directly asked about their perceptions of the degree of enactment" (p. 734). Along the same lines, we argue that this can be done by asking employees about the practical importance of safety in the decisions and behaviors taking place in the organization, a requirement for enacted values to be present in the Argyris

(1990), Shapiro (1995) and Simons (2002) studies. To obtain this information, we relied on the introduction to the questionnaire (see section 7.2.1.). First, the text that presents the SCEQ encourages the surveyed person to think about the practical importance of safety, leaving aside its theoretical value (what is said and how things should be) and focusing, in the words of Simons (2002, p. 29), on “the way things really get done”, and not just the “official policies and managerial philosophy”. Second, the introduction to the SCEQ forces the surveyed person to think about the importance of safety in the day-to-day running of the plant (i.e. the extent to which safety is a long-standing cultural element in their organization). Asking for the importance *in* practice we ask to report about the use of the safety values in real practice. An organizational member can easily observe and be aware of an espoused value, as these values may take the form of rationalizations, aspirations, or norms that are openly spread. However, to recognize an enacted value, this person needs to consistently experience over time that the value in question is considered *in* practice and implemented consistently as a non-negotiable priority. The SCEQ tries to capture the way participants perceive that the value of safety is aligned with and embedded in strategic and daily operations and practices, and the extent to which safety is a long-standing cultural element in their organization. Thus, the SCEQ differs from most existing safety culture questionnaires, which typically focus on espoused values and provide a “snapshot” of culture.

Moreover, Forty years ago, Guttman and Levy (1976) established the criteria for an item to be considered to belong to the universe of value items. For these authors, an item belongs to the universe of value items if and only if its domain asks for an estimation of the degree of importance of a goal or behavior in a life area, with a range from very important to obtain the goal to very important to avoid the goal. Elizur (1984), following Guttman and Levy's criteria, states that "an item belongs to the universe of work value items if its domain asks for an assessment of the importance of a goal in the work context, with a range from very important to very unimportant" (p. 379). These criteria are widely accepted in the scientific community. Accordingly, the response scale of the SCEQ fulfills these requirements for the assessment of work values by asking for an estimation of the importance of (the goal) safety *in* practice.

To our knowledge, so far there is no safety culture questionnaire in the nuclear industry that meets these criteria and that approaches the level of work values and, in particular, the enactment of the value of safety.

But what aspects can provide significant information about the enactment of safety values in an NPP or HRO? This question is addressed in the next section.

7.1.4. An organizational model for the enactment of safety culture

The IAEA emphasizes the importance of safety as a clearly recognized value (IAEA, 2006a) that must be present throughout the entire nuclear installation (IAEA, 2008a). That is, safety culture implies that safety is the most important value and consequently, one that has to be enacted. Therefore, when an NPP or HRO has a high and strong safety culture, safety should be reflected in "everything" the NPP or HRO does, and in the way its members behave. When this happens, it inspires and drives the behaviors and attitudes of the people who contribute to the organization's functioning and the outputs they produce

(González-Romá and Peiró, 2014). Thus, IAEA (1991) and Kao et al. (2007), among others, conceptualize safety culture as the degree to which different hierarchical levels contribute to the safety of an organization. The IAEA safety culture model (1991) highlights three levels: policies, managerial, and individual. Kao et al. (2007) adapted the IAEA proposal by relating the policy level to top management functions, the managerial level to supervisory, support and personnel management functions, and the individual level to attitudes, involvement and behaviors of the basic operating core. As Mintzberg (1979) reported, and in line with the IAEA (1991) and Kao et al. (2007), the main levels of an organization are: the strategic apex (i.e., top management), the middle line (i.e., supervisory level), and the operating core (i.e., employee level), each of which has a different mission and distinct functions in the organization. Top management's main role is to make decisions and guarantee the conditions for the plant's smooth running; supervisors must manage the work of employees, mainly by enacting formal and informal human resources practices; and employees operate in the organization by implementing the work system. The safety culture of an NPP or any other HRO must be enacted by showing the alignment between the espoused importance of the value of safety and the behaviors and attitudes of its members at any of these levels.

Following this line of reasoning, we developed a safety culture model that comprises these three fundamental components of the functioning and operation of HROs, where the value of safety must be put into practice: strategic decisions, personnel management, and operating behaviors. Therefore, an NPP has a high intensity and strong safety culture when the strategic and important decisions guarantee the priority of safety at all times (strategic level), a set of human resources practices promotes the safety of the plant (managerial level), and safety is the primary determinant of all operating actions and behaviors (operational level).

7.1.4.1. Strategic decisions ensuring safety

Safety culture manifests itself in the role safety plays in the strategic decisions made in NPPs. This dimension covers decisions that are carefully and thoughtfully made for the smooth running of the plant. It encompasses decisions about the operation of the plant and the conflicts between safety and other competing goals, and decisions about the allocation of resources and the establishment of procedures.

Due to competitiveness and stakeholder pressure, NPPs often face the dilemma of how to achieve production goals without compromising the safety of the plant through their strategic decisions. Having a 'safety first' policy as a strategy does not guarantee that it will become an operational reality in NPPs, where *profitability tends to compete with non-productive investments* in nuclear safety (Perin, 2005). The IAEA (1999) warns that there are times when the emphasis on safety might come into conflict with the requirement to meet all the demands for electricity generation. What happens in these situations? Is safety still the number one priority when money comes into play? Or are NPPs taking risky cost-cutting measures (e.g. deferring maintenance, downsizing staff, reducing training, etc.) to cope with competitive pressures (Meshkati, Butler and Pelling, 2001)? The practical importance of safety will be reflected in the decisions NPPs' leaders make when facing these competing demands. The extent to which safety is favored over productivity when they come into direct conflict will allow organizational members to align their behaviors accordingly (Zohar and Hofmann, 2012).

Satisfying these safety and productivity demands often becomes a difficult task in NPPs, as they have limited resources. Deciding how to allocate and manage these resources is critical to the survival and success of the plant. The use of adequate qualitative and quantitative risk assessments helps NPPs to make *decisions about the allocation of resources* for safety improvements, by directing attention to the features that dominate plant risk (Colombo and Saiz de Bustamante, 1990), accident-related events, the level of technical knowledge, etc. Important resources for safety (IAEA, 2006a) can include: information to make fact-based decisions, material and financial resources to meet safety standards, enough personnel and training for the safe operation of the plant (see section 7.1.4.2.), or adequate infrastructures (e.g., workspace, equipment, support services, communication technology, etc.) and resources. But unfortunately, essential resources are not always available (e.g., regulators have taken corrective actions because decisions about the allocation of resources have sometimes been made without an understanding of what is required to maintain the defense of safety in depth [IAEA, 2003]).

To satisfy their financial and safety goals, NPPs must also specify, develop, implement, maintain, and improve the necessary processes. For this reason, possible hazards and risks must be identified and taken into account in all processes, along with any necessary mitigating actions (IAEA, 2009a).

Specifically, NPPs must count on *decision-making processes* that help the personnel to be systematic and rigorous in making decisions that support safe, reliable plant operations (INPO, 2004). In any case, these processes should not diminish organizational flexibility and the ability to adapt, which are essential for being prepared in crises (Reason, 1997). In this context, NPPs must allow for the possibility of changes in the decision-making processes, depending on the urgency of the decision and the expertise of the people involved (CANSO, 2008). However, when the consequences a decision can have for safety are not fully understood, a conservative approach must be taken (INPO, 2004).

A culture for safety will also be reflected in the quality of the *procedures* and the extent to which they are developed with the safety of the plant in mind. The management system documentation will include procedures and instructions that explain how the work is to be prepared, reviewed, carried out, recorded, assessed and improved (IAEA, 2009a), to ensure high levels of safety performance. In order to guarantee the safety of the plant, these procedures must be designed not only from a technical viewpoint, but also by integrating the socio-technical conditions required for their application (types of skills, type of environment, type of aids required, etc.) (Dien, 1998). Procedures must be easily understood and easy to use, and they must be regularly reviewed and updated to guarantee their adequacy and effectiveness (IAEA, 2009a). However, to guarantee the safety of the plant, procedures must be applied "intelligently" (Dien, 1998), which requires "strict adherence to procedures as long as they are adapted to the situation, and use of initiative at times when there is a divergence between the actual situation and what is expected by the procedure" (p. 184). Dien's (1998) work provides a thorough analysis of the nature of the problem of applying procedures in the nuclear industry.

On the whole, the practical importance of safety is reflected in *the way the plant is operated* and the extent to which safety is embedded in any decision related to its operation. Some examples of the way safety culture can be manifested in the plant operations are: the establishment of an operational quality assurance program to assist in ensuring satisfactory performance in the plant's operation and all plant activities relevant to safety (IAEA, 1999), and the existence of operational limits and conditions defined for all the stages of commissioning, power operation, shutting down, starting up, maintenance, testing and refueling (IAEA, 2000).The IAEA also inquires whether there is a plant life management program for long term operation, including ageing monitoring (IAEA, 2006b), and whether feedback on operating experience is obtained and evaluated, promptly taking the necessary corrective measures and disseminating information about them (IAEA, 1999).

7.1.4.2. Human resources practices driving safety

The safety culture of an NPP manifests itself in the extent to which the HR practices are coherently articulated to guarantee high levels of safety performance. For this purpose, the organization must be able to bring in new workers (e.g., by means of appropriate recruitment and selection practices) who share the priority of safety and have the ability and willingness to work safely; it must continuously prepare the employees, especially in safety matters (e.g., through training and performance appraisals), and it must encourage and motivate them (e.g., through formal reward systems, such as goal setting, promotions or salary, as well as informal rewards, such as recognition) to work safely under all conditions.

A number of regulatory bodies regulate their licensees' *recruitment practices*, determining, for example, the minimum length of experience or qualifications for specific positions (IAEA, 2002; IAEA, 2008b). In a strong safety culture, the management and supervisors go beyond these requirements, hiring only people who show attitudes, values and past experiences that support safe work. They look for "pre-socialized" members who already have a firm conviction that safety is the number one priority in NPPs. The IAEA (2002) makes several recommendations about recruitment in the nuclear sector, such as using aptitude and psychological tests for some key and critical positions, and performing medical examinations on all the operating staff whose duties have a bearing on safety, at the time of recruitment and periodically thereafter.

Attracting the "right" people cannot be an excuse for reducing the importance of *training personnel* in the safe running of the plant. A strong safety culture includes training practices to maintain a knowledgeable, safety aware, and competent workforce (including operations, maintenance, management and technical support personnel). The extent to which safety is important for the plant will be expressed in the training provided in plant specifics, quality assurance (QA), radiological protection, and safety aspects related to each specific job (IAEA, 2006c), as well as in personnel management and leadership, and theoretical and practical aspects of strong safety cultures, among others. All training programs and processes should be systematically evaluated (e.g. by plant supervisors, instructors, trainees, independent experts, and regulatory inspectors) and confirmed, improved or modified according to safety needs and safety values (IAEA, 1996). Management must make sure that there are general and specific training programs for each position, allowing job holders to develop the necessary competencies to carry out safe and quality work. In this context, employees' needs and suggestions must be listened to and considered (both in the day-to-day and in the formal performance appraisals) in relation to their contributions to the plant's safety. At the same time, managers and supervisors should be trained in how to conduct *performance appraisal* and use feedback techniques, in order to identify training needs that guarantee the safety of the plant. In a safety culture, performance appraisals must include specific sections on hazard awareness, safety-related competencies, and safety conscious attitudes and behaviors (Tronea, 2011). Formal performance appraisals should be systematically carried out (e.g. at the end of probation periods). However, they should not diminish the importance of continuous safety performance monitoring and feedback from employees in supervisory positions (e.g. project managers, department heads, etc.) (IAEA, 1998b).

The *goals of each employee* (e.g., production or maintenance goals) are set in a way that guarantees that their attainment will contribute to and not threaten the safety of the plant. Employees' active role in setting their own goals is important because nobody knows more about the level of performance they can achieve without compromising the safety of the plant. Participative goal setting is a recognized motivational strategy because it generates ownership of the goals and encourages workers to attain them (Karakowsky and Mann, 2008; Latham and Yukl, 1976). Participative goal setting can result in employees being more committed to their own personal safety goals, and in a reduction in organizational accidents and incidents (Leung, Chan and Yu, 2012). Individual employees and teams should have specific safety goals. These safety goals can often be translated into quantitative safety performance indicators (Reiman and Pietikäinen, 2010), making it possible to detect safety or risk trends and establish benchmarks with other plants. Examples of these indicators (Reiman and Pietikäinen, 2010) could be the percentage of critical safety equipment that fails inspection, the recurrence of incidents with similar root causes, the frequency and length of sick leave periods, or the number of proposals for safety improvement.

A critical aspect of a safety culture is the inclusion of a reward and recognition system to reinforce safe work performance (Monta, 2001) and the attainment of these safety-oriented goals. In fact, the (safety) culture of an organization is created and expressed through the actions that supervisors support and reward (Schein, 2010). Managers and experienced employees in an NPP must give *informal recognition* to employees who perform actions that are beneficial to safety (IAEA, 2008a). In a culture for safety, recognition is also given to safety suggestions (Clarke, 2006; Gibbons et al., 2006), including public recognition (e.g. safety celebrations) for employees who suggest potential safety improvements (IAEA, 2008a). Recognition must be timely, focus on specific behaviors, and consider safety as the primary reference. Moreover, the recognition of safety milestones is only productive if it does not inhibit incident reporting (Frazier et al., 2013).

Likewise, *financial rewards* must guarantee and improve the safety of the plant. However, care should be taken to avoid misleading effects. On the one hand, financial incentives to increase productivity (e.g., a bonus for an outage ending ahead of schedule or for extra energy produced) or to compensate for working in hazardous conditions can lead to safety being compromised (Gadd and Collins, 2002). As an example, Sawacha et al. (1999) found that employees eligible for hazard pay were at greater risk because they might perceive this increase as an inducement to take risks. On the other hand, risks can go hand in hand with the attainment of safety-related goals. Whereas financially rewarding zero accidents or no lost-time injuries (i.e., blame culture) may make employees reluctant to report incidents, accidents, injuries or near-misses (Gadd and Collins, 2002), linking employees' salaries to the identification of safety-related issues can lead to an over-reporting culture (Reason, 1997; Yule, 2003). For example, the IAEA (IAEA website) points out that if a low number of unplanned automatic scrams is highly valued, pressure could rise to adjust the set points for triggering the scram appropriately. Taking this double-edged sword into account, a safety culture should have salary systems that are cautiously designed and graded considering demonstrated performance, knowledge, attitudes and competences that contribute to organizational safety.

Along the same lines, the importance of safety in *promoting personnel* should be cautiously communicated within the NPP. Managerial and supervisory positions should be filled on the basis of safety-related criteria, such as personnel who have shown consistent attitudes and behaviors toward safety and conservative, safety-enhancing decision-making (IAEA, 2002c). Employees learn from cases where safety-related factors are decisive in approving or rejecting a promotion.

All these safety-oriented HR practices must be applied to all the members of the NPP and to the people who, without being members of the organization, have an effect on the safety of the plant (e.g. contractors). As the IAEA (2001b) states, NPPs in all Member States require *contractor personnel for outage work*, which often includes refueling. NPPs must ensure that contractors have the necessary qualifications and motivation to carry out an effective and safe refueling outage. Long-term relationships with contractors may be a good way to motivate them and support a strong safety culture, which may include defining common objectives for contractors and plant staff (IAEA, 2006c).

Finally, formal HR systems (attraction, development and motivation practices) must be aligned with the day-to-day work of management and with the supervisor-supervisee relationship. For example, if plant management does not actively support and reinforce the standards for safety and quality established in training programs, these standards may not be applied at the NPP. There is little point in having a formal rewards system if it is not coherent with the actions that supervisors reinforce in the day-to-day running of the plant.

7.1.4.3. Daily activities and behaviors supporting safety

The extent to which safety is important for an NPP is reflected in the daily behaviors of every employee in the organization, the relationship with external agents (e.g., contractors and regulatory bodies), and the day-to-day operations (such as meetings or internal publications, e.g., Gracia and Peiró, 2010).

Safety culture is enacted in *employees' behaviors* and attitudes. According to Schein (2010), observed behaviors are cultural artifacts and, as such, a product of deeper cultural layers. As culture is a reality that permeates the whole organization, safety culture must be reflected in the daily behaviors of the entire staff, from employees to supervisors and top management (e.g., core operating workers always use the necessary protective equipment to perform their duties safely; supervisors consistently show their support and willingness to help with any task that may have a direct or indirect impact on the safety of the plant; and top management frequently walk the plant and interact with workers in search of safety maintenance and improvement).

Moreover, the day-to-day operation of an NPP cannot be fully understood without considering its external relationships. Two external agents that are essential for the safety of NPPs are *regulatory bodies and contractors*. Safety is the primary purpose of regulatory bodies, and, therefore, one of their main functions is to ensure the development and maintenance of high and strong safety cultures in nuclear facilities. The extent to which the licensee collaborates with the regulator in the day-to-day operations not only helps to achieve that goal, but it is also an indicator of safety culture strength. Delays or failure to meet regulatory commitments, policies of minimal compliance with regulations on safety matters, attempts to dispute and defy the safety regulator, or efforts to maintain operations within the current licensing (NEA, 1999), among others, will inform workers about the practical importance of safety for the organization. Leveson's (2004) system-theoretical model of accidents (STAMP) helps to understand the role of relationships among different actors (including designers, operators, managers, and regulators) in the safety of increasingly demanding and complex high-tech systems, such as NPPs.

On the other hand, the management and interactions with contractors must be taken into special consideration, as contractors may make different assumptions and have different working values related to safety than those of the NPP. Carroll's (1998) study reported that employees at an NPP plant complained that contractors do not perform the same quality of work as permanent employees, either due to a lack of site-specific experience/training or because of a "don't care, I'm only here for 3 months" attitude. On the other hand, Alexander (1994 cited in Cox and Cheyne, 2000) found contractors to have a higher appreciation of risk and a higher personal need for safety than company employees. Either way, continuous efforts should be made to acculturate[8] contractors and benefit from their positive enactment of safety culture, in such a way that the priority of safety is guaranteed in the organization and operations are carried out accordingly. The IAEA (1998a) made a number of recommendations about contractors in the nuclear industry. It recommends that contractors involved in design, engineering, manufacturing, construction, operation, maintenance, or other areas participate in the enhancement of plant quality and safety, and that contractors be made aware of the quality and safety standards required. In addition, the HSE (2003; cited in HSE 2005) adds other recommendations, such as the idea that major accident risks must be communicated and explained, not only to employees, but also to contractors.

To maintain and enhance safety awareness, the central role of safety should always be considered in *meetings, internal publications, bulletins, and other*

[8]Acculturation is the process of converting a non-member of the culture to a member

formal and informal communications. These are cultural elements included in the Schein (1985) and Guldenmund (2000) culture models. In a strong safety culture, near misses and safety improvements are addressed and communicated in daily practice through all possible methods, including meetings with staff, bulletins, newspapers and posters (IAEA, 2010). The HSC (2001) also recommends using company bulletins and communications to encourage safety commitment by all employees. Moreover, Shafai-Sahrai (1971, cited in Mearns et al., 2003) found that the priority of safety in meetings was a characteristic of organizations with lower accident rates. Regular attendance and active participation in safety meetings show the importance of safety at all the hierarchical levels in an NPP. Moreover, meetings and publications that are not explicitly focused on safety matters should carefully address the impact of the topics discussed on the safety of the plant and take the opportunity to share constructive safety-related messages (Gracia and Peiró, 2010). For safety messages to be effective, they must be embedded and enacted in the day-to-day operations of the NPP.

Changes are a frequent reality in NPPs; therefore, safety has to be guaranteed and prioritized in *the way changes are managed* by all employees. Changes affecting the nuclear industry may consist of government policy changes, open market demands, or regulatory and social pressures (IAEA, 2001b), to name a few. Other changes occurring in NPPs may just take the form of internal improvements, such as the implementation of a new performance appraisal system or a new information system. Changes can modify cultural values and, consequently, safety behaviors. Properly managed in the day-to-day of the NPP, changes have the power to enhance not only nuclear safety and plant reliability, but also cost competitiveness, from the design stage to decommissioning (IAEA, 2001b). In a strong safety culture, safety must be the priority when implementing changes and safety-focused change management processes will be constantly applied (e.g. proposed changes are frequently studied by multi-disciplinary teams to ensure that as many viewpoints as possible are used to minimize the chances of overlooking a hazard [Hackman, 2011]).

Every hierarchical level in an organization (top management, supervisory level and operating core) plays a role in preserving and enhancing the safety of an NPP through all three fundamental components of the functioning and operation of an NPP (strategic decisions ensuring safety, human resources practices driving safety, and daily activities and behaviors supporting safety). However, each hierarchical level has different opportunities to enact safety values through each of these organizational components. Nevertheless, our focus here is on the appraisal of the enactment by every member of the organization, because this shared appraisal constitutes the ‘real’ safety culture of organizations and may influence the safety climate, behaviors and performance in NPPs.

Thus, the appraisal of these three dimensions, measured with the Safety Culture Enactment Questionnaire, by the members of organizations offers an encompassing assessment of safety culture ‘in action’ in NPPs.

7.2. METHOD

The purpose of this study is to fill a gap in the measurement of safety culture in the nuclear industry through the development and validation of the Safety

Culture Enactment Questionnaire (SCEQ). This measurement tool goes beyond the surface levels of culture and is supported by a theoretical framework.

7.2.1. Development of the questionnaire

The development of the SCEQ was based on: (a) a literature review of different conceptualizations and theoretical frameworks of organizational culture and safety culture, and the integration of this knowledge into our organization's core functions; (b) a critical examination of safety culture questionnaires currently available in the literature; (c) observations and reflections stemming from our consulting experience in organizational behavior, particularly within the nuclear industry; and (d) the critical analysis of the multiple facets considered in the "Analysis, Management and Intervention Guidelines in Organizations (AMIGO) model" (Peiró and Martínez-Tur, 2008). Through an experts' focus group session (including both experts from the nuclear industry and organizational behavior researchers and academics), the most significant facets to preserve and promote safety in NPPs were selected. This procedure resulted in an initial pool containing 24 items that covered the three fundamental components of the functioning and operation of NPPs presented in our safety culture model; that is: *strategic decisions ensuring safety, HR practices driving safety,* and *daily activities and behaviors supporting safety*. Therefore, the dimensions of the SCEQ are not intended to be dimensions of safety culture per se, but rather dimensions of fundamental sets of actions of an NPP where the value of safety can be crystallized. Each item was designed to obtain information about the degree to which nuclear safety is important to the organization and enacted in decisions and actions carried out in one of the dimensions considered. Five-point Likert-type scales with responses ranging from 1 (not important at all) to 5 (very important) were used to record this information. Three of the items were dropped, in response to theoretical or methodological concerns, as explained in Study 1. The full list of the remaining 21 items grouped in the three dimensions of the SCEQ is presented in Table 16. The text introducing the questionnaire to the survey-respondents reads as follows: “We would like to know your opinion about ***how important safety is to your company***. We are not as interested in discovering its theoretical importance as in ***finding out its practical importance on a daily basis***. For this purpose, we request that you answer the following questionnaire carefully”. This introduction is important to emphasize and focus on the enacted value of safety culture.

Table 16

Items and dimensions of the Safety Culture Enactment Questionnaire (SCEQ) and its descriptive statistics

To what degree is nuclear safety important…

		Mean	SD	Skewness	Kurtosis
Dimension 1 - Strategic decisions ensuring safety					
SC1	… in decision-making processes about the work?	4.29	.74	-1.14	2.02
SC2	… when allocating resources (time, personnel, money)?	4.12	.81	-.95	1.27
SC3	… when establishing procedures?	4.20	.77	-.96	1.42
SC4	… in the operation of the plant?	4.46	.72	-1.57	3.35
SC5	… when resolving conflicts between safety and production?	4.04	.83	-.81	.90
Dimension 2 - HR practices driving safety					
SC6	... in hiring personnel?	3.44	1	-.39	-.30
SC7	… in training personnel?	3.99	.93	-.93	.73
SC8	… in promoting personnel?	2.90	1.15	-.04	-.86
SC9	… in paying the personnel?	2.95	1.12	-.10	-.70
SC10	… in establishing objectives?	3.60	1.04	-.62	-.08
SC11	… in evaluating the performance of the workers?	3.32	1.04	-.41	-.38
SC12	… in planning and hiring personnel for refueling?	3.17	1.11	-.11	-.75
SC13	… in the recognition the bosses give to their collaborators?	3.33	1.01	-.36	-.39
Dimension 3 - Daily activities and behaviors supporting safety					
SC14	… in bulletins and other publications?	3.98	.86	-.58	-.10
SC15	… in the meetings?	3.85	.82	-.52	.21
SC16	… in the relationship with the regulator?	4.12	.85	-.72	.14
SC17	… in the relationship with the contractors?	3.79	.89	-.59	.17
SC18	… in the daily behavior of the employees?	3.88	.83	-.68	.74
SC19	… in the daily behavior of the bosses?	3.82	.87	-.56	.19
SC20	… in the daily behavior of top management?	3.90	.94	-.86	.63
SC21	… in the change management processes	3.73	.86	-.32	-.16

7.2.2. Sample

Study 1. 566 workers from two Spanish NPPs belonging to the same company completed the questionnaire. The total size of the company was 760 employees. Thus, we obtained a response rate of 74.47%. To guarantee the quality of the data, those questionnaires with more than three unanswered items were not considered in the analyses. Through this screening process, approximately 6% of the returned questionnaires were dropped from the data set. Therefore, 533 questionnaires were accepted for data analysis. The sample included all the responsibility levels and functional areas in the nuclear facility. Among the participants, 45% had completed university studies, 4% were under 30 years old, 23% were between 30 and 45 years old, and 73% were older than 45.

Study 2. 617 workers from the same Spanish NPPs completed the SCEQ and other questionnaires measuring different safety culture outcomes. The total size of the company was 806 employees. Thus, we obtained a response rate of 76.55%. Following the same screening process described in Study 1, approximately 3% of the returned questionnaires were dropped from the data set, as they had more than three unanswered items. Therefore, 598 questionnaires were accepted for data analysis. As in Study 1, the sample included all the responsibility levels and functional areas in the nuclear facility. Among the participants, 55% had completed university studies, 6% were under 30 years old, 21% were between 30 and 45 years old, and 73% were older than 45.

7.2.3. Survey administration

The present research was conducted in accordance with international ethical guidelines, which are consistent with the American Psychological Association (APA) guidelines. In both studies, the questionnaire was administered by the researchers, who stayed at the NPPs to ensure that any doubts when filling out the questionnaire could be immediately resolved. The SCEQ was part of a battery of questionnaires designed to assess different constructs and variables related to safety culture and safety climate. The administration of the battery took place during work time in small groups in a quiet and convenient room, and participants needed around 30 minutes to complete the entire battery. They were provided with instructions explaining the purpose of the study and the way the questionnaire should be completed. Participants were encouraged to answer honestly and take as much time as they needed to accurately complete the questionnaire. Voluntary participation, confidentiality and anonymity were guaranteed.

Data collection for Study 1 and Study 2 took place during 2008 and 2014 respectively.

7.2.4. Variables

Safety culture was measured by the Safety Culture Enactment Questionnaire (SCEQ). Additionally, in Study 2, four safety culture outcomes (safety climate, safety satisfaction, job satisfaction and risky behaviors) were also assessed to provide evidence of the validity of the SCEQ, based on its relationship with other related constructs. Variables of different natures were chosen to show the pervasiveness and influence of safety culture in respondents' cognitive processes and behaviors. The variable "psychological safety climate" refers to individual perceptions of safety in the organization; "safety satisfaction" and "job satisfaction" are closer to respondents' attitudes and affective responses; and "risky behaviors" asks for information about individuals' actions. On the other hand, and in line with the literature about attitudes, specific and general attitudinal referents have been considered (e.g., "safety satisfaction" and "job satisfaction", respectively).

Safety climate was measured by a Spanish version of Zohar and Luria's (2005) questionnaire developed by Latorre et al., 2013. This adaptation kept the 16 items from Zohar and Luria's questionnaire, although the referent for workers' perceptions was modified. The original scale was designed to capture workers' perceptions about top management's commitment to safety (e.g. "Top management in this plant/company... "...provides all the equipment needed to do the job safely", "...reacts quickly to solve the problem when told about safety hazards"), while the referent in our version was the whole organization (e.g. "My company… "...provides all the equipment needed to do the job safely", "...reacts quickly to solve the problem when told about safety hazards"). Following Zohar and Luria's scale, respondents were asked to answer these questions on a five-point Likert-type scale ranging from 1 (completely disagree) to 5 (completely agree).Cronbach's alpha for the scale in Study 2 sample was .94.

Safety satisfaction was assessed by the "Safety Satisfaction Questionnaire (SSQ)", a scale developed by our team. The questionnaire was composed of 6 items designed to explore participants' satisfaction with organizational safety (e.g.

“To what extent are you satisfied with radiological issues?”). Respondents answered on a five-point Likert-type scale ranging from 1 (very unsatisfied) to 5 (very satisfied). Cronbach’s alpha for this scale in Study 2 sample was .91.

Job satisfaction was measured with 3 items. It was conceptualized as overall satisfaction with the company, with the unit of work, and with the work itself. Consequently, participants were asked about their job satisfaction in relation to each of these domains: “How satisfied are you with your work?”, “How satisfied are you with your team?” and “How satisfied are you with your company?” A five-point Likert-type scale ranging from 1 (very unsatisfied) to 5 (very satisfied) was employed for this purpose. Cronbach’s alpha for this scale in Study 2 sample was .84.

Individuals’ risky behaviors were assessed by a scale based on Mearns et al. (2001). This questionnaire was designed to address the level of fulfillment of safety norms, procedures, and rules. The original scale was composed of 12 items; however, two of them were not included because they were not considered appropriate for the nuclear industry, as they could induce resistance in respondents to other items or scales in the battery. These items were: ‘‘I carry out activities that are forbidden’’ and ‘‘I get financial rewards for breaking the rules’’. The resulting scale was composed of 10 items answered on a five-point Likert-type scale ranging from 1 (never or almost never) to 5 (always or almost always). Higher scores on this scale would indicate risky behaviors. A sample item from this scale is: “I take shortcuts that involve little or no risk”. Cronbach’s alpha for this scale in the Study 2 sample was .92.

Hierarchical status was also requested in a dichotomous variable that differentiates respondents with managerial responsibilities from those who do not hold this type of position.

7.2.5. Analyses

Study 1. Descriptive statistics (mean, standard deviation, skewness and kurtosis) of individual items on the SCEQ were obtained. Factorial structure was tested through exploratory factor analysis (EFA) using unweighted least squares as the extraction method and applying an oblique rotation criterion (Lloret-Segura et al., 2014; Sass and Schmitt, 2010). Internal consistency (homogeneity) analyses were performed for individual items (corrected item-scale correlations) and for entire scales (Cronbach's alpha). Corrected item-scale correlations should be higher than .30 (Nunnally and Bernstein, 1994). Additionally, values of .70 or more indicate acceptable reliability for Cronbach's alpha coefficient (Nunnally, 1978). The analyses were carried out using SPSS 21.

Study 2. To test the internal structure of the SCEQ, confirmatory factor analyses (CFAs) were performed using Mplus (Muthén and Muthén, 1998-2010) and robust weighted least squares (WLSMV) as the estimation method. Two alternative models were tested: a one-factor model (all 21 items measuring a single dimension) and the hypothesized three-factor model. Model fit was assessed using the chi-square statistic and a number of goodness-of-fit indices (RMSEA, NNFI and CFI). Values of RMSEA lower than .05, lower than .08, and greater than .10, indicate a close fit, a fair fit, and a poor fit of the model, respectively (Browne and Cudeck, 1993; Browne and Du Toit, 1992). NNFI and

CFI values greater than .90 and .95 are typically taken to reflect acceptable and excellent fit to the data, respectively (Marsh, Hau and Grayson, 2005). To compare the alternative models' goodness of fit, the incremental fit indices were estimated. It has been suggested that differences not larger than .01 between NNFI and CFI are considered to indicate irrelevant differences between models (Cheung and Rensvold, 2002; Widaman, 1985). Differences lower than .015 in RMSEA are also proposed as an indicator of negligible practical differences (Chen, 2007). When differences between models cannot be proven, it is preferable to keep the most parsimonious solution.

Internal consistency was tested by means of different reliability indices: Cronbach's alpha coefficient (α), and composite reliability index (rho). Rho values of .70 or greater indicate an acceptable reliability (Hair et al., 1998; Raykov, 2001).

Correlations between questionnaire dimensions were also estimated. It is widely accepted that factor discrimination can be established when inter-factor correlations are below .85 (Kline, 2005).

Evidence of validity based on relationships with external variables was obtained by correlating the scores on the SCEQ with four scales that measure constructs conceptualized in the literature as consequences of safety culture or safety culture outcomes: safety climate, safety satisfaction, job satisfaction, and risky behaviors.

In order to validate the new measure of safety culture, we also collected evidence of discriminant validity between the SCEQ and safety climate. First, we compared the pair correlations among the three factors of safety culture to the pair correlations between each of these factors and safety climate. If the SCEQ and Zohar's safety climate questionnaire measure different constructs, the correlations among the different factors of safety culture should be higher than the correlations of these factors with safety climate. Second, CFAs were carried out with the items on the SCEQ and the items on the Safety Climate scale. Different models were tested to provide further evidence of discriminant validity between the SCEQ and safety climate.

7.3. RESULTS

7.3.1. Study 1

7.3.1.1. Descriptive analyses

Descriptive statistics (mean, standard deviation, skewness and kurtosis) for individual items on the SCEQ are presented in Table 1.The items on the questionnaire showed standard deviations between .72 and 1.15, which indicates some discriminant power of the questionnaire items. The average skewness and kurtosis values are .63 and .74, respectively, with 4 items presenting values out of range (SC1, SC2, SC3 and SC4).

7.3.1.2. Factorial structure: Exploratory factor analysis

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .95, and the Bartlett test of sphericity was statistically significant ($p < .01$), indicating the suitability of these data for factor analytic procedures. The results obtained showed a three-factor solution that accounted for 58% of common variance. Three of the items were removed, as two of them did not load uniquely into any one factor. In addition, both of these items had low communality scores, indicating that the extracted factors explained little of these items' variance. Regarding the third item, it was difficult to theoretically justify its location in the factor where it showed a high factor loading. Thus, we also decided to remove this item. The results presented here are related to the factor analysis conducted with the 21 remaining items. The three factors identified, comprising 21 of the original 24 items, accounted for 59% of the common variance. All the items' factor loadings were equal to or higher than .40 (see Table 17).

Table 17
Factor loadings of the SCEQ items in Study 1

	Strategic decisions	HR practices	Daily activities and behaviors
SC1	.77 (.64)		
SC2	.76 (.63)		
SC3	.85 (.69)		
SC4	.73 (.59)		
SC5	.46 (.47)		
SC6		.53 (.56)	
SC7		.40 (.51)	
SC8		.88 (.75)	
SC9		.84 (.65)	
SC10		.50 (.52)	
SC11		.71 (.61)	
SC12		.65 (.48)	
SC13		.42 (.58)	
SC14			.50 (.39)
SC15			.81 (.59)
SC16			.66 (.59)
SC17			.57 (.59)
SC18			.62 (.64)
SC19			.65 (.70)
SC20			.59 (.59)
SC21			.66 (.62)
Eigenvalue	1.00	2.15	10.38

Note. Factor loadings lower than .40 were not reported. Item communalities are in brackets.

7.3.1.3. Reliability

The Cronbach alpha values were satisfactory for the three subscales: .87 for the dimension *strategic decisions ensuring safety*; .90 for the dimension *HR practices driving safety*; and .91 for the dimension *daily activities and behaviors supporting safety*. Finally, all corrected item-scale correlations were high and fell into the proposed optimal range. Results are as follows: corrected item-scale correlations ranging from .60 to .73 in the dimension *strategic decisions ensuring safety;* from .64 to .77 in the dimension *HR practices driving safety;* and from.55 to .78 in the dimension *daily activities and behaviors supporting safety*.

Therefore, reliability analyses showed strong internal consistency (homogeneity) for the three scales of the SCEQ. In addition, each of the 21 items on the questionnaire was shown to contribute to the homogeneity of its corresponding scale. These results support the stability of the scores on the SCEQ.

7.3.2. Study 2

7.3.2.1. Reliability

Reliability values in Study 2 were satisfactory for the three subscales: *strategic decisions ensuring safety* (α = .87; rho = .92), *HR practices driving safety* (α = .92; rho = .94), and *daily activities and behaviors supporting safety* (α = 93; rho = .96).

7.3.2.2. Validity

Evidence based on internal structure.

Confirmatory factor analysis revealed that the goodness-of-fit of the proposed three-factor model fit the data adequately ($\chi 2$ = 1115.05, df = 186, $p < .01$; RMSEA = .091; NNFI = .964; CFI = .968). By contrast, the one-factor solution provided a poorer fit to the data ($\chi 2$ = 2001.72, df = 189, $p < .01$; RMSEA = .127; NNFI = .931; CFI = .938). Moreover, differences between the fit of the three- and one-factor models were relevant from a practical point of view (ΔNNFI= 0.033, ΔCFI = 0.030 and ΔRMSEA= 0.036). Thus, the three-factor model proposed by the authors was empirically supported.

All factor loadings were statistically significant ($p<.01$) and high enough according to the standards (> .60). Average factor loadings were .83, ranging from .66 to .94, thus supporting convergent validity. The correlation coefficients among the three dimensions of the questionnaire are shown in Table 18. All correlations are high (ranging from .65 to .79), but did not exceed the accepted criterion, thus supporting factor discrimination. These correlations show that the three dimensions represent highly interrelated components of the functioning and operation of any NPP. In line with the safety culture model presented, coherence in the practical importance of safety among the three dimensions was expected, due to the influence they have on each other.

Evidence based on relationships with external variables.

Pearson correlations between each of the three dimensions of the SCEQ and each of the four external criteria are also presented in Table 18. All correlation coefficients are statistically significant ($p< .01$) and exhibit the correct sign, as safety culture is expected to be positively correlated with safety climate, safety satisfaction, and job satisfaction, and negatively with risky behaviors.

Table 18

Inter-factor correlations of the SCEQ and correlations with external criteria

	M	SD	Factor 1	Factor 2	Factor 3
Factor 1 - Strategic decisions	4.36	.59			
Factor 2 - HR practices	3.58	.81	.65		
Factor 3 - Daily activities and behaviors	4.08	.70	.79	.75	
Safety climate	4.05	.64	.65	.68	.65
Safety satisfaction	4.27	.66	.61	.57	.60
Job satisfaction	4.15	.92	.43	.46	.42
Risky behaviors	1.47	.55	-.37	-.77	-.36

Note. All correlations are significant at $p < .01$ (2-tailed)

Discriminant validity between the SCEQ and safety climate.

The correlation between Factor 3 (Daily activities and behaviors) and Factor 2 (HR Practices) was higher than the correlation between either of these two factors and safety climate, and the difference was statistically significant ($t = 4.38$, $p<.01$; $t = 3.08$, $p<.01$, respectively). Additionally, the correlation between Factor 3 (Daily activities and behaviors) and Factor 1 (Strategic decisions) was higher than the correlation between either of these two factors and safety climate, showing a statistically significant difference ($t = 6.65$, $p<.01$; $t = 6.86$, $p<.01$, respectively). However, the correlation between Factor 2 (HR practices) and Factor 1 (Strategic decisions) was not statistically different than the correlation between either of these two factors and safety climate ($t = -1.32$, $p>.05$; $t = -0.04$, $p>.05$, respectively).

Regarding the CFAs, as previously stated, four different models were tested to provide further evidence of discriminant validity between the SCEQ and safety climate. In the one-factor model (model 1) all the items on both questionnaires loaded in the same latent factor. In the two-factor model (model 2), items on the SCEQ loaded in one latent factor, and items on the safety climate questionnaire loaded in a different latent factor. In the four-factor model (model 3), four latent factors where defined (safety climate, strategic decisions, HR practices, and daily activities and behaviors). A final model (model 4) was tested with the same four first-order latent factors and a second-order latent factor comprising the three dimensions of safety culture.

The one-factor model (model 1) did not show adequate fit to data. The two-factor model (model 2) showed adequate fit to data. Additionally, the four-factor model (model 3) showed a better fit than the two-factor model, and differences in fit between the two models were not trivial (ΔRMSEA = .016, ΔNNFI = .019). Finally, the fit of the four-factor model with second-order factors (model 4) showed a satisfactory fit to data, and differences between this model and the four-factor model were not relevant (ΔRMSEA = .002, ΔNNFI = .002, ΔCFI = .002) (see Table 19).

Together, those results provide evidence of discriminant validity between the SCEQ and safety climate.

Table 19

Fit indices of different tested models with SCEQ and Safety climate items

	χ^2	gl	χ^2/gl	RMSEA	NNFI	CFI
One-factor model	7128.52	629	11.33	.131	.875	.882
Two-factormodel	3617.59	628	5.76	.089	.942	.946
Four-factor model	2603.94	623	4.18	.073	.961	.964
Four-factor with second order model	2724.29	625	4.36	.075	.959	.962

Note. $\chi 2$ = Chi-square; gl = degrees of freedom; $\chi 2$/df = relative/normed chi-square; RMSEA = root mean square error of approximation, NNFI = non-normed fit index, CFI = comparative fit index.

Scores of top managers vs. the rest of the employees.

We computed the differences in the SCEQ dimensions across hierarchical levels (managers and supervisors: N=27, rest of employees, N=539). *T*-tests revealed significant differences between top managers and the rest of the employees, with higher mean values for top managers in all three dimensions of the SCEQ: *strategic decisions ensuring safety* ($mean_{top\_managers}$ = 4.87, $mean_{others}$ = 4.34; t = 13.52, p<.01), *HR practices driving safety* ($mean_{top\_managers}$ = 4.25, $mean_{others}$ = 3.53; t = 6.96, p<.01), and *daily activities and behaviors supporting safety (*$mean_{top\_managers}$ = 4.54, $mean_{others}$ = 4.06; t = 6.97, p<.01).

7.4. DISCUSSION

This paper presents a new questionnaire (the SCEQ) to assess safety culture in NPPs. The SCEQ is based on a safety culture model that assesses how the value of safety is embedded in the behaviors displayed in the functioning and operation of NPPs in fulfilling their core functions: strategic decisions, human resources management, and behaviors and activities. It specifically focuses on how the enactment of safety in these areas is appraised by the members of the organizations. Empirical evidence was obtained showing the validity of the SCEQ. Results also support the dimensionality derived from the theory. The 21 items on the questionnaire were found to be good indicators of the three dimensions of the fundamental sets of actions to be considered for this purpose in NPPs. The three dimensions of the SCEQ are highly related to a variety of constructs that are theoretically and empirically associated with enacted safety culture, such as safety climate, safety satisfaction, and job satisfaction, and negatively associated with risky behaviors. Moreover, our study obtained significant differences in the three dimensions of SCEQ between managers and the rest of the employees, with managers scoring significantly higher in the three dimensions of our model. Thus, the perceptual gap in organizational safety, often found in the literature across the organizational hierarchy (Huang et al., 2014), is confirmed for the appraisal of safety values enactment. This gap may be interpreted from different perspectives. First, the results of the hierarchical analysis could have been influenced by hierarchical sub-cultures. The different basic assumptions and beliefs specific to each hierarchical level could have influenced participants' answers. Moreover, managers could have more precise knowledge about items related to strategic decisions and HR practices; therefore, they might better perceive the extent to which safety is important in relation to those items. However, managers also perceive higher enactment in daily activities, even though we can assume that managers and employees have similar access to the information and knowledge. Thus, a third potential interpretation would be that the positive gap in the management perceptions could be influenced by an attribution bias. Respondents who were more responsible for a number of safety measures might perceive them more positively in order to support a more positive self-image (Grote and Künzler, 2000). Interestingly, Huang et al. (2014) point out that employees' interpretations of safety climate are more reliable than those of supervisors when trying to gauge and improve safety climate. Future research should clarify these issues related to the enactment of safety culture.

This paper opens the door to a new approach to understanding and assessing safety culture in NPPs. Two main contributions can be highlighted. On the one hand, we believe that the SCEQ makes it possible to capture the extent to which safety is an enacted value in an NPP. Therefore, the SCEQ may serve as a better predictor of safety performance than existing safety questionnaires that merely assess the endorsement of safety values. On the other hand, the safety culture model formulated helps to understand the main organizational components where the value of safety is expressed, and where the safety culture is constructed and carried out. Thus, it has an excellent diagnostic value, indicating the behavioral dimensions where culture can be improved. Through decisions, organizational practices, and behaviors, the deep layers of the culture are manifested and influence the outputs of the organizational culture. As Schein's model states, culture is composed of three layers that have the power to influence employees' behavior. The deepest layer (i.e., the basic assumptions) has the most powerful influence on these behaviors (Schein, 1992). However, its proper assessment is hardly achieved by questionnaires; instead, it is better obtained through other methods. As these alternative methods are costly, in terms of time and money, and too intrusive (e.g., they may interrupt the daily operation of organizations), methods are needed that, although not reaching the deepest cultural layer, can capture part of its essence. The SCEQ has the advantages of questionnaire methods, while providing more accurate and relevant information than existing conventional questionnaires because it focuses on the degree to which safety is an enacted value, and not just a theoretical aspiration, and it is appraised by the members of the organization.

The SCEQ may be extremely useful for the assessment of safety culture in NPPs, fulfilling diagnostic functions and providing guidance for interventions to improve safety culture. First, each item has been included in the SCEQ because of its influence on the safety performance of NPPs. Thus, the analysis of the scores on each of the items may provide further information about strengths and opportunities for improvement. The scores on the questionnaire provide powerful diagnostic information to identify the operational areas that strengthen safety culture and those that need improvement. It is advisable to pay attention to the dimensions and specific behaviors (items) that receive lower scores, as they can help to identify latent weaknesses that could compromise the safety of the plant. Second, due to the relationships among the dimensions of the model, low scores in one dimension may lead to a decrease in other dimensions. Third, aggregate dimension scores for different units of the NPP may also provide relevant information to identify sub-cultures of safety values and, thus, plan ways to improve the situation. The analysis of the SCEQ scores on the basis of subsamples (e.g., departments and work units, hierarchical levels, employees vs. contractors, etc.) can help to make a more powerful and precise diagnosis of the real importance of safety in the NPP. Whenever possible, it is advisable to investigate items and dimensions where perceptions of different groups differ. A proper design of the study and data collection makes it possible to perform a culture assessment with a multilevel analysis, where safety culture can be assessed at the work unit or organizational level, which in turn could provide collective indicators such as culture strength (see González-Romá and Peiró, 2014) that enrich the assessment and diagnosis of safety culture in NPPs. This multilevel approach to the assessment of safety culture makes it possible to answer a number of questions related to cross-level influences, such as how a work-unit indicator of safety culture can predict individual outcomes beyond the individual endorsement of the safety values (Peiró, Gracia and Martinez-Córcoles, 2015). Finally, the use of the SCEQ in a longitudinal design makes it possible to analyze changes in the safety culture across time, and the antecedents and consequences of these changes. The dynamic of change can also be explored at both the individual and collective levels of analysis.

The model depicted and the developed assessment tool also provide a guiding framework for practitioners to develop interventions to improve safety culture in NPPs. The three dimensions of the model may serve as the basis for understanding in which sets of actions an organizational safety culture is formed, and the critical importance of the enactment of safety in each of them. This model can be presented in training sessions, meetings, etc., and it may inspire learning strategies to promote and build culture values in the members of the organization. It also helps to promote enacted safety values in the decisions, policies, and operations of organizational members at every hierarchical level. Moreover, it indicates to what extent different organizational and behavioral aspects are related and can influence each other. Thus, the model helps the members of the organization to reflect and act on the areas considered.

Two possible limitations of our study are highlighted next. One is the fact that only two NPPs have been included in our sample, and both are from the same country. In future studies, other organizations, including other types of HROs, should be studied to prove the generalizability of the SCEQ and the model supporting it. Moreover, the validity of the questionnaire has been established basically through its concurrent criterion validity with a significant, although limited, number of variables. Future studies will have to extend and consolidate the validity of the questionnaire by paying attention to its predictive validity and extending the criteria for concurrent validity, focusing on significant variables.

In spite of these limitations, in this study significant evidence has been presented to support the psychometric properties of the SCEQ and the theoretical model on which it is based. The results provide empirical evidence of its usefulness for the diagnosis and intervention in the safety culture of NPPs. Moreover, its focus on the enactment of the safety value in several strategic decisions, human resources practices, and daily behaviors in organizations is an innovation that contributes to a more reliable assessment and diagnosis of the "real" safety culture of the organization, avoiding the situation where scores obtained on questionnaires just reflect the espoused values, but not the values in action.

Different arguments have been used to theoretically support the SCEQ's ability to reach the level of enacted values; however, we would like to encourage future studies to provide further empirical evidence about this matter. In future studies on safety culture, half of the sample could receive a questionnaire that includes the differential elements of the SCEQ, and the other half could receive a questionnaire without these elements, thus making it possible to investigate whether there are significant differences between the scores of the two sub-samples.

We hope that future studies will further contribute to the validation of this tool and to a more comprehensive understanding of the process of assessing the safety culture and the way it impacts the processes that ensure safety in HROs. It is also important to identify the most appropriate tools and strategies to introduce changes in these organizations that can strengthen the safety culture in a way that effectively influences the decisions, practices, and behaviors that can ensure safer HROs.

CHAPTER VIII.

ORGANIZATIONAL CULTURE OR SAFETY CULTURE ASSESSMENT?

Abstract

The main goal of the present paper is to shed light on the usefulness of organizational culture and safety culture assessment tools in High Reliability Organizations and, consequently, of general-purpose and domain-specific assessments tools. For this purpose, the Organizational Culture Inventory (OCI) and the Safety Culture Enactment Questionnaire (SCEQ) were studied and compared based on the answers given by the workers of a Spanish NPP. The first (transversal) study in 2008 used the answers of participants (N=566) to the OCI, the SCEQ, and four other questionnaires measuring safety culture outcomes (group safety climate, organizational safety climate, safety satisfaction, and job satisfaction). In the second (longitudinal) study, in 2011, respondents who participated in the first study (N=163) completed three questionnaires measuring safety performance (safety compliance, safety participation, and risky behaviors). Results obtained supported the factor structures of the OCI and the SCEQ proposed by their corresponding theoretical models. Internal consistency of the SCEQ was supported, whereas reliability analyses for the Spanish version of the original 120-item OCI scale showed room for improvement. A 113-item version of the OCI resulted in strong internal consistency for the three dimensions and for 11 (out of 12) sub-dimensions of the OCI. Regression analyses and hierarchical regression modeling were used to investigate the power of the OCI and the SCEQ to predict (separately or together) the safety performance in the NPP under study. Practical implications for researchers and practitioners are included. The empirical studies are complemented by a theoretical clarification of the nature of the

relationship between organizational culture and domain-specific cultures (especially safety culture).

Keywords: culture assessment, nuclear industry; nuclear power plant, organizational culture, safety culture, safety performance, safety outcomes.

8.1. INTRODUCTION

Safety must be a top priority in high reliability organizations (HROs) in order to avoid devastating consequences that can even go beyond organizational limits, as in the case of nuclear power, where failures can "have adverse effects upon whole continents over several generations" (Reason, 1990, p. 1). The scientific community, practitioners, and regulatory bodies have worked to identify, understand, measure, and optimize the determinant factors in the final safety outcomes of HROs. Analyses of major accidents in these organizations have concluded that their cultures had a direct impact on the accidents (Baker, 2007; BEA, 2012; CAIB, 2003; Cullen, 1990; Committee on Lessons Learned from the Fukushima Nuclear Accident for Improving Safety and Security of U.S. Nuclear Plants, 2014; Dawson and Brooks, 1999; Fennell, 1988; HAEA, 2003; Hidden, 1989; IAEA, 1986; Sheen, 1987). Consequently, the HROs' culture and its impact on the safety of operations have been a key study topic for the past 30 years.

The cultures of HROs, and in particular of nuclear power plants (NPPs), have typically been assessed with specific safety culture assessment methodologies, and less often with general-purpose organizational culture assessment tools. In the case of the nuclear industry, the direct assessment of safety culture has been favored. Despite the use of these two approaches, there are practically no studies revealing whether assessing safety culture is more effective in HROs and in the nuclear industry than employing assessment tools that capture the general organizational culture.

The main goal of this paper is to shed light on the usefulness of safety culture and organizational culture assessment tools in HROs and in the nuclear industry by comparing the Safety Culture Enactment Questionnaire (SCEQ) and the Organizational Culture Inventory (OCI), especially the extent to which they can predict safety performance in an NPP. Furthermore, this paper aims to validate the Spanish version of the OCI in the Spanish nuclear industry and gather further evidence for the validation of the SCEQ in the Spanish nuclear industry. These contributions are complemented by a clarification of theoretical aspects surrounding the concepts of organizational culture and safety culture, and the relationship between the two constructs.

8.2. ORGANIZATIONAL CULTURE AND DOMAIN-SPECIFIC CULTURES

The concept of culture can be applied to social units of any type that have been able to learn and establish a vision of themselves and the surrounding environment. These units have their own basic assumptions (Schein, 1985), e.g., cultures belonging to Eastern and Western civilizations, specific countries, ethnic groups, occupations, families, and whole organizations, such as NPPs, or groups within them. Schein (1992) offers one of the most widely accepted definitions of culture:

> “Culture is a pattern of shared basic assumptions that was learned by a group as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and,

therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems" (p. 12).

When this group is the organization, we can talk about organizational culture.

Most scholars agree that organizational culture is made up of distinct elements that are hierarchically ordered from deeper to more surface levels (Deal and Kennedy, 1982; Detert et al., 2000; Furnham and Gunter, 1993; Hofstede, 1991; Lundberg, 1990; Rousseau, 1990; Sanders and Neuijen, 1987, cited in Guldenmund, 2000; Schein, 1985; Van Hoewijk, 1988, cited in Guldenmund, 2000). Deeper-level elements are habitually comprised of assumptions, values, and/or beliefs that guide workers' attitudes and behavior because they have been accepted as the path to success within the organizational context. Surface-levels comprise observable artifacts, such as policies, symbols, myths, and observable behaviors, which are believed to be manifestations of the deep-level elements. Among these authors, Schein's (1985) three-level classification – comprising artifacts, espoused values, and basic assumptions – has been shown to be of paramount influence in organizational contexts, as in the case of the International Atomic Energy Agency, henceforth IAEA (2006c), which has accepted his model and acknowledged its application to safety culture.

Enhancing the cultural elements that are critical to maintaining identity and promoting the 'unlearning' of increasingly dysfunctional cultural elements is one of the key roles of organizational development (Schein, 1985). Because organizational culture stems from the social environment's effect on the individual, and not from the person's genes, it can be evaluated, acted upon, and improved (García-Herrero, Mariscal, Gutiérrez and Toca-Otero, 2013). From an organizational psychology perspective (as opposed to a socio-anthropological perspective [see Section 8.2.2. of this Thesis for a distinction between the two]), the main interest in the organizational culture construct lies, therefore, in its power to shape organizations according to organizational interests and needs.

In the past two decades, significant progress has been made in understanding the impact of organizational culture on specific organizational outcomes. Researchers and practitioners have recast cultural frameworks in diverse ways to better address specific organizational outcomes, such as safety, innovation, quality, customer service, etc. When cultural elements of the organization guide the ultimate behavior of its members toward the attainment of these specific strategic organizational outcomes, these organizations are said to have domain-specific cultures, as in the case of safety culture, innovation culture, quality culture, customer service culture, etc.

There is increasing support for the use of domain-specific cultures in research and practice. The use of a general organizational culture may lose power if it does not capture the specific functional imperatives of the organization. Thus, Klein et al. (1995) highlight that the constructs of a general organizational culture may be distant from the functional imperatives of HROs and, in turn, may not capture specific values and norms that operate to enhance reliability and safety. In other words, the constructs used in research from a general organizational culture perspective may be too general (Frost et al., 1991; Klein et al., 1995). However, other authors state that the underlying elements of domain-specific cultures have a lot in common (Denison, 1996; Moorcroft, 2014; Xenikou and Furnham, 1996).

Moreover, there is evidence of the importance of a general organizational culture in a wide range of organizational outcomes, including safety and financial outcomes (Moorcroft, 2014; Sackmann, 2011).

In spite of the increasing use and popularity of domain-specific cultures, there is no consensus about their relationship with the construct of organizational culture. Instead, the focus has been placed on how to achieve domain-specific cultures that maximize organizational outcomes. In HROs, this means achieving a safety culture that guarantees the attainment of their desired safety outcomes.

8.3. SAFETY CULTURE

Safety culture is seen by a number of researchers as a focused aspect (Richter and Koch, 2004), sub-element (Kennedy and Kirwan, 1998), sub-facet (Cooper, 2000; Mohamed, 2003), or subset (Clarke, 1999; IAEA, 1998a; Reiman and Rollenhagen, 2014; Sorensen, 2002) of organizational culture that refers to organizational and/or worker features related to health and safety (López de Castro et al., 2013). This conceptualization can be extrapolated to other domain-specific cultures, that could be understood as focused aspects, sub-elements, sub-facets or subsets of a general organizational culture that allude to organizational and/or worker features related to innovation, quality, customer service, etc.

The first definition of safety culture was proposed by the IAEA (1991) as "that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance" (p. 1). A few years later, the IAEA (1998) enriched their definition by stating that these 'characteristics' and ‘attitudes’ should be stable and commonly held. This addition by the IAEA attributed two of the classic properties of organizational culture to safety culture: cultural traits are enduring and shared by the organization or by group of members within their limits (Schein, 1992).

Another well-known definition is that of the British Advisory Committee on the Safety of Nuclear Installations: safety culture is “the product of individual and group values, attitudes, perceptions, competences, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization’s health and safety management” (ACSNI, 1993, p. 23).

One of the most criticized aspects within the study of safety culture was highlighted by Cox and Flin (1998). It involves the extensive debate about definitions and theoretical aspects at the expense of empirical research focused on the usability of the concept. Whereas consensus about the definition and implications of the concept seem today out of reach, a number of commonalities across definitions of safety culture were identified by López de Castro et al. (2011) and reformulated in the present Thesis with the inclusion of new definitions (see Section 3.3.). Moreover, in light of the absence of a solid and commonly accepted definition of safety culture, out team proposed a definition that encompasses the agreement reached by researchers since the conception of the term (see Section 3.3. of this Thesis). This definition is also presented in this paper:

"Safety culture is an enduring and high value priority for safety, embedded in the assumptions, values, beliefs, and norms shared by organizational members

and manifested in the organizational policies, procedures and practices and in the members' attitudes, perceptions, and behaviors at work, that determines organizational safety performance and serves to protect the workers, public, and environment from risks, accidents, and illnesses"

8.4. SAFETY PERFORMANCE

To protect the public, workers, and environment from risks, accidents, and illnesses, HROs' organizational members must perform safely. Thus, safety performance refers to organizational members' behaviors that contribute to achieving positive safety outcomes (Martínez-Córcoles et al., 2012; Zohar, 2000, 2002).

Safety performance models have replicated general work or job performance models in the literature, which typically distinguish between task and contextual performance (Borman and Motowidlo, 1993; Motowidlo and Van Scotter, 1994). Whereas task performance refers to accomplishing tasks directly related to the job, contextual performance refers to performing tasks that, although not directly related to the job, have an effect on organizational performance (Borman and Motowidlo, 1997). A later review on job performance carried out by Rotundo and Sackett (2002) completed the domain of job performance with a third set of behaviors, counterproductive performance. Robinson and Bennett (1995) define counterproductive behaviors as voluntary behaviors that harm the wellbeing of the organization, such as theft, harassment, absenteeism, or inattention to quality.

Research on safety performance typically distinguishes between safety compliance (inherited from the concept of task performance) and safety participation (inherited from contextual performance) (Griffin and Neal, 2000; Neal and Griffin, 2004, 2006). Safety compliance refers to the work activities that organizational members must carry out to establish safety at the workplace (e.g., adhering to established safety procedures or wearing required personal protective equipment). Safety participation refers to behaviors that, although not contributing directly to an individual's personal safety, are beneficial for a work environment by supporting process safety (e.g., taking part in voluntary safety activities or helping co-workers with safety-related issues). Based on Rotundo and Sacket's model (2002), Martínez-Córcoles Gracia, Tomás, Peiró and Schöbel (2013) proposed the construct of risky behaviors as a third component in the domain of safety performance. Risky behaviors have the potential to cause adverse consequences for safety. However, Martínez-Córcoles et al. specified that risky behaviors, unlike counterproductive behaviors, do not necessarily produce detrimental effects on productivity. In particular, Martínez-Córcoles et al., following Ramanujam and Goodman's concept of latent errors (2003), consider risky behaviors to be deviations from standard organizational practices, procedures, and expectations that do not always result in adverse consequences and can lead to efficient (but not necessarily safe) outcomes.

Martínez-Córcoles et al. (2013) performed a CFA comparing their three-factor model of safety performance to two alternative models (a two-factor model and a one-factor model), and they found that the three-factor model was significantly better with regard to goodness of fit statistics, thus obtaining empirical support for their proposal.

8.5. CULTURE ASSESSMENT IN THE NUCLEAR INDUSTRY

There is a long-running debate in both academic discussions and practical implications about what methods should be used to capture and assess both organizational culture and safety culture. NPPs need reliable and valid information about the state of their cultures in order to identify which organizational and management aspects must be improved, changed, or reinforced to guarantee the plant's safe operation. This information is obtained by means of qualitative and quantitative assessment methodologies.

8.5.1. Qualitative vs. quantitative strategies

Qualitative approaches include in-depth interviews, employee observations, focus groups, audits, examinations of archival data, expert ratings, and case studies. With qualitative methods, researchers usually obtain non-restricted information from organizational members' own words and points of view. Individuals serve as 'informants' (Rousseau, 1990). Qualitative procedures provide rich and unique information based on participants' assumptions, values, perceptions, attitudes, etc. because the 'meaning' emerges without imposition (Reichers and Schneider, 1990). However, using qualitative methods for organizational culture and safety culture assessment is costly and more time consuming than paper-and-pen employee surveys. Organizations might be more reticent about participating in the large-scale and in-depth investigations that ethnographic approaches to culture usually require (Reichers and Schneider, 1990). In addition, these approaches tend to produce 'discovery data', rather than hard data that can be incorporated into a management action plan (Choudry et al., 2007; Glendon and Stanton, 2000).

Quantitative approaches include surveys, highly structured interviews and Q-sorts, and, especially, questionnaires. Using quantitative methods, researchers usually obtain restricted information from organizational members' responses to standardized sets of stimuli or questions. With this measurement strategy, researchers impose meaning on a set of data rather than letting the meaning emerge (Reichers and Schneider, 1990). In these cases, individuals serve as 'respondents' (Rousseau, 1990). Quantitative methods for organizational culture and for safety culture assessment ideally count on extensive empirical support that corroborates the reliability and validity of the chosen stimuli for the purpose for which they were created. That is, an organizational culture or a safety culture questionnaire will be useful in the nuclear industry to the extent that its items target specific organizational and management issues that have been shown to be relevant to nuclear safety. From this point of view, quantitative methods, such as safety culture questionnaires, are target-oriented by nature and often more efficient than qualitative approaches. Questionnaires provide instant quantified results that can be used to produce medians or means, compare subgroups, and benchmark the results obtained (Guldenmund, 2007). They are usually more practical and less time consuming. Most importantly, questionnaires allow the culture of HROs to be assessed more frequently and systematically than qualitative approaches, which in turn helps to monitor the extent to which the cultural aspects of the HROs are backing or compromising nuclear safety.

8.5.2. General vs. domain-specific approaches

In studying the culture of NPPs, two different approaches can be distinguished. In the first, the safety culture of an organization is captured through the study of its general organizational culture. Because safety culture is a focused aspect, sub-element, sub-facet, or subset of a broader organizational culture, organizational culture questionnaires can provide information about cultural elements that have an impact on plant safety performance. However, the authors of the present paper have found few studies that use general-purpose organizational culture questionnaires in the nuclear industry (e.g., Haber, O'Brien, Metlay and Crouch [1991] with the Organizational Culture Inventory; Reiman and Oedewald [2004] with the CULTURE-questionnaire).

The second and most widely used approach is the direct assessment of safety culture (Harvey et al., 2002; Lee and Harrison, 2000; López de Castro et al., 2013; López de Castro et al., 2017; and Ostrom et al., 1993; to name a few).

In the present study, the Organizational Culture Inventory (OCI) and the Safety Culture Enactment Questionnaire (SCEQ) are considered. The OCI is used because of its pervasiveness, as it is believed to be the most widely used organizational culture assessment instrument in the world (Balthazard, Cooke and Potter, 2006). The SCEQ is employed because of its functionality, as it claims to capture information about the enactment of safety in HROs and NPPs (López de Castro et al., 2017).

8.5.2.1. The Organizational Culture Inventory (OCI)

The Organizational Culture Inventory was developed by Human Synergistics International (Cooke and Lafferty, 1987). Since its introduction in prototype form in 1983, the inventory has been used by thousands of organizations, completed by over two million respondents, and translated into numerous languages. The OCI has been used in a wide array of organizations, such as nuclear power plants, research laboratories, universities, consulting firms, sales organizations, governments, hospitals, etc., for a variety of purposes, including to enhance system reliability and safety (Haber et al., 1991; Keenan, Cooke and Hillis, 1998; Shurberg and Haber, 1992), facilitate strategic alliances and mergers (Slowinski, 1992), predict the type of leadership that characterizes an organization's culture (Eppard, 2004), provide data for the development of person-organization fit selection criteria (Belova, 2003), find cultural elements critical to reducing turnover (Vukotich, 1996), or decrease stress levels (van der Velde and Class, 1995).

The OCI provides an assessment of the operating organizational culture in terms of the behaviors that members believe are required to “fit in" and "meet expectations” within their organization. The OCI comprises 12 cultural scales or behavioral norms that describe thinking and behavioral styles that organizational members may be expected to adopt in carrying out their work and in interacting with others. These 12 behavioral norms are defined by two underlying dimensions: first, a concern for people versus a concern for completing tasks; second, expectations for behaviors that fulfill higher-order satisfaction needs versus expectations for behaviors aimed to protect and maintain lower-order security needs (i.e. to protect one's own sense of security) (Maslow, 1954). At the same time, the 12 behavioral norms are categorized into three different general cultural styles: Constructive, Passive/defensive, and Aggressive/defensive.

In Constructive cultures, organizational members are encouraged to interact with others and approach tasks in ways that will help them meet their higher-order satisfaction needs. This cultural style is directed toward the attainment of organizational goals through the development of people. Constructive cultures account for synergy and explain why certain individuals, groups, and organizations are particularly effective in terms of performance, growth, and work quality (Human Synergistics International website). In Passive-Defensive cultures, organizational members believe they must interact with people in ways that will not threaten their own security. This cultural style characterizes organizations where people subordinate themselves to the organization, but in the process end up creating stress for themselves and allowing the organization to stagnate. Passive-Defensive cultures may ensure a predictable and secure situation, but sacrificing learning, adaptability, and even organizational survival (Human Synergistics International website). In Aggressive-Defensive cultures, organizational members are expected to approach tasks in forceful ways in order to protect their status and security (Cooke, 1989); tasks are emphasized over people. In the extreme, in Aggressive-Defensive cultures, organizational members focus on their own needs at the expense of those of the group. Though sometimes temporarily effective, Aggressive-Defensive cultures may lead to stress, decisions based on status rather than expertise, and conflict rather than collaboration (Human Synergistics International website).

Each of the three cultural styles of the OCI is further divided into four cultural norms. The four constructive cultural norms, as described by Cooke and Rousseau (1988, pp. 258-259), are:

A **Humanistic-encouraging culture** characterizes organizations that are managed in a participative and person-centered way. Members are expected to be supportive, constructive, and open to influence in their dealings with one another (helping others to grow and develop; taking time with people).

An **Affiliative culture** characterizes organizations that place a high priority on constructive interpersonal relationships. Members are expected to be friendly, open, and sensitive to the satisfaction of their work group (dealing with others in a friendly way; sharing feelings and thoughts).

An **Achievement culture** characterizes organizations that do things well and value members who set and accomplish their own goals. Members of these organizations set challenging but realistic goals, establish plans to reach these goals, and pursue them with enthusiasm (pursuing a standard of excellence; openly showing enthusiasm).

A **Self-actualizing culture** characterizes organizations that value creativity, quality over quantity, and both task accomplishment and individual growth. Members of these organizations are encouraged to obtain enjoyment from their work, develop themselves, and take on new and interesting activities (thinking in unique and independent ways; doing even simple tasks well).

The four passive/defensive cultural norms, as described by Cooke and Rousseau (1988, pp. 258-259), are:

An **Approval culture** describes organizations in which conflicts are avoided and interpersonal relationships are pleasant, at least superficially. Members feel that they should agree with, gain the approval of, and be liked by others (making sure people accept you; ‘going along’ with others).

A **Conventional culture** is descriptive of organizations that are conservative, traditional, and bureaucratically controlled. Members are expected to conform, follow the rules, and make a good impression (always following policies and practices; fitting into ‘the mold’).

A **Dependent culture** is descriptive of organizations that are hierarchically controlled and non-participative. Centralized decision-making in such organizations leads members to do only what they are told and clear all decisions with superiors (pleasing those in positions of authority; doing what is expected).

An **Avoidance culture** characterizes organizations that fail to reward success but punish mistakes. This negative reward system leads members to shift responsibilities to others and avoid any possibility of being blamed for a mistake (waiting for others to act first; not taking many chances).

The four aggressive/defensive cultural norms, as described by Cooke and Rousseau (1988, pp. 258-259), are:

An **Oppositional culture** describes organizations in which confrontation prevails and negativism is rewarded. Members gain status and influence by being critical and, thus, receive reinforcement if they oppose the ideas of others and make safe (but ineffectual) decisions (pointing out flaws; being hard to impress).

A **Power culture** is descriptive of non-participative organizations structured on the basis of the authority inherent in members' positions. Members believe they will be rewarded for taking charge, controlling subordinates, and, at the same time, being responsive to the demands of superiors (building up one's power base; motivating others any way necessary).

A **Competitive culture** is one in which winning is valued and members are rewarded for outperforming each other. People in such organizations operate in a 'win-lose' framework and believe they must work against (rather than with) their peers in order to be noticed (turning the job into a contest; never appearing to lose).

A **Competence/perfectionistic culture** characterizes organizations in which perfectionism, persistence, and hard work are valued. Members feel they must avoid all mistakes, keep track of everything, and work long hours to attain narrowly defined objectives (doing things perfectly; keeping on top of everything).

The theoretical framework underlying the OCI posits that constructive styles are indicative of positive and supportive environments that facilitate problem solving, decision making, teamwork, productivity, long-term effectiveness, etc., whereas passive/defensive and aggressive/defensive are posited to be negatively related to desirable outcomes and positively related to undesirable outcomes, detracting from effective organizational performance. Defensive styles are therefore useful in identifying potentially dysfunctional environments.

The nuclear industry has explored the influence of the OCI cultural styles and norms on safety, and tried to gather evidence of the validity of the OCI based on relationships between its cultural styles and norms and a number of outcomes. Haber and Shurberg (1993a) found that an aggressive/defensive culture could work in situations with an established anticipatory strategy in the nuclear industry. However, when situations were not anticipated or foreseen (requiring ad hoc strategies), a constructive culture was needed. Haber and Shurberg (1993b) also observed, when examining two NPPs, that the plant with the highest scores on constructive styles also scored higher on overall commitment to the organization’s perceived hazardous nature of work and attention to safety. In the aircraft industry, Human Synergistics found that organizations with constructive cultural styles paid more attention to safety, and organizations with defensive cultural styles did not comply with safety operative values (Gourley, 2005). Stewart (2014), from Human Synergistics, positions himself in favor of constructive cultures and summarizes some of the outcomes that HROs can expect with each of the three cultural styles: passive cultures produce ‘keep your head down’ and ‘do not rock the boat’ attitudes, which in turn lead to incompetence and ineffective safety procedures, among others. Aggressive cultures result in high stress levels and discourage ownership of safe practices. Moreover, they result in high employee turnover and absenteeism, which in turn increases the number of new and less-experienced employees in the HRO. Constructive cultures have a positive impact on training, written procedures, incident reporting, maintenance and testing, and management policies, among others. Furthermore, a constructive culture is more effective at following rules than a conventional one, more effective at catching and pointing out mistakes than an oppositional one, and more effective at reducing mistakes and operating safely than a perfectionistic one. Another study (Utility Service Alliance and Human Synergistics, 2004) tried to identify the optimal culture for nuclear organizations. For this purpose, 123 employees from NPPs in the US completed the OCI to identify the behaviors that should be expected and encouraged in a nuclear plant to maximize organizational effectiveness. Afterwards, a group of NPP leaders and three representatives of the Institute of Nuclear Power Operations (INPO) fine-tuned the ‘ideal’ model, taking into account INPO’s attributes of high-performing organizations and principles of excellence in human performance. The conclusion was that in an optimal culture for NPPs, constructive norms (in this order of importance: humanistic-encouraging, self-actualizing, achievement, and affiliative) should prevail over defensive norms. They also noted that some degree of defensive norms is needed, especially an oppositional norm that will encourage the type of questioning attitude and rigor required to perform at the highest levels of excellence in a NPP.

The 12 cultural norms of the OCI are represented by 120 statements (10 per cultural norm), where respondents have to indicate their level of agreement using a 1–5 scale, (1) not at all, (2) somewhat, (3) moderately, (4) mostly, and (5) strongly. A number of studies show empirical support for the structure and internal consistency of the 12 cultural norms (lower-order dimensions) and the three cultural styles (higher-order dimensions) provided by principal component analyses (e.g., Cooke and Rousseau, 1988; Cooke and Szumal, 1993; Xenikou and Furnham, 1996). However, Cook and Szumal (1993) also noted that some cultural scales showed dual loadings, which could be an indication of weaknesses in discriminant validity or a suggestion that norms for the Aggressive-Defensive and Passive-Defensive styles may be loosely linked in certain settings. Moreover, Oberholtzer (2005) could not find evidence to support the discriminant validity of the OCI because correlations over .90. were found among the three cultural styles it proposes.

8.5.2.2. The Safety Culture Enactment Questionnaire (SCEQ)

The Safety Culture Enactment Questionnaire was developed by the IDOCAL[9] (López de Castro et al., 2017) for the assessment of safety culture in High Reliability Organizations (HROs) in general, and in particular, in NPPs. Since its development in 2008, the SCEQ has been used in the Spanish nuclear industry to provide guidance for interventions to improve safety culture and, as a result, to enhance plant safety performance.

The SCEQ is designed to assess the degree to which safety is an enacted value within HROs and NPPs, going one step beyond existing safety culture questionnaires, which typically address the level of espoused values. Espoused values reflect what the organization articulates as essential, the managerial philosophy, and its aspirations. However, enacted values are those that are supported, prioritized, and rewarded in the day-to-day organizational functioning and, consequently, the ones that inform members about the actions expected from them (Schein, 1992). Therefore, enacted values guide employees' ultimate behavior in real situations and settings. Because of this, predicting future employee behaviors and future safety performance in a NPP calls for tools that

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capture the enactment of safety, and not only the culture reflected in its espoused values (López de Castro et al., 2017).

The SCEQ is based on a theoretical safety culture model that comprises three fundamental components of the functioning and operation of HROs, where the value of safety must be put into practice: strategic decisions, personnel management, and operating behaviors. These three components, as described by López de Castro et al. (2017), are:

Strategic decisions ensuring safety: "safety culture manifests itself in the role safety plays in the strategic decisions made in NPPs. This dimension covers decisions that are carefully and thoughtfully made for the smooth running of the plant. It encompasses decisions about the operation of the plant and the conflicts between safety and other competing goals, and decisions about the allocation of resources and the establishment of procedures" (p. 47).

Human resources practices driving safety: "the safety culture of an NPP manifests itself in the extent to which the HR practices are coherently articulated to guarantee high levels of safety performance. For this purpose, the organization must be able to bring in new workers (e.g., by means of appropriate recruitment and selection practices) who share the priority of safety and have the ability and willingness to work safely; it must continuously prepare the employees, especially in safety matters (e.g., through training and performance appraisals), and it must encourage and motivate them (e.g., through formal reward systems, such as goal setting, promotions or salary, as well as informal rewards, such as recognition) to work safely under all conditions" (p. 47).

Daily activities and behaviors supporting safety: "The extent to which safety is important for an NPP is reflected in the daily behaviors of every employee in the organization, the relationship with external agents (e.g., contractors and regulatory bodies), and the day-to-day operations (such as meetings or internal publications)" (p. 49).

The three fundamental components of the functioning and operation of HROs are represented by 21 items, on which respondents provide information about the degree to which nuclear safety is important to the organization and enacted in decisions and actions carried out in one of the components. Five-point Likert-type scales with responses ranging from 1 (not important at all) to 5 (very important) are used to record this information.

López de Castro et al. (2017) provided empirical evidence to support the validity of the SCEQ. Their empirical study in the nuclear industry supported the internal structure of the SCEQ and showed how the dimensions of the SCEQ were highly related to constructs that are theoretically and empirically associated with enacted safety culture and regarded in the literature as consequences of safety culture, such as safety climate, safety satisfaction, and job satisfaction, and negatively associated with risky behaviors. Furthermore, the study obtained significant differences in the three dimensions of the SCEQ between managers and the rest of the employees, with managers scoring significantly higher on the three dimensions of our model, providing support for the perceptual gap in organizational safety often found across the organizational hierarchy (Huang et al., 2014).

8.5.2.3. Ensuring safety: organizational culture or safety culture assessment?

Although a significant number of studies defend the usefulness of particular organizational culture and safety culture assessment tools in HROs and NPPs, there is almost no literature that empirically shows whether the assessment of a general organizational culture or a domain-specific safety culture is preferable in the nuclear industry.

We found a few studies that compared the answers to the OCI to the answers given to different versions of a safety culture scale developed by researchers at the University of California at Berkeley (Brown, 2000a; Haber et al., 1991). This safety culture scale was based in part on work with personnel serving on aircraft carriers, and it was developed for use in organizations where the consequence of making a mistake is very high (e.g., naval aircraft carriers, air traffic control centers). The scale was designed to assess an individual's perception of the importance of safety and acting safely to success in an organization (Haber et al., 1991).

As part of a research project conducted by Brookhaven National Laboratory for the United States Nuclear Regulatory Commission (NRC), Haber et al. (1991) administered a battery of questionnaires in a Fossil Fuel Plant (FFP) and, at a later stage, in an NPP. The battery for the Fossil Fuel Plant included the OCI and 19 items from the aforementioned safety culture questionnaire by the Berkeley group, which at the time was being developed (Roberts, 1990, cited in Haber et al., 1991). The battery for the NPP included the OCI and 40 items from the safety culture questionnaire by the Berkeley group, which by then had already been applied at several HROs (Roberts, 1990, cited in Haber et al., 1991). In both studies (FFP and NPP), several scales from the OCI yielded significant differences among departments and functional groups (e.g., between engineers and employees in the operations and maintenance departments), as well as differences between organizational levels (managers and non-managers). When the safety culture scale was applied in the FFP, managers scored significantly higher than non-managers, but no differences were obtained across any of the departments (e.g., operations vs. support departments), despite significant differences among these groups in the perceived hazard of their jobs. When the safety culture scale was applied in the NPP, no statistically significant differences were obtained across any of the departments or organizational levels. The authors of the study interpreted that either the safety scale could not distinguish among groups that would be expected to differ in safety culture or that there was a homogeneously high regard for attention to safety within this organization.

However, the main utility of culture assessment tools for organizations lies in their ability to predict specific organizational outcomes. In the case of HROs and NPPs, the key outcomes to be predicted are safety outcomes, most importantly, accidents. But the ratio of nuclear accidents occurring in the nuclear industry to active nuclear power reactors is extremely low, which limits the possibilities of studying the power of culture assessment tools to predict future accidents. Instead, attempts have been made to study the ability of these tools to predict more likely safety outcomes (e.g., work-related injuries or near-miss incidents, at best), and particularly to predict safety performance behaviors because they are understood as antecedents of safety outcomes, as shown in the literature (see the Meta-Analysis of Christian et al., 2009).

In the literature, two empirical studies were found that compare the OCI to safety questionnaires in terms of their power to predict safety outcomes and safety performance.

In the first study, Brown (2000a) elaborated on the work of Sonja Haber and Deborah Shurberg for the NRC. In particular, he analyzed the results of their application of the OCI and the 40-item safety scale of the Berkeley group in two research facilities. Archival data showed that the two facilities consistently - differed on work-related illness and injuries. Brown’s goal was to determine whether existing differences in these safety outcomes were related to general organizational factors or to safety culture. Brown (2000a) did not find significant differences between the two facilities on the 12 cultural norms of the OCI. He also did not find differences among occupational groups within each of the facilities. However, significant differences were found for all but one of the 12 cultural norms of the OCI in the responses given by the same occupational groups in different facilities. Meanwhile, the safety scale did not yield significant differences between the two facilities or among the groups within each facility and between facilities. Some differences on selected subsets of 40 items that comprise the safety scale were found, but they were not as large or reliable as those for the OCI. Brown (2000a) explained that his results were consistent with the findings of Haber et al. (1991) and with Cooke and Szumal’s (1993) suggestion that specialized scales are not necessarily more sensitive to safety-relevant organizational differences than general-purpose inventories like the OCI.

However, Brown (2000b) also argued that conclusions drawn from the comparison of the OCI with the Berkeley group's safety scale may not be reliable for two reasons. First, the wording of some of the items preserved the vocabulary of the aircraft carrier personnel and may not have 'translated' well from the original context. Second, the 'root' statement of the safety scale ("To what extent do each of the following help you meet what is expected of you to do your job well in this organization?") may have produced different responses depending on which part of the statement the participant pays more attention to (i.e., 'fulfilling what is expected' or 'doing your job well'). Consequently, Brown (2000b) concluded that it cannot be stated that specialized surveys 'per se' are not sensitive to cultural differences, but rather that the Berkeley group's scale may not perform as intended.

In the second study, Smith, Garrett and Calvert (2006) presented a safety culture model that included a re-analysis of survey data from nuclear facilities gathered by the IAEA (1991) and input from discussions with Safety Managers who developed meaningful questions for mining employees. The resulting model covered five safety factors (safety leadership, safety communication, safety management, safety change readiness, and safety performance), further operationalized by 60 items, whose structure was supported by confirmatory factor analysis. Safety leadership, safety communication, safety management, and safety change readiness were found to be predictors of safety performance (measured as a safety system rating), accounting for 59% of the variance in safety performance. Of this percentage, 47% of the variance was predicted by the safety leadership factor. As part of their study, Smith and Garrett also explored the predictive power of the OCI, in particular of the Constructive style, which accounted for 22% of the variance in the safety performance factor of the aforementioned safety culture model. Along with constructive styles, passive/defensive styles predicted 23% of the variance in safety performance. However, the fact that safety performance is portrayed both as one of the dimensions of the safety culture model and as a consequent of the other four safety culture dimensions questions the results obtained in this study. Furthermore, the authors of the study do not state whether safety performance was measured at a later point than the OCI and the other four safety culture measures, which would be a requirement for talking about predictive validity.

The nuclear industry calls for tools that provide information about the future safety performance of employees and future safety outcomes. For this purpose, a variety of organizational culture and safety culture questionnaires have been used. However, empirical support for one approach or the other in HROs seems insufficient. The present paper aims to shed light on this matter by collecting evidence about the suitability of organizational culture assessment tools and safety culture assessment tools for the nuclear industry. To do so, the Safety Culture Enactment Questionnaire (SCEQ) and the Organizational Culture Inventory (OCI) will be analyzed and compared in two different studies. In particular, the main goals pursued in each of these two studies are described:

Study 1 (N=566) is cross-sectional because all the variables were measured in 2008. The goals of this study are:

1) To validate the OCI in the Spanish nuclear industry.

2) To further validate the SCEQ in the Spanish nuclear industry.

Study 2 (N=163) is longitudinal because organizational culture and safety culture were measured in 2008, and three safety performance indicators were measured in 2011. The goals of this study are:

3) To provide insights into the power of organizational culture questionnaires (measured by the OCI) and safety culture questionnaires (measured by the SCEQ) to predict safety performance.

Furthermore, both Study 1 and Study 2 have two goals:

4) To empirically examine the relationships between organizational culture (measured by the OCI) and safety culture (measured by the SCEQ).

5) To provide insights into which OCI cultural styles and cultural norms should be favored in the nuclear industry.

8.6. METHOD

8.6.1. Study 1

8.6.1.1. Participants and procedure

566 workers from two NPPs belonging to the same company completed the questionnaire. The total size of the company was 760 employees. Thus, we obtained a satisfactory response rate of 74.47%. The sample included all the responsibility levels and functional areas in the nuclear facility. Regarding demographic variables, 59.5% of the sample did not have university studies, 4%

were under 30 years old, 23% were between 30 and 45 years old, and 73% were older than 45.

The scale was administered in their workplace as part of a broader battery of questionnaires designed to evaluate different constructs and variables related to safety culture and safety climate. The administration of the battery took place during work time in small groups in a quiet and convenient room, and participants needed around 30 minutes to complete the entire battery. The questionnaire was administered by the researchers, who stayed at the NPPs to ensure that any doubts about filling out the questionnaire could be immediately resolved. Participants were provided with instructions explaining the purpose of the study and the way the questionnaire should be completed. They were encouraged to answer honestly and take as much time as they needed to accurately complete the questionnaire. Voluntary participation, confidentiality, and anonymity were guaranteed. The present research was conducted in accordance with international ethical guidelines, which are consistent with the American Psychological Association (APA) guidelines.

8.6.1.2. Measures

Organizational culture

Organizational culture was assessed by the Organizational Culture Inventory (OCI). As described in Section 5.2.1., the OCI, developed by Human Synergistics International (Cooke and Lafferty, 1987), provides an assessment of the operating organizational culture in terms of the behaviors that members believe are required to ‘fit in’ and ‘meet expectations’ within their organization. The OCI comprises

12 cultural norms categorized into three different general cultural styles: *Constructive* (e.g., “resolve conflicts constructively”, “show concern for people”, “do even simple tasks well”), *Passive/defensive* (e.g., “switch priorities to please others”, “willingly obey orders”, “put things off”), and *Aggressive/defensive* (e.g. “turn the job into a contest”, “refuse to accept criticism”, “stay on the offensive”). Each cultural norm is represented by 10 items with which respondents report their degree of agreement using a five-point Likert-type scale ranging from 1 (not at all) to 5 (strongly), with a total of 120 items. In the present study, we addressed the validation of the original 120-item version of the OCI adapted to Spanish. However, in our sample, some items were found to show unsatisfactory psychometric properties. Thus, as a result of the validation process, a 113-item version of the OCI was proposed and used to carry out further analyses in studies 1 and 2. Cronbach’s alphas in the 113-item version were as follows: $\alpha = .96$ for the *Constructive style*, ranging from .78 to .92 for its sub-dimensions of cultural norms. $\alpha = .90$ for the *Passive/defensive style*, ranging from .76 to .84 for its cultural norms. $\alpha = .91$ for the *Aggressive/defensive style*, ranging from .68 to .88 for its cultural norms.

Enacted safety culture

Safety culture was assessed by the SCEQ (López de Castro et al., 2017). The SCEQ measures the degree to which the value of safety is enacted in three fundamental components of the functioning and operation of NPPs that correspond to the three dimensions of the questionnaire: *Strategic decisions ensuring safety*, *Human Resources practices driving safety*, *Daily activities and* *behaviors supporting safety*. Participants were asked to give their opinion about the practical importance of safety on a daily basis in their organization. Five-point Likert-type scales with responses ranging from 1 (not important at all) to 5 (very important) were used to respond to the 21 items of the SCEQ. *Strategic decisions ensuring safety* was measured by five items (To what degree is nuclear safety important…"when allocating resources (time, personnel, money)?", "when solving conflicts between safety and production?"). Cronbach's alpha was .87. *Human resources practices driving safety* was assessed by eight items (To what degree is nuclear safety important … "in hiring personnel", "in evaluating employees' performance". Cronbach's alpha for this dimension was .90. *Daily activities and behaviors supporting safety* was measured by eight items (To what degree is nuclear safety important … "in the daily behavior of the employees", "in the meetings"). Cronbach's alpha for this dimension was .91.

Group safety climate

Group safety climate was assessed by an adapted version of the Group-level Safety Climate scale (Zohar and Luria, 2005), which was validated in another study (Latorre, Gracia, Tomás and Peiró, 2013). The scale is composed of 15 items that assess employees' perceptions about the group leader's safety policies, procedures, and practices, and about the group members' safety behaviors. Some examples of items are: "our boss insists that we follow the safety norms while repairing equipment, machines, or systems", "we make sure we have everything we need to do the job in a safe way", "there is a frequent check on whether the safety norms and procedures are being followed", or "we talk about how to improve safety”. The questionnaire has a 5-point Likert scale from “strongly disagree” to “completely agree.” Cronbach’s alpha was .96.

Organizational safety climate

Organizational safety climate was measured with an adapted version of the Organizational-Level Safety Climate scale (Zohar and Luria, 2005), which has been used in other previous studies (e.g., López de Castro et al., 2017). This adaptation kept the 16 items from Zohar and Luria’s questionnaire, although the referent for workers’ perceptions was modified from top management to the whole organization. Examples of items are: Our company…“reacts quickly to solve problems when told about safety hazards”, “provides all the equipment needed to do the job safely”, and “gives safety personnel the power they need to do their job”. Following Zohar and Luria’s scale, respondents were asked to answer these questions on a five-point Likert-type scale ranging from 1 (completely disagree) to 5 (completely agree). Cronbach’s alpha was .94.

Safety satisfaction

Safety satisfaction was assessed by the “Safety Satisfaction Questionnaire (SSQ)”, a scale developed by our team and used previously in other studies (e.g., López de Castro et al., 2017). The questionnaire was composed of 6 items designed to explore participants’ satisfaction with organizational safety (e.g., “To what extent are you satisfied with radiological issues?”). Respondents answered on a five point Likert-type scale ranging from 1 (very unsatisfied) to 5 (very satisfied). Cronbach’s alpha was .90.

Job satisfaction

Job satisfaction was measured with three items. It was conceptualized as overall satisfaction with the company, with the unit of work, and with the work itself. Consequently, participants were asked about their job satisfaction in relation to each of these domains: “How satisfied are you with your work?”; “How satisfied are you with your team?” and “How satisfied are you with your company?” A five-point Likert-type scale ranging from 1 (very unsatisfied) to 5 (very satisfied) was employed for this purpose. Cronbach’s alpha was .80.

8.6.1.3. Analyses

Descriptive statistics (mean, standard deviation, skewness, and kurtosis) were obtained for individual items on the OCI. To test the internal structure of the OCI, confirmatory factor analyses (CFAs) were performed with Lisrel 8.80 (Jöreskog and Sörbom, 2006). Maximum likelihood (ML) was selected as the estimation method, and Pearson correlations were used as input matrices. The ML estimation procedure assumes continuous, multivariate normal observed variables (e.g., Jöreskog, 1969, 1977). However, it has been stated that the linear approach can be an adequate approximation to ordered categorical data when the items have a sufficient number of categories (minimum 5) and reasonably fit a normal distribution (Lloret et al., 2014; Muthén and Kaplan, 1985). An averaged absolute value of the skewness of the variables lower than 1 (Boomsma, 1983), and most variables with univariate skewness and kurtosis in the range from –1 to +1 (Muthén and Kaplan, 1985) have been considered as criteria to support a reasonable fit to normal distribution. In the present study, the linear approach was an adequate approximation to the data because the items had a 5-category response scale and reasonably fitted a normal distribution.

The following alternative models were tested with CFA using the global scale: 1) a one-factor model (all 120 items measuring a single dimension called organizational culture); 2) a three-factor model (representing the three styles of organizational culture: Constructive style (40 items), Passive/defensive style (40 items) and Aggressive/defensive style (40 items)); and 3) a 12-factor model (representing the 12 types of organizational culture, each consisting of 10 items). Additionally, with only the items from each of the three styles of organizational culture, the following alternative models were compared using CFA: 1) a one-factor model (all items from the specific general style, measuring a single dimension); and 2) a four-factor model (representing the four types of organizational culture included in each specific style of organizational culture).

In order to interpret the results of the CFAs, model fit was assessed using the chi-square statistic and a number of goodness-of-fit indices (RMSEA, NNFI and CFI). Values of RMSEA lower than .05, lower than .08, and greater than .10 indicate a close fit, a fair fit, and a poor fit of the model, respectively (Browne and Cudeck, 1993; Browne and Du Toit, 1992). NNFI and CFI values greater than .90 and .95 are typically taken to reflect acceptable and excellent fit to the data, respectively (Marsh et al., 2005). To compare the alternative models' goodness of fit, the incremental fit indices were estimated. It has been suggested that differences not larger than .01 between NNFI and CFI are considered to indicate irrelevant differences between models (Cheung and Rensvold, 2002; Widaman, 1985). Differences lower than .015 in RMSEA are also proposed as an indicator of negligible practical differences (Chen, 2007). When differences between models cannot be proven, it is preferable to keep the most parsimonious solution.

Internal consistency (homogeneity) analyses were performed for individual items (corrected item-scale correlations) and for entire scales (Cronbach’s alpha). Corrected item-scale correlations should be higher than .30 (Nunnally and Bernstein, 1994). Additionally, values of .70 or more indicate acceptable reliability for Cronbach’s alpha coefficient (Nunnally, 1978). The analyses were carried out using SPSS 22.

Correlations between the scales and subscales of the OCI were also estimated. It is widely accepted that factor discrimination can be established when inter-factor correlations are below .85 (Kline, 2005).

Finally, evidence of validity based on relationships with external variables was obtained by correlating the scores on the OCI and the SCEQ with four scales that measure constructs that are theoretically and empirically associated with (safety) culture and regarded in the literature as consequences of safety culture (group safety climate, organizational safety climate, safety satisfaction, job satisfaction). From this point on, we will refer to these four constructs as safety culture outcomes. Further evidence of validity was provided by correlating the scores on the OCI with those of the three dimensions of the SCEQ (daily activities and behaviors supporting safety, human resources practices driving safety, and strategic decisions ensuring safety). Descriptive statistics, Cronbach’s alpha coefficients, and correlations among the external variables were also estimated.

8.6.2. Study 2

8.6.2.1. Participants and procedure

Three years later we administered a similar battery of questionnaires in the same company, along with safety performance scales. On this occasion, we received a completed questionnaire from 495 workers. The total size of the company was 760 employees. Thus, we obtained a response rate of 65.13%. Again, the sample included all responsibility levels and functional areas in the nuclear facility. 47% of participants had completed university studies; 3% of participants were under 30 years old; 18% were between 30 and 45; and 79% were older than 45.

The questionnaire administration procedure was exactly the same as the one described for study 1. For our second study, the final sample was composed only by those subjects who answered both surveys, the present one and the survey administered three years before. In order to make this match and maintain anonymity, at the end of both surveys, participants had to respond to a few questions only they knew the answer to (f.i., “write the first letter of the month when your father was born”). Participants’ answers to these questions allowed us to create an alphanumeric code to identify them. The sample in study 2 was finally composed of 163 employees.

8.6.2.2. Measures

Organizational culture

Data for organizational culture collected in Study 1 were used in Study 2. As previously stated, organizational culture was measured by the OCI (see measures section for Study 1). Cronbach's alpha values for the dimensions and sub-dimensions of this scale in the reduced longitudinal sample (N = 163) at Time 1 were as follows: α = .96 for the *Constructive style*, ranging from .76 to .92 for its sub-dimensions of cultural norms; α = .90 for the *Passive/defensive style*, ranging from .78 to .83 for its cultural norms; α = .89 for the *Aggressive/defensive style*, ranging from .61 to .87 for its cultural norms.

Enacted safety culture

Data for enacted safety culture collected in Study 1 were used in Study 2. Enacted safety culture was assessed by the SCEQ, as previously mentioned (see measures section in Study 1). Cronbach's alphas for the dimensions of this scale in the reduced longitudinal sample (N = 163) at Time 1were as follows: α = .87 for *Strategic decisions ensuring safety*; α = .90 for *Human resources practices driving safety*; and α = .91 for *Daily activities and behaviors supporting safety*.

Safety compliance

The original scale by Neal and Griffin (2006) was used. The scale consists of three items, with a five-point Likert response scale ranging from 1 (completely disagree) to 5 (completely agree). Scale items were: "I use all the necessary safety equipment to do my job", "I use the correct safety procedures for performing my job," and "I ensure the highest levels of safety when I do my job." Cronbach's alpha was .91.

Safety participation

As in the case of safety compliance, we used the original safety participation scale by Neal and Griffin (2006). The scale consisted of three items, with a 5-point Likert response scale ranging from 1 (Completely disagree) to 5 (Completely agree). Scale items were: “I promote the safety program within the organization”, “I make extra effort to improve safety in the workplace”, and “I voluntarily carry out tasks or activities that help to improve workplace safety”. Cronbach’s alpha was .87.

Risky behaviors

Risky behaviors were assessed by a scale based on Mearns, Flin, Gordon and Fleming (2001). The original scale had 12 items, but two items were deleted because they were not appropriate for the nuclear sector. Therefore, our scale was composed of 10 items. This modified scale was used in previous studies (Latorre et al., 2013; Martínez-Córcoles, Gracia, Tomás and Peiró, 2011; Martínez-Córcoles, Gracia, Tomás, Peiró and Schöbel, 2013). A 5-point Likert scale ranging from 1 (never) to 5 (usually) was used, so that higher scores reflected risky behaviors. Sample items include: “I ignore safety regulations to get the job done”, “In order to be more effective in my job, I have to break work procedures”, or “I take shortcuts that involve little or no risk”. Cronbach’s alpha was .91.

8.6.2.3. Analyses

Data were collected for three safety performance indicators (safety compliance, safety participation, and risky behavior) at Time 2. Descriptive statistics, Cronbach’s alpha coefficients, and correlations among the safety performance variables were estimated. Descriptive statistics, Cronbach's alpha coefficients, and correlations were also estimated for the SCEQ and OCI dimensions and sub-dimensions within the reduced longitudinal sample (N=163) collected at Time 1. Correlations among variables collected at Time 1 (SCEQ and OCI dimensions and sub-dimensions), and variables collected at Time 2 (safety performance indicators) were estimated.

Multiple regression analyses were carried out with SPSS 22 in order to test whether the OCI and the SCEQ scales gathered at Time 1 were able to predict the three safety performance indicators at Time 2. Independent variables were standardized to avoid collinearity problems.

8.7. RESULTS

8.7.1. Study 1

8.7.1.1. Descriptive analyses for the OCI items

Descriptive statistics (mean, standard deviation, skewness, and kurtosis) for individual items on the original 120-item version of the OCI are presented in Table 20. The items on the questionnaire showed standard deviations between .78 and 1.19, which indicates some discriminant power of the questionnaire items. The averaged absolute skewness (|M| = .44) and kurtosis (|M| = .38) values for the items on the OCI were less than 1. Moreover, 97.5% of the items (117 out of 120) had skewness in the range from –1 to +1, and, additionally, 98.3% of the items (118 out of 120) had kurtosis values in the range from –1 to +1. Thus, only 5 items (OCIc_x, OCId_i, OCIe_d, OCIb_m and OCIe_j) presented skewness or kurtosis values that were out of range.

Table 20
Descriptive statistics of the items of the Organizational Culture Inventory (OCI)

To what extent...

	Mean	SD	Skewness	Kurtosis
Dimension 1 – **Constructive style**				
Humanistic-encouraging culture				
OCIa_b …2.	3.30	.91	-.38	-.13
OCIa_c …3.	3.37	.89	-.46	-.09
OCIa_d …4.	3.72	.86	-.64	.23
OCIa_e …5.	3.60	.96	-.66	.21
OCIa_r …18.	3.55	.95	-.56	.03
OCIa_s …19.	3.77	.90	-.70	.55
OCIa_t …20.	3.36	.98	-.40	-.14
OCIb_h …34.	3.27	.95	-.44	-.12
OCIb_i …35.	3.55	.94	-.60	.13
OCIb_x …50.	3.25	.98	-.44	-.25
Affiliative culture				
OCIc_i …61.	3.99	.79	-.73	.93
OCIc_j …62.	3.90	.84	-.74	.76
OCIc_k …63.	3.73	.87	-.62	.39
OCIc_l …64.	3.62	.92	-.51	-.06
OCIc_x …76.	3.63	.82	-.69	1.03
OCIc_y …77.	3.36	.98	-.33	-.31
OCIc_z …78.	3.09	.99	-.32	-.35
OCId_m …91.	3.36	.94	-.52	-.01
OCId_n …92.	3.43	.91	-.63	.24
OCIe_b …106.	3.67	.83	-.73	.74
Achievement culture				
OCIa_k …11.	2.95	1.08	-.16	-.64
OCIa_z …26.	3.71	.92	-.35	-.31
OCIb_a …27.	3.32	.92	-.65	.19
OCIb_o …41.	2.60	.93	-.13	-.41
OCIb_p …42.	3.35	1.13	-.38	-.57
OCIb_q …43.	3.28	1.00	-.53	-.10
OCIc_d …56.	3.85	.89	-.68	.18
[OCIc_e …57.]	2.05	1.02	.77	-.03
OCIc_f …58.	3.22	.95	-.32	-.01
OCIc_g …59.	3.84	.88	-.70	.50

Self-actualizing culture					
OCIc_w	…75.	3.58	.95	-.73	.34
OCId_k	…89.	3.31	.98	-.47	-.02
OCId_l	…90.	3.08	1.00	-.28	-.52
OCId_y	…103.	2.82	.94	-.28	-.43
OCId_z	…104.	3.97	.81	-.63	.45
OCIe_a	…105.	3.70	.92	-.80	.51
OCIe_m	…117.	3.35	.87	-.46	.18
OCIe_n	…118.	3.55	.98	-.62	.05
OCIe_o	…119.	2.92	.99	-.12	-.45
OCIe_p	…120.	3.68	1.05	-.59	-.20
Dimension 2 – **Passive/defensive style**					
Approval culture					
OCIc_w	…6.	3.20	.90	-.33	.05
OCId_k	…7.	3.60	.98	-.60	.06
OCId_l	…8.	3.06	.98	-.28	-.28
OCId_y	…9.	2.28	.99	.21	-.79
OCId_z	…21.	2.64	.97	.09	-.36
OCIe_a	…22.	2.39	1.03	.18	-.66
OCIe_m	…23.	2.89	.93	-.18	-.28
OCIe_n	…36.	3.19	.96	-.14	-.37
OCIe_o	…37.	2.39	1.02	.22	-.83
OCIe_p	…51.	3.20	.93	-.29	-.10
Conventional culture					
OCIc_o	…67.	3.41	1.11	-.49	-.44
OCIc_p	…68.	3.64	1.06	-.74	.01
OCIc_q	…69.	3.57	.89	-.49	.19
OCIc_r	…70.	3.49	.92	-.48	.04
OCId_e	…83.	3.09	.94	-.21	-.20
OCId_f	…84.	2.07	1.07	.66	-.52
OCId_g	…85.	3.09	.98	-.22	-.30
OCId_u	…99.	3.60	.87	-.37	-.17
OCId_v	…100.	2.87	.96	-.04	-.39
OCIe_k	…115.	3.41	.93	-.40	-.03
Dependent culture					
OCIa_l	…12.	2.82	1.08	-.01	-.63
OCIa_m	…13.	3.34	.87	-.28	-.16
OCIa_n	…14.	2.98	1.10	.08	-.61
OCIa_o	…15.	3.71	.82	-.48	.17
OCIb_b	…28.	3.40	.82	-.59	.26

[OCIb_c	…29.]	3.35	.93	-.45	-.09
OCIb_d	…30.	2.89	1.10	-.13	-.75
OCIb_r	…44.	2.50	1.14	.41	-.59
[OCIb_s	…45.]	3.13	1.04	-.29	-.45
OCIc_h	…60.	3.75	.78	-.64	.86
Avoidance culture					
OCIc_s	…71.	2.14	1.01	.39	-.79
OCIc_t	…72.	2.14	1.02	.49	-.54
OCIc_u	…73.	2.77	1.15	.07	-.85
OCIc_v	…74.	1.83	.95	.84	-.25
OCId_h	…86.	2.23	.98	.39	-.45
OCId_i	…87.	1.82	.99	1.04	.29
OCId_j	…88.	2.24	1.08	.48	-.56
OCId_w	…101.	2.03	1.00	.53	-.71
OCId_x	…102.	2.01	.96	.56	-.59
OCIe_l	…116.	2.52	1.00	.10	-.62
Dimension 3 – **Aggressive/defensive style**					
Oppositional culture					
[OCIa_a	…1.]	3.26	.89	-.44	-.04
[OCIa_p	…16.]	3.49	.92	-.41	.01
OCIa_q	…17.	2.07	.99	.47	-.78
OCIb_e	…31.	2.74	.82	-.41	-.06
[OCIb_f	…32.]	3.35	1.05	-.41	-.27
OCIb_g	…33.	2.03	.91	.33	-.93
OCIb_t	…46.	2.66	.92	-.03	-.36
OCIb_u	…47.	2.14	.98	.46	-.43
OCIb_v	…48.	1.99	1.01	.66	-.49
OCIb_w	…49.	2.46	.98	.11	-.50
Power culture					
OCIc_m	…65.	2.61	.97	.13	-.46
[OCId_a	…79.]	3.54	.92	-.65	.34
OCId_b	…80.	3.13	.97	-.33	-.11
OCId_o	…93.	1.84	.93	.84	-.05
OCId_p	…94.	2.08	1.02	.56	-.45
OCId_q	…95.	2.17	1.01	.46	-.57
OCIe_c	…107.	3.13	.91	-.28	-.13
OCIe_d	…108.	1.92	1.05	1.01	.22
OCIe_e	…109.	2.76	1.02	-.09	-.58
OCIe_f	…110.	2.53	1.07	.13	-.84

Competitive culture				
OCIa_j …10.	2.43	1.04	.11	-.80
OCIa_x …24.	2.02	.94	.52	-.48
OCIa_y …25.	2.17	.97	.27	-.87
OCIb_l …38.	1.87	.99	.90	.02
OCIb_m …39.	1.68	.89	1.07	.20
OCIb_n …40.	1.87	.94	.75	-.32
OCIb_z …52.	2.33	.91	.01	-.72
OCIc_a …53.	2.82	.94	-.27	-.58
OCIc_b …54.	2.16	1.00	.35	-.81
OCIc_c …55.	1.79	.96	.95	-.08
Perfectionistic culture				
OCIc_n …66.	3.04	.86	-.17	-.13
OCId_c …81.	2.62	1.01	.14	-.42
OCId_d …82.	2.90	1.19	-.12	-.99
OCId_r …96.	2.00	.94	.60	-.35
OCId_s …97.	3.08	1.01	-.30	-.46
OCId_t …98.	3.48	.93	-.62	.10
OCIe_g …111.	3.40	.98	-.63	.04
OCIe_h …112.	2.98	1.04	-.20	-.51
OCIe_i …113.	3.12	.97	-.33	-.17
OCIe_j …114.	3.74	.79	-.74	1.06

Note. Items within [ ] were not considered for creating the dimensions (constructive style, passive/defensive style and aggressive/defensive style) and sub-dimensions (achievement culture, dependent culture, oppositional culture, and power culture). The original formulation of the items is not given due to confidentiality reasons. Each item is identified by a code (for our research purposes) and on the left, by a number that corresponds to the order in which each of the items is presented in the original questionnaire.

8.7.1.2. Confirmatory factor analysis: Factorial structure of the OCI (120-item version)

As Table 21 shows, confirmatory factor analysis of the original 120-item version of the OCI revealed that the three-factor model ($\chi 2$ = 40338.40, df = 7017, $p < .01$; RMSEA = .108; CFI = .901; NNFI = .900) and the twelve-factor model ($\chi 2$ = 27435.15, df = 6954, $p < .01$; RMSEA = .085; CFI = .917; NNFI = .915) fitted the data adequately. By contrast, the one-factor solution provided a poorer fit to the data ($\chi2$ = 79421.36, df = 7020, $p < .01$; RMSEA = .159; CFI = .879; NNFI = .877). Moreover, differences between the fit of the three-factor and one-factor models (ΔNNFI=.023, ΔCFI =.022 and ΔRMSEA=.051), and between the twelve-factor and one-factor models (ΔNNFI=.038, ΔCFI =.038 and ΔRMSEA=.074), were relevant from a practical point of view. Additionally, differences between the fit of the three-factor and twelve-factor models (ΔNNFI=.015, ΔCFI =.016 and ΔRMSEA=.023) were also non negligible. Thus, the three-factor model and the twelve-factor model were empirically supported, but the twelve-factor model appeared to be the best fitting model.

Table 21
Fit indices of different tested models with OCI (120 items version)

	χ^2	gl	χ^2/gl	RMSEA	CFI	NNFI
One-factor model	79421.36	7020	11.31	.159	.879	.877
Three-factor model	40338.40	7017	5.75	.108	.901	.900
Twelve-factor model	27435.15	6954	3.95	.085	.917	.915

Note. $\chi2$ = Chi-square; gl = degrees of freedom; $\chi2$/df = relative/normed chi-square; RMSEA = root mean square error of approximation, CFI = comparative fit index, NNFI = non-normed fit index.

8.7.1.3. Reliability

For the initial 120-item version of the OCI, the Cronbach's alpha values were satisfactory for the three dimensions of the questionnaire: .95 for *constructive style*; .87 for *passive/defensive style*; and .90 for *aggressive/defensive style*. However, when estimating the Cronbach's alpha values for the twelve sub-dimensions, two scales (dependent culture and oppositional culture) showed non-satisfactory values (α = .68 and α = 59, respectively). Two items on the "dependent culture" scale (OCIb_c and OCIb_s) and three items on the "oppositional culture" scale (OCIa_a, OCIa_p, and OCIb_f) were found to have corrected item-scale correlations of less than .30 (values were -.08, .10, .08, .05 and .09, respectively). We decided to eliminate these items in order to improve the reliability of their corresponding sub-dimensions. Two additional items, one belonging to the "achievement culture" scale (OCIc_e) and the other belonging to the "power culture" scale (OCId_a), showed very low corrected item-scale correlations (values were .02 and .05 respectively). These items were also eliminated from further analyses. After eliminating the aforementioned 7 items, for the 113-item version of the OCI, the Cronbach's alpha values were satisfactory for the three dimensions of the questionnaire (see Table 22): .96 for *constructive style*; .90 for *passive/defensive style*; and .91 for *aggressive/defensive style*. Moreover, reliability analyses showed strong internal consistency for the sub-dimensions of the OCI (see Table 23), except for the "oppositional culture" scale, whose Cronbach's alpha value was still below the .70 criterion (specifically, α = .68). For the other sub-dimensions, Cronbach's alpha values were satisfactory, ranging from .76 to .92.

Table 22

Study 1 (N=566). Descriptive statistics, reliability and correlations for the 3 dimensions of the OCI (113 items version)

	M	SD	1	2	3
1. Constructive style	3.38	.56	(.96)		
2. Passive/defensive style	2.86	.45	.03	(.90)	
3. Aggressive/defensive style	2.47	.55	.07	.63**	(.91)

Note. ** *p*< .01. Cronbach's alpha coefficients are in brackets.

Table 23

Study 1 (N= 566). Descriptive statistics, reliability and correlations for the 12 sub-dimensions of the OCI (113 items version)

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12
Constructive Style														
1. Humanistic-encouraging culture	3.47	.72	(.92)											
2. Affiliative culture	3.58	.67	.75**	(.91)										
3. Achievement culture	3.35	.59	.68**	.62**	(.78)									
4. Self-actualizing culture	3.40	.61	.70**	.77**	.67**	(.84)								
Passive/defensive style														
5. Approval culture	2.89	.56	.27**	.29**	.23**	.14**	(.76)							
6. Conventional culture	3.22	.58	-.12**	-.01	.15**	-.05	.40**	(.80)						
7. Dependent culture	3.17	.61	-.13**	-.09*	.15**	-.10*	.45**	.65**	(.77)					
8. Avoidance culture	2.17	.65	-.42**	-.39**	-.24**	-.38**	.31**	.43**	.36**	(.84)				
Aggressive/defensive style														
9. Oppositional culture	2.29	.56	-.11*	-.10*	.01	-.09*	.41**	.23**	.24**	.57**	(.68)			
10. Power culture	2.47	.61	-.13**	-.12**	.13**	-.08	.30**	.51**	.37**	.54**	.47**	(.78)		
11. Competitive culture	2.11	.67	-.23**	-.18**	.05*	-.16**	.43**	.40**	.38**	.64**	.62**	.64**	(.88)	
12. Perfectionistic culture	3.04	.55	.03	.02	.33**	.11*	.27**	.60**	.47**	.33**	.25**	.60**	.42**	(.76)

Note. ** $p< .01$; * $p< .05$. Cronbach's alpha coefficients are in brackets.

8.7.1.4. Confirmatory factor analysis: Factorial structure of the OCI dimensions (113-item version)

As previously stated, two alternative models (a one-factor model and a four-factor model) were tested for each of the three dimension of the OCI (constructive style, passive/defensive style, and aggressive/defensive style). In the one-factor model, all the items from a particular dimension loaded in a single latent factor. In the four-factor model, four latent factors (representing the corresponding sub-dimensions) were defined, and items from each particular sub-dimension loaded in the corresponding one.

For all three dimensions of the OCI (constructive style, passive/defensive style, and aggressive/defensive style), the four-factor model showed a better fit than the one-factor model. Moreover, the differences in fit between the two models were not trivial for the "constructive style" (ΔRMSEA = .021, ΔCFI = .013; ΔNNFI = .014), the "passive/defensive style" (ΔRMSEA = .046, ΔCFI = .049; ΔNNFI = .051), and the "aggressive/defensive style" (ΔRMSEA = .027, ΔCFI = .029; ΔNNFI = .031).

For the four-factor models, all factor loadings were statistically significant ($p<.05$). Average factor loadings for "constructive style" were .69, ranging from .22 to .91. Average factor loadings for "passive/defensive style" were .56, ranging from .10 to .82. Finally, average factor loadings for "aggressive/defensive style" were .57, ranging from .20 to .89. The correlation coefficients among the sub-dimensions of the questionnaire are shown in Table 23. All correlations among sub-dimensions belonging to the same dimension are positive and statistically significant ($p<.01$), ranging from .62 to .77 for the “constructive style” sub-dimensions, from .31 to .65 for the “passive/defensive style” sub-dimensions, and from .25 to .64 for the “aggressive/defensive style” sub-dimensions. Moreover, none of the correlations exceeded the accepted criterion ($r_{xy}< .85$), thus supporting factor discrimination. These correlations show that the different sub-dimensions represent interrelated but clearly differentiated components of a particular style.

8.7.1.5. Evidence of validity based on relationships with external variables

Table 24 presents descriptive statistics, Cronbach’s alpha coefficients, and correlations among the external variables, including safety culture outcomes (group safety climate, organizational safety climate, safety satisfaction, job satisfaction) and the three dimensions of the SCEQ (daily activities and behaviors supporting safety, human resources practices driving safety, and strategic decisions ensuring safety).

Table 24
Study 1.Descriptive statistics, reliability and correlations among the SCEQ dimensions and the safety culture outcomes

	M	SD	1	2	3	4	5	6	7
1. Group safety climate	3.74	.79	(.96)						
2. Organizational safety climate	3.85	.65	.72**	(.94)					
3. Safety satisfaction	4.16	.67	.62**	.71**	(.90)				
4. Job satisfaction	3.91	.92	.51**	.50**	.48**	(.80)			
5. SCEQ-Daily activities and behaviors	3.88	.68	.54**	.60**	.58**	.41**	(.91)		
6. SCEQ-Human Resources Practices	3.35	.82	.51**	.58**	.52**	.38**	.69**	(.90)	
7. SCEQ-Strategic decisions	4.22	.64	.52**	.58**	.58**	.38**	.74**	.57**	(.87)

Note. ** $p< .01$. SCEQ = safety culture enactment questionnaire. Cronbach’s alpha coefficients are in brackets.

Table 25 presents Pearson correlations between the three dimensions and 12 sub-dimensions of the OCI, the three dimensions of the SCEQ, and the four safety culture outcomes. Constructive style, as well as each of its corresponding sub-dimensions (humanistic-encouraging culture, affiliative culture, achievement culture, and self-actualizing culture) showed positive and statistically significant correlations with the four safety culture outcomes (group safety climate, organizational safety climate, safety satisfaction, job satisfaction) and with the three SCEQ dimensions (daily activities and behaviors supporting safety, human resources practices driving safety, and strategic decisions ensuring safety).

Passive/defensive style showed negative and statistically significant correlations with the four safety culture outcomes (group safety climate, organizational safety climate, safety satisfaction, job satisfaction), but no relationship with the three SCEQ dimensions. Considering its sub-dimensions, only “avoidance culture” showed negative and statistically significant correlations with all the external variables (except with the SCEQ dimension “daily activities and behaviors supporting safety”). “Dependent culture” also showed negative and statistically significant correlations with safety satisfaction and job satisfaction.

Aggressive/defensive style showed negative and statistically significant correlations with three of the safety culture outcomes (organizational safety climate, safety satisfaction, job satisfaction), but no relationships with the SCEQ dimensions. Considering its sub-dimensions, “oppositional culture” and “competitive culture” showed negative and statistically significant correlations with all the external variables. “Power culture” showed negative and statistically significant correlations with organizational safety climate, safety satisfaction, and job satisfaction. Finally, “perfectionistic culture” showed positive and statistically significant correlations with group safety climate and two of the SCEQ dimensions (daily activities and behaviors supporting safety, and strategic decisions ensuring safety).

Table 25
Study 1 (N=566). Correlations of the OCI dimensions and sub-dimensions (113 items version) with the SCEQ dimensions and with the safety culture outcomes.

	Group Safety Climate	Organizational Safety Climate	Safety Satisfaction	Job Satisfaction	SCEQ DA&B	SCEQ HR-P	SCEQ SD
Constructive Style	**.43****	**.40****	**.36****	**.44****	**.41****	**.34****	**.40****
Humanistic-encouraging culture	.45**	.44**	.38**	.45**	.40**	.42**	.38**
Affiliative culture	.37**	.38**	.33**	.40**	.31**	.31**	.30**
Achievement culture	.40**	.36**	.31**	.40**	.38**	.30**	.37**
Self-actualizing culture	.39**	.39**	.40**	.45**	.38**	.36**	.37**
Passive/defensive style	**-.09***	**-.14****	**-.13****	**-.16****	**-.07**	**-.06**	**-.08**
Approval culture	.02	-.01	-.02	.01	.00	.08	-.04
Conventional culture	.01	-.04	-.02	-.07	.05	.00	.04
Dependent culture	-.04	-.08	-.09*	-.11**	-0.1	-.06	-.02
Avoidance culture	-.22**	-.26**	-.25**	-.28**	-.22	-.19**	-.22**
Aggressive/defensive style	**-.03**	**-.012****	**-.11****	**-.09***	**-.07**	**-.03**	**-.06**
Oppositional culture	-.13**	-.19**	-.18**	-.11**	-.20**	-.10*	-.21**
Power culture	-.02	-.10*	-.10*	-.08*	-0.6	-.02	-.05
Competitive culture	-.15**	-.23**	-.19**	-.13**	-.17**	-.10*	-.17**
Perfectionistic culture	.13**	.04	.06	.03	.15**	.07	.15**

Note. ** *p*< .01; * *p*< .05. SCEQ = safety culture enactment questionnaire; DA&B = daily activities and behaviors; HR-P = human resources practices; SD = strategic decisions.

8.7.2. Study 2

8.7.2.1. Descriptive analyses, reliability and correlations

Table 26 presents descriptive statistics (means and standard deviations) and reliability values for the three safety performance indicators (safety compliance, safety participation, and risky behavior) collected at Time 2. Cronbach's alpha values were satisfactory: .91 for safety compliance; .87 for safety participation; and .91 for risky behaviors.

Table 26 offers descriptive statistics and reliability values for the SCEQ and OCI dimensions found in the reduced longitudinal sample (N=163) collected at Time 1. Table 27 offers descriptive statistics and reliability values for the OCI sub-dimensions in the reduced longitudinal sample (N=163) collected at Time 1. Values at Time 1 for the SCEQ and the OCI dimensions and sub-dimensions in the entire sample (N=566) and the reduced longitudinal sample (N=163) were quite similar. Cronbach's alpha values were satisfactory for the SCEQ dimensions (ranging from .87 to .91) and the OCI dimensions (ranging from .89 to .96). Reliability analyses showed strong internal consistency for the sub-dimensions of the OCI (see Table 27), except for the "oppositional culture" scale, whose Cronbach's alpha value was below the .70 criterion (concretely, α = .61). For the other sub-dimensions, Cronbach's alpha values were satisfactory, ranging from .70 to .92.

Table 26

Study 2 (N = 163). Descriptive statistics, reliability and correlations among the dimensions of the OCI (113 items version), the SCEQ dimensions and the safety performance indicators.

	M	SD	1	2	3	4	5	6	7	8	9
1. OCI Constructive styleT1	3.47	.52	(.96)								
2. OCI Passive/defensive style T1	2.86	.45	-.15	(.90)							
3. OCI Aggressive/defensive styleT1	2.47	.49	-.01	.54**	(.89)						
4. SCEQ-Daily activities and behaviors T1	3.93	.65	.39**	-.20*	-.16*	(.91)					
5. SCEQ- Human Resources Practices T1	3.31	.79	.22**	-.17*	-.13	.62**	(.90)				
6. SCEQ-Strategic decisions T1	4.25	.66	.31**	-.10	-.13	.74**	.49**	(.87)			
7. Safety compliance T2	4.58	.62	.27**	-.14	-.15	.25**	.15	.33**	(.91)		
8. Safety participation T2	4.09	.71	.19*	-.03	-.05	.33**	.22**	.33**	.57**	(.87)	
9. Risky behavior T2	1.45	.51	-.17*	.18*	.25**	-.20*	-.21**	-.19*	-.48**	-.36**	(.91)

Note. ** *p*< .01. OCI = organizational culture inventory; SCEQ = safety culture enactment questionnaire; T1 = time 1; T2 = time 2. Cronbach's alpha coefficients are in brackets.

Table 27

Study 2 (N = 163). Descriptive statistics, reliability and correlations for the 12 OCI sub-dimensions (113 items version) at Time 1

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12
Constructive Style														
1. Humanistic-encouraging culture	3.47	.70	(.92)											
2. Affiliative culture	3.59	.65	.79**	(.92)										
3. Achievement culture	3.45	.54	.65**	.65**	(.76)									
4. Self-actualizing culture	3.45	.57	.73**	.75**	.62**	(.83)								
Passive/defensive style														
5. Approval culture	2.83	.56	.13	.21**	.13	-.02	(.78)							
6. Conventional culture	3.23	.54	-.29**	-.16*	-.03	-.33**	.31**	(.78)						
7. Dependent culture	3.24	.65	-.29**	-.20*	.06	-.28*	.47**	.63**	(.80)					
8. Avoidance culture	2.13	.64	-.52**	-.48**	-.35**	-.58**	.35**	.41**	.41**	(.83)				
Aggressive/defensive style														
9. Oppositional culture	2.29	.50	-.12	-.15	-.07	-.11	.42**	.04	.12	.51**	(.61)			
10. Power culture	2.46	.55	-.21**	-.21**	.06	-.22**	.21**	.40**	.29**	.53**	.42**	(.73)		
11. Competitive culture	2.10	.64	-.30**	-.24**	.02	-.29**	.45**	.35**	.38**	.62**	.53**	.62**	(.87)	
12. Perfectionistic culture	3.11	.49	-.02	-.02	.32**	-.05*	.26**	.56**	.39**	.28**	.13	.52**	.43**	(.70)

Note. ** *p*< .01; * *p*< .05. Cronbach's alpha coefficients are in brackets.

Pearson correlations between the three dimensions and 12 sub-dimensions of the OCI and the three safety performance indicators are presented in Table 28. Constructive style, as well as each of its corresponding sub-dimensions (humanistic-encouraging culture, affiliative culture, achievement culture, and self-actualizing culture) showed positive and statistically significant correlations with safety compliance and safety participation, and negative and statistically significant correlations with risky behavior (except achievement culture, which did not show a statistically significant correlation). Passive/defensive style showed a positive and statistically significant correlation with risky behaviors. Moreover, only the avoidance culture sub-dimension showed statistically significant correlations (negative with safety compliance and safety participation, and positive with risky behaviors). The aggressive/defensive style showed positive and statistically significant correlation with risky behaviors. Furthermore, the oppositional culture sub-dimension showed negative statistically significant correlations with safety compliance and safety participation; competitive culture showed a negative statistically significant correlation with safety compliance; and power culture showed a positive statistically significant correlation with risky behaviors.

Finally, as Table 28 shows, all dimensions of the SCEQ showed positive and statistically significant correlations with safety compliance and safety participation (except for the correlation between “human resources practices” and safety compliance), and negative and statistically significant correlations with risky behaviors.

Table 28
Study 2 (N = 163). Correlations of the OCI (113 items version) and SCEQ with safety performance indicators.

	Safety Compliance T2	Safety Participation T2	Risky behaviors T2
Organizational Culture Inventory (OCI) T1			
Constructive Style T1	**.27****	**.19***	**-.17***
Humanistic-encouraging culture	.25**	.22**	-.24**
Affiliative culture	.23**	.17**	-.24**
Achievement culture	.25**	.17*	-.12
Self-actualizing culture	.25**	.21*	-.26**
Passive/defensive style T1	**-.14**	**-.03**	**.18***
Approval culture	-.10	-.01	.07
Conventional culture	-.01	.14	.10
Dependent culture	-.04	-.01	.12
Avoidance culture	-.24**	-.19*	.24**
Aggressive/defensive style T1	**-.15**	**-.05**	**.25****
Oppositional culture	-.26**	-.28**	.15
Power culture	-.14	-.03	.25**
Competitive culture	-.20*	-.15	.11
Perfectionistic culture	.05	.12	.14
Safety Culture Enactment Questionnaire (SCEQ) T1			
Daily activities and behaviors	.25**	.33**	-.20**
Human Resources Practices	.15	.22**	-.21**
Strategic decisions	.33**	.33**	-.19*

Note. ** *p*< .01; * *p*< .05. T1 = time 1; T2 = time 2.

8.7.2.2. Regression analyses

As Tables 29, 30 and 31 reveal, only the “strategic decisions” dimension of the SCEQ at Time 1 appeared as a positive and significant predictor of safety compliance and safety participation at Time 2. None of the SCEQ dimensions were significant predictors of risky behaviors.

Considering the OCI dimensions, “constructive style” was a positive and statistically significant predictor of safety compliance and safety participation at Time 2 and a negative and significant predictor of risky behaviors at Time 2. Additionally, the “aggressive/defensive style” dimension was a positive and statistically significant predictor of risky behaviors.

When considering the constructive style sub-dimensions, none of them appeared to be a significant predictor of any of the safety performance indicators. These results could be explained by the inter-correlations among the variables.

Regarding the passive/defensive style sub-dimensions, the “avoidance culture” negatively predicted safety compliance and safety participation and positively predicted risky behaviors at Time 2. Moreover, “conventional culture” positively predicted safety participation at Time 2.

Finally, when considering the aggressive/defensive sub-dimensions, “oppositional culture” negatively predicted safety compliance and safety participation at Time 2. Furthermore, “power culture” positively predicted risky behaviors at Time 2.

When including the SCEQ dimension (daily activities and behaviors, human resources practices, strategic decisions) and the OCI dimensions (constructive style, passive/defensive style, aggressive/defensive style) in a hierarchical regression model, results indicated the R-square change for the consecutive models. The SCEQ dimensions (step 1) explained 11% of the variance in safety compliance ($p < .01$); when including the OCI dimensions (step 2), the regression model explained 16% of the variance in safety compliance ($p < .01$), with ΔR-square = .05 being statistically significant ($p < .05$). Regarding safety participation, the SCEQ dimensions (step 1) explained 12% of the variance in safety participation ($p < .01$); when including the OCI dimensions (step 2), the regression model explained 13% of the variance in safety participation ($p < .01$), with ΔR-square = .01 not being statistically significant ($p > .05$). Finally, regarding risky behaviors, the SCEQ dimensions (step 1) explained 6% of the variance in risky behaviors ($p < .05$); when including the OCI dimensions (step 2), the regression model explained 11% of the variance in risky behaviors ($p < .01$), with ΔR-square = .05 being statistically significant ($p < .05$).

Table 29. Results of the regression analyses for predicting Safety Compliance in Time 2.

Predictors in Time 1	B	SE	R^2
SCEQ dimensions			.11**
Daily activities and behaviors	.02	.08	
Human Resources Practices	-.03	.06	
Strategic decisions	.21**	.07	
OCI dimensions			.10**
Constructive Style	.16**	.05	
Passive/defensive style	-.02	.06	
Aggressive/defensive style	-.09	.06	
OCI sub-dimensions			
Constructive style sub-dimensions			.08*
Humanistic-encouraging culture	.06	.09	
Affiliative culture	-.01	.09	
Achievement culture	.08	.07	
Self-actualizing culture	.07	.08	
Passive/defensive style sub-dimensions			.07*
Approval culture	-.03	.06	
Conventional culture	.06	.06	
Dependent culture	.02	.07	
Avoidance culture	-.17**	.06	
Aggressive/defensive style sub-dimensions			.09**
Oppositional culture	-.12*	.06	
Power culture	-.04	.07	
Competitive culture	-.07	.07	
Perfectionistic culture	.10	.06	

Note: $p \leq .05$, ** $p \leq .01$. B = non-standardized regression coefficients; SE = standard error.

Table 30. Results of the regression analyses for predicting Safety Participation in Time 2.

Predictors in Time 1	B	SE	R^2
SCEQ dimensions			.12**
Daily activities and behaviors	.13	.09	
Human Resources Practices	-.01	.07	
Strategic decisions	.14*	.08	
OCI dimensions			.04
Constructive Style	.14*	.06	
Passive/defensive style	.03	.07	
Aggressive/defensive style	-.05	.07	
OCI sub-dimensions			
Constructive style sub-dimensions			.06
Humanistic-encouraging culture	.13	.10	
Affiliative culture	-.05	.10	
Achievement culture	.02	.08	
Self-actualizing culture	.08	.09	
Passive/defensive style sub-dimensions			.09**
Approval culture	.03	.06	
Conventional culture	.21**	.07	
Dependent culture	-.06	.08	
Avoidance culture	-.20**	.06	
Aggressive/defensive style sub-dimensions			.11**
Oppositional culture	-.19**	.07	
Power culture	.04	.08	
Competitive culture	-.08	.08	
Perfectionistic culture	.12	.07	

Note: $p \leq .05$, $**p \leq .01$. B = non-standardized regression coefficients; SE = standard error.

Table 31. Results of the regression analyses for predicting Risky Behaviors in Time 2.

Predictors in Time 1	B	SE	R^2
SCEQ dimensions			.06*
Daily activities and behaviors	-.02	.07	
Human Resources Practices	-.07	.05	
Strategic decisions	-.05	.06	
OCI dimensions			.09**
Constructive Style	-.08*	.04	
Passive/defensive style	.02	.05	
Aggressive/defensive style	.11*	.05	
OCI sub-dimensions			
Constructive style sub-dimensions			.09**
Humanistic-encouraging culture	-.05	.07	
Affiliative culture	-.05	.07	
Achievement culture	.07	.06	
Self-actualizing culture	-.10	.06	
Passive/defensive style sub-dimensions			.06*
Approval culture	-.02	.05	
Conventional culture	-.01	.05	
Dependent culture	.03	.06	
Avoidance culture	.12**	.05	
Aggressive/defensive style sub-dimensions			.07*
Oppositional culture	.05	.05	
Power culture	.13*	.06	
Competitive culture	-.06	.06	
Perfectionistic culture	.02	.05	

Note:p≤.05, ***p* ≤ .01.B = non-standardized regression coefficients; SE = standard error.

8.8. DISCUSSION

The Safety Culture Enactment Questionnaire (SCEQ) and the Organizational Culture Inventory (OCI) were studied and compared on the basis of answers given by the workers of an NPP in 2008 and 2011.

Summary and discussion of the results

Reliability. Internal consistency of the three OCI dimensions (cultural styles) was found. However, reliability analyses detected two OCI cultural norms (sub-dimensions) and seven problematic items that did not meet the established criteria for reliability acceptance. As part of the validation of the OCI questionnaire, these items were left out, and further analyses in this paper were performed with a 113-item version of the OCI, which showed substantially improved psychometric properties. On the other hand, internal consistency of the 21 items and the three dimensions of the SCEQ was found. However, it should be noted that the SCEQ already went through a validation process in 2017, where three of the original 24 items were found to contribute to reliability weaknesses and, therefore, dropped from the questionnaire (López de Castro et al., 2017). In conclusion, results obtained in our sample suggest that the SCEQ is slightly stronger than the Spanish version of the OCI, as it stands now, in terms of reliability.

Evidence of validity based on the analysis of the internal structure. Empirical support for the three-factor structure (corresponding to the Constructive, Passive/defensive, and Aggressive/defensive styles or dimensions of the OCI) and the 12-factor structure (corresponding to the 12 cultural norms or sub-dimensions of the OCI) of the OCI was found. In addition, the internal structure of each of the three OCI styles was individually analyzed and supported. Analyses to gather evidence of validity based on the internal structure of the SCEQ are not included in this manuscript because they were previously performed with the same sample (2008) in López de Castro et al. (2017), where the three-factor structure of the SCEQ and its underlying theoretical model were empirically supported. In conclusion, both the OCI and the SCEQ showed solid internal structures, which, at the same time, validates their underlying organizational culture and safety culture models.

Evidence of validity of the OCI and the SCEQ based on their relationships with safety culture outcomes (Group safety climate, Organizational safety climate, Safety satisfaction, Job satisfaction) (transversal study).

1) Insights into the relationships between the OCI styles, the SCEQ dimensions, and the four safety culture outcomes. The Constructive style played the main role in the analyses carried out with the OCI. The Constructive style correlated moderately with all four safety culture outcomes, whereas correlations between the other two OCI styles and the safety culture outcomes were low. Moreover, each of the four sub-dimensions of the Constructive style also correlated moderately with each of the four safety culture outcomes. However, most of the correlations between the sub-dimensions of the Aggressive/defensive style and the safety culture outcomes were low and significant, and most of the correlations between the sub-dimensions of the Passive/Defensive style and the safety culture outcomes were not significant. In addition, the Constructive style and its four cultural norms were found to correlate moderately and positively with each of the SCEQ dimensions, whereas the defensive styles did not present a relationship with the SCEQ dimensions, and some of its cultural norms had a low correlation with the SCEQ dimensions. These results suggest that organizations characterized by the Constructive style will have a more positive safety culture and safety climate, and its employees will be more satisfied with the company, the unit of work, the work itself, and the organizational safety. This agrees with the theoretical propositions behind the OCI, which posit that the Constructive style is associated with positive and desired aspects and outcomes of the organization and its employees. However, this theory also proposes that organizations with defensive styles result in negative and unwanted aspects and outcomes for the organization and its employees. Thus, a higher correlation (negative in this case) between the two defensive styles (and their corresponding cultural norms) and the safety culture outcomes criteria, and between the two defensive styles (and their corresponding cultural norms) and the SCEQ dimensions, would have been expected. The results obtained may be due to the fact that safety-oriented organizations, such as the NPP studied in the present work, must be characterized by a prominent Constructive style, but they may also benefit from the presence of some degree of defensive cultural styles, as reported by García-Herrero et al. (2013). Regarding the correlations presented by the SCEQ, in addition to their relationships with the Constructive style and its norms, the three SCEQ dimensions were highly and positively correlated with the four safety culture outcomes. These results also supports that a positive safety culture will be reflected in the employees' safety climate perceptions, and in their satisfaction with their company, their unit of work, their work itself, and the safety of their organization.

2) Insights into the relationships between the OCI cultural norms, the SCEQ dimensions, and four safety culture outcomes. Analyzing the four Constructive norms, as expected, supportive and constructive organizations (Humanistic-encouraging culture) that are concerned about the interpersonal relationships and satisfaction of their employees (Affiliative culture), and not only value accomplishing organizational and individual goals with enthusiasm (Achievement culture), but also individual growth and quality over quantity work (Self - actualizing culture), showed a positive relationship with employees' satisfaction at work, with the perception of a safer work context, and with safety climate and safety culture. In a Self-actualizing culture (which positively correlated with the four safety culture outcomes and the SCEQ, like the rest of the Constructive norms), creativity is highly valued (as seen in items such as "think in unique and independent ways" or "communicate ideas"). Although creativity is not always looked upon favorably in NPPs(Klein et al., 1995), it is very important to find safe solutions to unexpected circumstances and unpredictable events for which procedures, protocols, and preferred actions are not established or are of no use. However, creativity is also a requirement in order to anticipate (more expected) scenarios where something could potentially fail, and develop effective strategies to address these possible future situations beforehand. Creativity can therefore help HROs to use mindful organizing. According to Weick and Sutcliffe (2007), mindful organizing serves to maintain resilience during both unexpected and expected events through anticipation and containment. Other research findings suggest that NPPs with Constructive norms perform better under emergency conditions than those with more defensive norms (Shurberg and Haber, 1992).

Analyzing the low correlations presented by the defensive styles in greater detail, the Avoidance culture is found to be the only Passive/defensive cultural norm that showed a relationship with the four safety culture outcomes and the dimensions of the SCEQ (specifically with the dimensions "Human Resources practices driving safety" and "Strategic decisions ensuring safety"). As expected, the correlations showed a negative sign. An avoidance culture is characterized by punishing employees for the mistakes they make, leading them to shift responsibilities to others. An avoidance culture is described as producing fear and lack of trust between employees, which could explain the negative correlation between this cultural norm and employees' satisfaction with their company, unit of work and, the work itself. On the other hand, the nuclear industry is aware that NPPs must be managed under 'no blame' principles and that members must feel free to report mistakes (Turner and Pidgeon, 1997; Reason, 1998). Fear averts the identification and analysis of critical events and inhibits organizational learning (Catino and Albolino, 2007), both requirements to guarantee safety in NPPs. This may be one reason that the avoidance cultural norm correlated negatively with safety climate, safety culture, and safety satisfaction. The Dependent cultural norm correlated negatively with Safety satisfaction and Job satisfaction, although it did not present any relationship with the safety climate variables or the safety culture dimensions. A dependent culture describes hierarchically controlled organizations where employees only do what they are told, and where own-decisions and creativity are generally not accepted. Thus, the results obtained suggest that employees working under such constraints are not satisfied with their work and with the safety of the organization. On the other hand, the fact that this cultural norm does not present any relationship with safety climate or safety culture may be explained by the nature of NPPs. They present hierarchical structures and are governed by clear and rigid procedures and processes, but at the same time they need to leave a certain degree of flexibility and autonomy to react to the unexpected and unwritten (Haber and Shurberg, 1993a), as mentioned above. The Oppositional and Competitive cultural norms correlated negatively with both satisfaction and safety climate variables, as well as with all the SCEQ dimensions. An oppositional culture characterizes organizations in which confrontation prevails and employees are reinforced for opposing the ideas of others. In a competitive culture, members are reinforced for outperforming one another and working against their peers. These two Aggressive/defensive cultural norms may lead to strained and poor relations among employees, which contributes to low satisfaction with their company, teams, and work, and to the perception of a non-supportive unsafe work context. On the other hand, close collaboration and criticism (but constructive) are essential to increasing employees' knowledge and expertise about safe plant operations. This could be one reason the Oppositional and Competitive cultural norms presented a negative relationship with safety climate and safety culture in our study. The Perfectionistic culture was also found to be related to both satisfaction and safety climate variables, as well as to SCEQ dimensions. However, it was the only defensive cultural norm that correlated positively with the safety culture outcomes and with safety culture. Perfectionistic cultures describe organizations that strive to do things perfectly and without mistakes, and anything necessary to accomplish organizational goals. The scale measures the value placed on persistence, hard work, and perfectionism (Haber and Shurberg (1996). It is in the nature of safe HROs to seek perfection and work hard to achieve safety goals. Thus, the results obtained suggest that employees of HROs with positive safety cultures and safety climates also perceive that they are required to work in a perfectionistic manner. Along these lines, Haber and Shurberg (1996) also found that nuclear organizations scored higher than non-nuclear organizations on the Perfectionistic cultural scale of the OCI. In conclusion, the expected pattern of relationships among the OCI, the SCEQ, and the safety culture outcomes was confirmed to a large extent, providing another source of evidence of the validity of the scales under study.

Evidence of validity based on the predictive power of the OCI and the SCEQ (longitudinal study). Safety compliance was predicted by one of the three dimensions of the OCI (Constructive style) and by one of the three dimensions of the SCEQ (Strategic decisions ensuring safety). The SCEQ questionnaire explained a slightly higher percentage of the variance in safety compliance than the OCI questionnaire. Safety participation was also predicted by one of the three dimensions of the OCI (Constructive style) and by one of the three dimensions of the SCEQ (Strategic decisions ensuring safety). In this case, the SCEQ questionnaire explained a much higher percentage of the variance in safety participation than the OCI questionnaire. Risky behavior was predicted by two of the three dimensions of the OCI (Constructive style and Aggressive/defensive style) and by none of the dimensions of the SCEQ. The SCEQ questionnaire explained a slightly lower percentage of the variance in Risky behaviors than the OCI questionnaire. Studying the predictive power of the OCI at a sub-dimensional level, each of the three safety performance indicators was predicted by two of 12 cultural norms. Surprisingly, although the Constructive style was the OCI dimension that showed the strongest power to predict safety performance, none of the four cultural norms of the Constructive style was able to predict safety performance. This result could be explained by the high inter-correlations among the variables of the Constructive style. The predictive power of the cultural norms (sub-dimensions) of the OCI could not be compared to the SCEQ because the three dimensions of the SCEQ are not further divided into sub-dimensions. In conclusion, evidence was provided of the validity of the SCEQ and OCI based on their power to predict safety performance. Results suggest a similar power of the OCI and SCEQ to predict Safety compliance, whereas it seems more appropriate to use the OCI to predict Risky behaviors and the SCEQ to predict Safety participation.

Practical implications and contributions

In light of the results of the studies, the present paper has served to initially validate the OCI and further validate the SCEQ in the Spanish nuclear industry. This validation process has given rise to several practical implications and contributions to HROs and, in particular, to the nuclear industry.

Reliability implications in the use of the OCI. The process of validating the Spanish version of the OCI revealed that the psychometric properties of the original 120-item version substantially improved in our sample when seven of these items were removed from the questionnaire. Specifically, the reliability analyses did not provide enough support for the original 120-item version. Reliability refers to the degree to which questionnaire scores are unaffected by measurement error; that is, reliability is concerned with accuracy. Thus, our results suggest that using the Spanish original 120-item version of the OCI may not guarantee that the individual score differences obtained are due to ‘true’ differences in the constructs being assessed by the OCI. Should this be the case, some of the results obtained from the application of the OCI could be misinterpreted and, ultimately, lead to wrong corrective actions in the nuclear industry.

Proposed OCI cultural constellation for NPPs. Results from the transversal and longitudinal studies presented propose a preferred OCI cultural constellation for NPPs. This constellation may help practitioners interpret the extent to which the culture of their organizations ensures the safety of operations. Three arguments are given in this regard: a) If we only look at the predictive power of the OCI and analyze its dimensions and sub-dimensions that show power to predict safety performance, the results suggest that NPPs that want to optimize safety performance and safety outcomes (like the rate of accidents) should be characterized by the Constructive style instead of the defensive styles. Particularly, they should not be marked by the Aggressive/defensive style. At a cultural norm level, these NPPs should not have the presence of Avoidance, Oppositional and Power cultural norms; b) the correlations (not predictions) found in this paper suggest the importance of having some degree of Perfectionistic culture. As explained above, it is in the nature of safe HROs to seek perfection, and other authors have also found a prominence of the Perfectionistic cultural norm in nuclear organizations (Haber and Shurberg, 1996); c) the correlations found between the OCI and the SCEQ indicate that the Constructive style is the

OCI style that provides the most information about the safety culture of an organization. In this regard, OCI-Ideal surveys[10] administered in other NPPs and HROs have been found to consistently produce ideal culture profiles that are predominantly Constructive (Cooke and Szumal, 2000). More specifically, Haber and Shurberg (1996) found that nuclear organizations, compared to non-nuclear organizations, tend to score higher on the Constructive cultural norms, lower on the Passive Defensive style, and more or less the same on the Aggressive/Defensive style. Furthermore, García-Herrero et al. (2013) found that the Constructive Style and its norms have the greatest influence on the safety culture, whereas the defensive styles do not show clear relationships with safety culture. One explanation might be found in the conclusions of Brooks (2012 p. 5), who argued that the contents of the Constructive style are “absolutely in alignment with those attributes and principles that contribute to a strong nuclear safety culture, clearly articulated by IAEA, INPO and WANO”.

The SCEQ or the OCI? Safety culture or organizational culture assessment? In our opinion, based on the presented results, it cannot be concluded that the OCI or the SCEQ is more adequate for HROs, or for NPPs in particular. If the results of this paper are extrapolated, a clear recommendation to lean toward the use of organizational culture assessment tools or safety culture assessment tools in HROs cannot be provided. However, as suggested by the hierarchical regression model presented in section 7.2., the use of both approaches at the same time to predict safety performance should offer better results than the single application of an

[10]The OCI-Ideal is a complement to the traditional form of the OCI that aims to identify the optimal or preferred culture for the organization under study. It assesses the behaviours that leaders and other members believe should be expected to maximize effectiveness and enable the organization to reach its goals (Human Synergistics International website).

organizational culture questionnaire or a safety culture questionnaire separately. If a decision has to be made and only one questionnaire can be applied, two arguments can be made in favor of the OCI or the SCEQ. In favor of the OCI, it could be argued that its power to predict risky behaviors could be more determinant for the nuclear industry than the stronger power of the SCEQ to predict Safety participation. As explained in this paper, Risky behaviors refer to behaviors that have the potential to cause adverse consequences for safety ("I ignore safety regulations to get the job done"; "I take shortcuts that involve little or no risk"). On the other hand, Safety participation refers to behaviors that, although not contributing directly to an individual's personal safety, are beneficial for a work environment supporting safety ("I promote the safety program within the organization"; "I make extra effort to improve safety in the workplace"; and "I voluntarily carry out tasks or activities that help to improve workplace safety"). Thus, the absence of Safety participation behaviors and a proactive attitude to safety in the organization could also lead to negative safety outcomes. However, to our knowledge, whether Safety behaviors or Safety participation has a stronger influence on organizational safety outcomes has not yet been empirically studied. Two points are highlighted in favor of the SCEQ. First, the 21-item SCEQ questionnaire presented better psychometric properties than the original 120-item and suggested 113-item versions of the OCI. Second, it could be argued that, all else being equal, short questionnaires offer more advantages than long questionnaires: a) Shorter questionnaires are less time-consuming, and, therefore, organizations may be less reluctant to administer them often to monitor safety culture. Frequent monitoring in NPPs is extremely important for the early detection of declining and weakening safety cultures (IAEA, 2006a), allowing time to take remedial action before minimum acceptable safety levels are challenged (IAEA, 2003). Moreover, systematic monitoring by comparing quantified results at different times makes it possible to detect trends (Hale, 2009; Håvold, 2005; IAEA, 2003) and evaluate the evolution of safety culture; b) When studying the effects of questionnaire length on the response rate, a number of authors have found better response rates for shorter questionnaires (Roszkowski and Bean, 1990; Sahlqvist, Song, Bull, Adams, Preston and Ogilvie, 2011). We could not show that questionnaire length affects non-response because both questionnaires were administered together as a part of a larger battery of questionnaires.

Limitations and future research

Although theoretical insights and practical implications for the use of the SCEQ and OCI have been provided, this paper has not elaborated on single items on the questionnaires. Such an analysis was beyond the scope of this paper and not practical in terms of the extension required. However, we strongly recommend performing a detail analysis of the answers to the questionnaires at an item level, especially when the questionnaires are used to take possible actions in the organization. This recommendation is also given by García-Herrero et al. (2013). As an example, they identified items from the Oppositional cultural norm of the OCI that have a direct positive influence on the safety (culture) of the organization (e.g., "pointing out flaws"; "adopting an impartial and completely objective attitude"; "looking for errors") and other items from the same cultural norm that have an adverse influence (e.g., “remaining on the sidelines”; “refusing criticism”).

We encourage the nuclear community to contribute to the empirical validation and understanding of the predictive capabilities of the OCI and the SCEQ for the nuclear industry. The empirical studies presented in this paper could be replicated to determine whether our results are consistent across different samples and NPPs. In particular, researchers and practitioners are encouraged to gather further evidence to support the reliability of the OCI (especially the Spanish version) scores in order to maximize its usefulness in practical settings. Future studies could replicate the validation process carried out in this paper to find out whether the seven ‘problematic’ items also show poor psychometric properties in other Spanish samples, or even in samples where the OCI is administered in other languages. Furthermore, future studies could also compare other organizational culture questionnaires to other domain-specific (e.g., safety, innovation, quality, customer service) culture questionnaires in order to gain insights into the suitability of general-purpose and domain-specific approaches to ensure the accomplishment of priority organizational goals (e.g., safety, innovation, quality, customer service).

CAPÍTULO IX.

DISCUSIÓN GENERAL

En este capítulo, en primer lugar, se resumen los principales resultados obtenidos en cada uno de los estudios realizados. En segundo lugar, se discuten las principales contribuciones e implicaciones que de esta tesis se derivan. Seguidamente, se concreta el ámbito de aplicación y posibilidades de generalización de los estudios realizados. El cuarto apartado acota a nivel global el alcance de la evidencia empírica obtenida. Finalmente se sugieren futuras líneas de investigación relacionadas con esta tesis en el campo de la cultura de seguridad.

9.1. Resumen de resultados

En este apartado resumimos los resultados principales obtenidos en los estudios de la presente tesis, que han satisfecho las motivaciones que llevaron a realizarlos y los objetivos propuestos.

9.1.1. Resultados principales obtenidos en la introducción de la tesis

Por una parte, el análisis de 40 de las definiciones de cultura de seguridad más influyentes en HROs hizo evidente la patente falta de acuerdo entre expertos en la materia sobre el significado del constructo. El número encontrado de interpretaciones del concepto fue tan amplio como se esperaba. Cada una de las definiciones ofreció un número de elementos que concretan la naturaleza del constructo. El análisis de las definiciones permitió resumir en 10 puntos el acuerdo alcanzado sobre la naturaleza de cultura de seguridad en los últimos 30 años: la cultura de seguridad hace referencia a una prioridad máxima concedida a la seguridad; está integrada en las asunciones, valores, creencias, y normas de los miembros de la organización; se manifiesta en políticas, prácticas, y procedimientos organizacionales, así como en las actitudes, percepciones, y comportamientos de estos miembros; debe ser compartida por todos los miembros de la organización; es estable y duradera; requiere el compromiso y responsabilidad de todos los miembros de la organización hacia la seguridad; determina el desempeño de seguridad de la organización; los líderes desempeñan un rol importante en la canalización de la cultura de seguridad; la formación/aprendizaje y los sistemas de recompensas juegan un papel determinante en la cultura de seguridad; y finalmente, el objetivo de la cultura de seguridad es fomentar y garantizar la seguridad en la organización, protegiendo así a los trabajadores, público, y medio ambiente de riesgos, accidentes y enfermedades. La integración de los contenidos identificados permitió ofrecer una definición que se ofrece a investigadores y HROs como marco de comprensión de cultura de seguridad:

"*Safety culture is an enduring and high value priority for safety, embedded in the assumptions, values, beliefs, and norms shared by organizational members and manifested in the organizational policies, procedures and practices and in the members' attitudes, perceptions, and behaviors at work, that determines organizational safety performance and serves to protect the workers, public, and environment from risks, accidents, and illnesses.*"

Por otra parte, el análisis de 20 de los cuestionarios más reconocidos de cultura de seguridad puso de manifiesto la falta de consenso entre expertos en la materia sobre la dimensionalidad del constructo. El análisis de los cuestionarios mostró cómo el contenido de la cultura de seguridad se ha desglosado para poder ser medido a través de cuestionarios y permitió la identificación de las 30 dimensiones más utilizadas para este propósito. Tres de las cuatro dimensiones más utilizadas en los cuestionarios que analizamos (gestión/supervisión, formación y riesgo) habían sido también identificadas previamente por Flin y cols., (2000) y Guldenmund (2000) en sus revisiones de cuestionarios como contenidos utilizados más comúnmente.

9.1.2. Resultados principales obtenidos en el Estudio 1

En el Estudio 1 se investigó la dimensionalidad del modelo de cultura de seguridad de la IAEA, así como las propiedades psicométricas de los atributos del modelo, a través de tres estudios empíricos independientes y complementarios con tres muestras distintas. Los resultados obtenidos sugirieron que la mayoría de los 37 atributos del modelo no están relacionados con las dimensiones de cultura de seguridad de las que, de acuerdo con la propuesta de la IAEA, deberían de formar parte. Es decir, nuestros resultados sugieren que la mayoría de los atributos no miden las dimensiones que deberían medir. Por otro lado, los resultados sugirieron que el modelo de IAEA podría ser unidimensional en vez de estar formado por las cinco dimensiones que la IAEA propone. Adicionalmente, los resultados sugirieron que el modelo tiene una validez de contenido moderada y una validez aparente baja.

9.1.3. Resultados principales obtenidos en el Estudio 2

En el Estudio 2 se presentó y validó nuestro cuestionario de cultura de seguridad (el SCEQ) y el modelo tridimensional de cultura de seguridad en que éste se sustenta a través de dos estudios. Un primer estudio con la muestra de 2008 permitió explorar la estructura interna del cuestionario y conllevó la eliminación de tres ítems de los 24 originales. Los análisis de fiabilidad, a nivel de ítems y de dimensiones, apoyaron la fiabilidad de la versión final de 21 ítems del SCEQ. Un segundo estudio con la muestra de 2014 confirmó la estructura de tres dimensiones propuesta en el modelo tridimensional que sustenta el SCEQ decisiones estratégicas que garantizan la seguridad (strategic decisions ensuring safety), prácticas de gestión de recursos humanos que impulsan la seguridad (human resources practices driving safety), y comportamientos y actividades del día a día en apoyo de la seguridad (daily activities and behaviors supporting safety), lo que contribuyó a la validación tanto del cuestionario como del modelo. Por otro lado, se confirmaron las relaciones esperadas entre el SCEQ y cuatro resultados de la cultura de seguridad (clima de seguridad, satisfacción con la seguridad, satisfacción con el trabajo, y comportamientos arriesgados). Adicionalmente, se obtuvieron evidencias de validez discriminante entre el SCEQ y clima de seguridad.

9.1.4. Resultados principales obtenidos en el Estudio 3

En el Estudio 3 se analizaron y compararon el SCEQ y el OCI a través de un estudio transversal y de un estudio longitudinal con la finalidad de arrojar luz sobre la utilidad de ambos en las HROs y, en consecuencia, de herramientas de medición específicas (como es un cuestionario de cultura de seguridad) y generales (como es un cuestionario de cultura organizacional). Se encontraron mayores evidencias de fiabilidad de las puntuaciones del SCEQ que de las del OCI. Como parte del proceso de validación de la versión española del OCI, se eliminaron siete ítems de los 120 de la escala original debido a las bajas correlaciones corregidas que mostraron con sus escalas correspondientes, lo que mejoró la fiabilidad de las dimensiones y sub-dimensiones del cuestionario y las propiedades psicométricas de los ítems. En el resto de análisis se trabajó con la versión mejorada de 113 ítems. Los resultados apoyaron la estructura interna de la versión española del OCI, lo que contribuyó a su validación y a la validación del modelo teórico en que se sustenta. Por otro lado, se confirmaron las relaciones esperadas entre el OCI, el SCEQ y los resultados de cultura de seguridad investigados (clima de seguridad organizacional, clima de seguridad grupal, satisfacción con la seguridad, y satisfacción con el trabajo). Se obtuvieron evidencias de validez basadas en el poder del OCI y del SCEQ para predecir, de forma conjunta o por separado, tres indicadores de desempeño de seguridad. En concreto, los resultados sugirieron que el OCI podría ser más útil para predecir comportamientos arriesgados, el SCEQ para medir participación en seguridad, y ambos cuestionarios predecirían de forma similar el cumplimiento de la seguridad. Adicionalmente, los resultados favorecieron la utilización conjunta de ambos cuestionarios para predecir desempeño de seguridad. Finalmente, en base a las evidencias de validación obtenidas y a estudios previos sobre el OCI, se propuso que las centrales nucleares deberían estar marcadas predominantemente por un estilo cultural 'constructivo', cierta presencia de la norma cultural 'perfeccionista', y evitar las normas culturales de 'evitación', 'oposición' y 'poder'.

9.2. Contribuciones e implicaciones de la tesis

La presente tesis doctoral se postula como una referencia para aquellos investigadores y profesionales interesados en la medición de cultura de seguridad en HROs. La contribuciones principales de esta tesis son la clarificación del constructo de cultura de seguridad y, principalmente, el avance en medidas cuantitativas de cultura de seguridad. Por un lado, esta tesis pretende contribuir a la clarificación del significado y dimensionalidad del concepto de cultura de seguridad, demandada por investigadores, organismos reguladores y profesionales de las HROs, centralizando el conocimiento aportado y compartido por expertos en la materia, y ofreciéndose como una guía y/o punto de partida sobre el que aunar el esfuerzo generado por unos y otros para su comprensión. Por otro lado, esta tesis recuerda a la comunidad científica y, sobre todo, pretende sensibilizar y alertar a los profesionales y organismos reguladores de las HROs, de la necesidad de contar con modelos y herramientas de medición que permitan obtener información crítica sobre la cultura de seguridad de la organización, y de la importancia teórico-práctica de validar empíricamente aquellos modelos y herramientas de medición, de los cuales se puedan derivar decisiones que tengan un impacto en la seguridad de las organizaciones. Estos son los dos pilares sobre los que asientan las principales contribuciones de nuestra tesis.

Los principales investigadores en cultura de seguridad han mostrado tener formas de entender la cultura de seguridad que difieren en mayor o menor medida. Esto es sin duda enriquecedor por las posibilidades que puede ofrecer trabajar con cultura de seguridad, sin embargo, una comprensión y definición comúnmente aceptada serviría como punto de referencia para guiar los esfuerzos de investigación sobre el constructo. Como expone Guldenmund, destacando la necesidad de una definición compartida de cultura de seguridad, “la definición de un constructo prepara el terreno para su subsiguiente investigación, esto es, es la base de las hipótesis, paradigmas de investigación e interpretación de los resultados. Demarca las fronteras del concepto y enfoca la investigación" (2000, p. 227). Partiendo de la propuesta de que la base para la creación de esta definición de referencia requiere aunar el conocimiento compartido del concepto por los expertos en la materia, la definición propuesta en esta tesis reúne los elementos más comunes de las definiciones ofrecidas hasta ahora y refleja en pocas palabras el acuerdo conseguido durante los últimos 30 años. Esta definición se ofrece, por tanto, como marco común para la comprensión de la cultura de seguridad y de trampolín para aunar los esfuerzos para su medición, gestión y optimización.

La creación de cuestionarios para medir cultura de seguridad ha seguido distintos cursos. Algunos cuestionarios se han sustentado en modelos teóricos previos (de cultura de seguridad y cultura organizacional, principalmente) (Chinda y Mohamed, 2008; Díaz-Cabrera y cols., 2007; Filho y cols., 2010; Gordon y cols., 2007; Kao y cols., 2007; Schöbel y cols., 2017) o se han desarrollado de forma paralela a los modelos en que se sustentan (Grote y Kunzler, 2000; López de Castro y cols., 2017). Generalmente, este curso de acción utiliza las dimensiones o bloques de contenido de los modelos teóricos como dimensiones de cultura de seguridad donde poder operacionalizar el constructo. Otro curso de acción, más utilizado en el desarrollo de cuestionarios de medición de cultura de seguridad, es la identificación de ítems que puedan proporcionar información sobre el papel de la seguridad en la organización, y la posterior agrupación de estos ítems a través de AFCs o ACPs en dimensiones referidas por sus autores como dimensiones de cultura de seguridad. Nuestra presentación y análisis de cuestionarios puede servir de utilidad para aquellos investigadores que deseen proceder de cualquiera de las dos formas en el desarrollo de futuros cuestionarios en HROs. Si se opta por construir un cuestionario partiendo de las dimensiones, las dimensiones de cultura de seguridad identificadas como más comunes en los cuestionarios revisados, podrían servir como dimensiones de futuros cuestionarios, como bloques de contenido que permitan posteriormente operacionalizar el constructo de cultura de seguridad. Si el curso elegido es la construcción del cuestionario partiendo de los ítems, las 180 dimensiones identificadas en los 20 cuestionarios pueden servir de guía para la asignación de etiquetas a las dimensiones que emerjan de los EFAs o PCAs aplicados. En ambos cursos de acción (partiendo desde las dimensiones o desde los ítems), los cuestionarios presentados podrían servir de referencia para escoger ítems (críticos para la seguridad de la organización) para la construcción de cuestionarios. En todo caso, se destaca que la finalidad de este estudio de comparación no es alentar la creación de numerosos nuevos cuestionarios, sino mostrar el alcance y grado de acuerdo de los cuestionarios de cultura de seguridad existentes.

Sin embargo, a pesar de la utilidad de la medición de cultura de seguridad a través sus dimensiones, la medición del constructo no requiere forzosamente trabajar con sus dimensiones. Los investigadores de la presente tesis entienden que la presencia de una cultura de seguridad requiere que la seguridad esté presente en todo lo que la organización hace y en cómo lo hace. Partiendo de esta premisa, sería posible que los dos acercamientos previamente expuestos en la creación de cuestionarios de cultura de seguridad estuviesen dejando escapar elementos críticos donde el valor de la seguridad pueda y deba ponerse en práctica. De acuerdo con esta posibilidad, proponemos un cuestionario de cultura de seguridad, que no busca las supuestas dimensiones de cultura de seguridad, sino que quiere evaluar en qué medida los valores de una organización (en concreto, la seguridad) se plasman en las actuaciones fundamentales de las organizaciones. Como exponemos en nuestra definición de cultura de seguridad, y en línea con la comprensión de la IAEA (2006) del concepto, la cultura de seguridad hace referencia a que la seguridad es un valor en acción, el valor más importante, una prioridad innegociable, que por lo tanto debe inspirar, influir e impregnar día a día las actuaciones de las organizaciones. Éste es uno de los dos pilares de nuestro cuestionario (el SCEQ), cuyas dimensiones no son facetas de cultura de seguridad, sino conjuntos de actuaciones fundamentales en el funcionamiento de las organizaciones alrededor de los cuales la cultura de seguridad se construye, se pone en práctica y se cristaliza. Se destaca que, a pesar de no estar formado por dimensiones de cultura de seguridad, el modelo que respalda el SCEQ se ha conceptualizado como un modelo de cultura de seguridad, debido al contexto en que ha sido creado y por su capacidad para recabar información sobre la cultura de seguridad en HROs.

La presente tesis muestra, por tanto, como la evaluación de cultura de seguridad puede también beneficiarse de estrategias de medición que, en línea con nuestro modelo y cuestionario, en lugar de basarse en supuestas dimensiones de cultura de seguridad, se nutren de modelos organizacionales más generales, cuyos elementos puedan permitir identificar áreas del funcionamiento de las organizaciones donde es imprescindible que el valor prioritario de la seguridad se haga realidad.

Pero no menos importante, la identificación y medición de estos elementos fundamentales para la seguridad deben ser complementadas por estrategias que permitan evaluar el valor real de la seguridad en ellos en la organización bajo estudio. La medición de cultura de seguridad a través de herramientas cuantitativas se ha focalizado en recabar información de las mencionadas dimensiones o facetas de cultura de seguridad, principalmente a través de las percepciones de los trabajadores. Sin embargo, este enfoque no ha contribuido a que los cuestionarios aplicados en HROs puedan sobrepasar los niveles más superficiales de cultura, siendo los niveles más profundos los que determinan en mayor medida el funcionamiento de la organización y su desempeño de seguridad. Por tanto, maximizar la utilidad y el valor diagnóstico de un cuestionario de cultura de seguridad, requiere estrategias que le permitan acercarse lo más posible a los niveles más profundos de cultura. Éste es el otro pilar del SCEQ, que ha incorporado estrategias para alcanzar el nivel de los valores en acción, y se ofrece a las HROs como una herramienta que, sin ser cualitativa, ofrece mayores garantías de medición de la cultura de seguridad real (no teórica o deseada) de las organizaciones.

Otro tema importante es el enfoque escogido a la hora de estudiar cultura de seguridad. El SCEQ y el modelo de la IAEA, por ejemplo, abordan el estudio de cultura de seguridad de forma directa e inmediata. Sin embargo, hay otro enfoque (distal) que entiende que la cultura de seguridad es parte de una cultura organizacional más amplia, y que estudiando esta última, podemos también obtener información sobre la cultura de seguridad, o sobre la importancia de la seguridad en la cultura de la organización o del grupo bajo estudio. Sin embargo, apenas se encuentra evidencia empírica en la literatura sobre cuál de estos dos enfoques debería ser preferido en las HROs. La presente tesis profundiza en la utilidad de ambos enfoques, demostrado que una herramienta de medición de cultura organizacional también puede ofrecer información sobre la cultura de seguridad y sobre el futuro desempeño de seguridad de las HROs. Esto a su vez retroalimenta la propuesta de que modelos más generales (no basados en dimensiones de cultura de seguridad) pueden ser apropiados para la medición de cultura de seguridad.

Pero siempre y en todo lugar, además de que los modelos y cuestionarios utilizados deben ofrecer el mayor potencial para la medición de cultura de seguridad, estos deben también contar con el mayor respaldo empírico posible. La utilización de modelos y cuestionarios, que no cuentan con apoyo empírico, puede llevar a investigadores a construir nuevo conocimiento sobre premisas teóricas que no se corresponden en la praxis con el funcionamiento y las relaciones de los constructos incluidos en estos modelos y cuestionarios. Por otro lado, los organismos reguladores se nutren en ocasiones de modelos y herramientas de medición, como el modelo de cultura de seguridad de la IAEA, para determinar políticas y normativas que afectan el funcionamiento de HROs. La utilización por parte de organismos reguladores de modelos y cuestionarios no validados, puede afectar el alcance de las políticas y normativas que estos organismos imponen a las organizaciones que regulan. Finalmente, la aplicación de cuestionarios (y la adopción de los modelos en que éstos se respaldan) en HROs, sin contar con evidencias de fiabilidad y validez de los resultados que de estos se obtienen, puede incrementar las posibilidades de que la interpretación de estos resultados lleve a los profesionales a tomar decisiones y acciones erróneas (o menos apropiadas) sobre aspectos en la organización, que sean claves para asegurar la seguridad de sus operaciones. Un ejemplo sería el caso (frecuente) de profesionales que basan sus intervenciones en los resultados que un cuestionario ofrece a nivel dimensional, debido al enfoque más intuitivo o al ahorro de tiempo que conlleva no analizar los ítems de una herramienta, sobre todo si los ítems son muchos. Si hay ítems en una dimensión, por ejemplo 'comunicación', que en realidad no la están midiendo, las puntuaciones obtenidas a nivel dimensional podrían ofrecer una imagen más positiva o más negativa de la contribución de la comunicación a la seguridad de la organización, lo que a su vez podría llevar a no intervenir (quizá siendo necesario hacerlo) o a intervenir (quizá habiendo otras áreas donde una intervención sea más prioritaria, aunque ésta no se ha identificado) en la comunicación de la organización.

Por tanto, partiendo de la importancia y necesidad constatadas de la validación empírica de cuestionarios y modelos de cultura (de seguridad) aplicados en HROs, cada uno de nuestros estudios empíricos ha contribuido en esta dirección. Por un lado, hemos contribuido a la clarificación de la dimensionalidad y propiedades psicométricas del modelo de cultura de seguridad probablemente más aceptado en la industria nuclear, abriendo de esta forma la puerta hacia su reconsideración y optimización. Por otro lado, hemos validado el SCEQ y el modelo de cultura de seguridad en que éste se sustenta, ofreciendo así un cuestionario de cultura de seguridad, con respaldo empírico, cuyo objetivo es llegar al nivel de los valores en acción. Y finalmente, hemos contribuido a la validación de la versión española del OCI, cuestionario de cultura organizacional más utilizado en el mundo (incluyendo en HROs), y ofrecido, entre otros, evidencias del poder del SCEQ y del OCI para predecir el desempeño de seguridad.

9.3. Ámbito de aplicación de la presente tesis y generalización de resultados

A lo largo de la tesis se ha hecho constante mención tanto a Organizaciones de Alta Fiabilidad (HROs) y a centrales nucleares (NPPs), como a la aplicación de nuestros estudios en las mismas. Las HROs generalmente se han entendido desde dos perspectivas. Por un lado, como aquellas organizaciones que son fiables, entendiendo fiabilidad como la baja probabilidad de error de una organización, y por otro lado, como aquellas organizaciones que buscan ser fiables (Hopkins, 2007). Las primeras definiciones de HROs enfatizaban los resultados que estas conseguían, y hablaban de ‘desempeños libres de errores’ (e.g., Roberts, 1989; Roberts y Gargano, 1990; Rochlin, La Porte y Roberts, 1987). Posteriormente se empezó a poner el énfasis en los procesos, es decir, en lo que estas organizaciones hacen para ‘buscar ser fiables’ (Rochlin, 1993). Estas organizaciones se enmarcan en la industria nuclear, aeronáutica, marítima, espacial y petroquímica, entre otras. De una forma más intuitiva, se pueden entender las HROs, como las organizaciones ‘que no pueden fallar’. En la introducción general de la tesis resaltamos en mayor detalle qué distingue una HRO de una que no lo es. La pregunta es por tanto, ¿son los resultados obtenidos en esta tesis aplicables únicamente a la industria nuclear o también a HROs y a industrias de alto riesgo en general? Los tres estudios empíricos incluidos en la tesis se han llevado a cabo en centrales nucleares, las muestras han estado formadas por trabajadores de centrales nucleares, y los cuestionarios han sido utilizados no solamente para fines de investigación, sino también para ofrecer información sobre las variables estudiadas que permita a las centrales bajo estudio incrementar la seguridad de sus operaciones. Por estos motivos, se ha enfatizado la industria nuclear frecuentemente a lo largo de la presente tesis y de sus estudios empíricos. Sin embargo, todas las dimensiones y atributos del modelo de la IAEA, todos los estilos culturales, normas culturales e ítems del OCI, y todas las dimensiones e ítems del SCEQ (con la excepción del ítem "en la planificación y contratación de personal para la recarga"), no hacen referencia directa a centrales nucleares ni tienen ítems que puedan aplicarse únicamente en la industria nuclear. Nuestra opinión es que los resultados y las principales conclusiones obtenidas en esta tesis son aplicables no solamente a la industria nuclear, sino también a las HROs y a las industrias de alto riesgo en general, donde al igual que en el sector nuclear, la seguridad debe ser el valor prioritario que determine la forma pensar, sentir y actuar de sus trabajadores. No obstante, para poder concluir empíricamente si los resultados obtenidos son aplicables a otras organizaciones que no sean centrales nucleares, los estudios empíricos se deberían replicar previamente en muestras de otras HROs, previo análisis de la idoneidad de cada uno de los ítems utilizados (del SCEQ, del OCI y del modelo de la IAEA) en el tipo de organización bajo estudio.

Por otro lado, si bien es cierto que nuestro estudio está enfocado en HROs y en particular en la industria nuclear, otro tipo de organizaciones podrían también beneficiarse, tanto del modelo de cultura de seguridad presentado que respalda el SCEQ, como de la estrategia seguida en el SCEQ para alcanzar el grado en que la seguridad es un valor en acción. Estos dos aspectos se explicación a continuación.

1) Generalización del modelo. Como se ha explicado a lo largo de la tesis, el modelo que sustenta el SCEQ no está compuesto por tres dimensiones de cultura de seguridad exactamente, sino que las dimensiones son tres conjuntos de actuaciones fundamentales de las organizaciones a través de las cuales se pretende obtener información sobre el valor o la prioridad real de la seguridad. Cada una de las tres dimensiones del modelo se ha operacionalizado en el SCEQ a través de ítems que cubren actuaciones que tienen poder de influir en el desempeño de seguridad de la organización. El SCEQ se convierte por tanto en una herramienta diagnóstica de cultura de seguridad que permite, a través del análisis de las respuestas dadas a sus dimensiones e ítems, detectar fortalezas y posibles áreas donde una intervención puede ser necesaria para garantizar la seguridad de la organización. Sin embargo, el modelo de cultura de seguridad presentado tiene la capacidad de poder ser también aplicado a otro tipo de organizaciones para las cuales su valor prioritario sea otro que la seguridad. De esta forma, los tres conjuntos de actuaciones fundamentales del modelo propuesto podrían servir como marco para desarrollar herramientas de medición de cultura de innovación, cultura de calidad, o de cultura de atención al cliente, entre otros. Por otro lado, parece razonable argumentar que varios de los ítems del SCEQ podrían arrojar información valiosa sobre la presencia de otros valores prioritarios en una organización (p.e., evaluado la importancia del valor bajo estudio en la adjudicación de recursos, en el reconocimiento de los jefes, en los comportamiento de la alta dirección, en la retribución de los trabajadores), mientras algunos ítems, tal y como están formulados en el SCEQ, no serían generalizables a otros valores o prioridades (p.e., resolución de conflictos entre

seguridad y producción) ni a otras organizaciones que no fuesen centrales nucleares (p.e., planificación y contratación de personal para la recarga). En todo caso, la aplicación de nuestro trabajo a otro tipo de organizaciones que no fuesen HROs, requeriría las operacionalización de las tres dimensiones en ítems que cubran actuaciones donde el valor prioritario buscado (p.e., innovación, calidad, atención al cliente) se pueda y deba ponerse en práctica, así como la posterior validación empírica del cuestionario. 2) Generalización de la estrategia del SCEQ para medir la presencia de otros valores en acción. Como acabamos de comentar, las dimensiones del modelo que hemos desarrollado, e incluso varios de sus ítems, podrían ser utilizados para obtener información sobre otros tipos de cultura. Sin embargo, para poder medir a través de un cuestionario el grado en que estos valores (p.e., innovación, atención al cliente, la calidad) son puestos en práctica e impregnan el día a día de las actuaciones de la organización, se recomienda tomar como referencia los elementos diferenciales del SCEQ explicados en el Estudio 2: introducción al cuestionario, escala de respuesta y naturaleza de los ítems.

9.4. Alcance de los estudios

El objetivo de este apartado es acotar el alcance de la evidencia empírica y conclusiones extraídas de la presente tesis. Es importante recordar que ya hemos analizado en cada estudio sus limitaciones con el fin de comprender mejor el significado de los resultados obtenidos. En este apartado consideramos el alcance del estudio de forma global.

En primer lugar, la evidencia empírica que se presenta en esta tesis procede de la aplicación de medidas de auto-informe, lo que plantea el problema de la varianza del método común como una limitación de los resultados presentados. La correlación entre las variables estudiadas podría haber sido más alta debido a que para su medición se ha utilizado el mismo método. Para paliar esta posible limitación se tomaron varias medidas. Por un lado, se utilizaron escalas de respuesta diferentes para las distintas variables. Por otro lado, para evitar el problema de la varianza del método común, se hizo hincapié en todo momento en que el anonimato y la confidencialidad de las respuestas estaban garantizados, minimizando así las posibilidades de obtener respuestas sesgadas por la deseabilidad social. Adicionalmente, se utilizó el test del factor único de Harman en el Estudio 1. En todo caso, para minimizar el problema de la varianza del método común en estudios como los presentados en esta tesis, siempre que sea posible, se recomienda la utilización de diferentes métodos para la medición de las variables (Podsakoff y cols., 2003).

En segundo lugar, se destaca que las muestras de trabajadores del sector nuclear, utilizadas en los tres estudios empíricos, pertenecen a dos centrales nucleares. Aunque pertenecientes a la misma organización, dichas centrales están ubicadas en lugares geográficos distintos y funcionan de manera autónoma. Pocos estudios psicosociales se pueden encontrar en la literatura que hayan podido tener la oportunidad de recoger una muestra compuesta por más de una planta (p.e., Crichton y Flin, 2004; O’Connor, O'Dea y Flin, 2008). No obstante, habida cuenta que la muestra de este trabajo está compuesta por dos plantas nucleares, es necesario tomar con precaución la generalización de los resultados obtenidos a la industria nuclear, así como a las HROs en general.

Finalmente, matizamos que por razones de practicabilidad, la definición propuesta de cultura de seguridad no incluyó tres de los diez elementos comunes identificados, sino aquellos que fueron considerados más relevantes para formar parte de la definición. Hubo, por tanto, tres contenidos comunes que no se incluyeron en la definición pero que deberían tenerse también en cuenta a la hora de investigar y trabajar con cultura de seguridad. Estos elementos fueron: el papel de los líderes en la canalización de la cultura de seguridad; la importancia del aprendizaje, formación y sistemas de reconocimiento en la cultura de seguridad; y la necesidad del compromiso y responsabilidad hacia la seguridad por parte de todos los trabajadores de la organización.

9.5. Futuras líneas de investigación

El Estudio 1 ha preparado el camino hacia la validación del modelo cultura de seguridad de la IAEA, que ha sido ampliamente utilizado en la industria nuclear para la comprensión y medición de cultura de seguridad. Del Estudio 2 se desprende la posibilidad de alcanzar niveles más profundos de cultura (valores en acción) a través de cuestionarios, lo que alienta a la comunidad científica a profundizar en nuestra propuesta y a investigar nuevas formas para conseguirlo. El Estudio 3 muestra que la cultura de seguridad se puede medir desde un enfoque directo (a través de herramientas de medición de cultura de seguridad) y desde un enfoque distal (a través de herramientas de medición de cultura organizacional), instando así a la comunidad científica a evaluar cuál de las dos estrategias debería utilizarse en las HROs.

El párrafo anterior describe en líneas generales las puertas de investigación que ha abierto cada uno de los estudios empíricos de la presente tesis. A su vez, cada estudio propone en mayor detalle vías de investigación para construir sobre el conocimiento aportado en cada uno de ellos. Sin embargo, en este apartado proponemos futuras líneas de investigación en cultura de seguridad, a nivel más global, que no se han abordado hasta este momento.

En primer lugar, la visión de cultura de seguridad que se ha ofrecido a lo largo de esta tesis doctoral, es la de una cultura global a nivel organizacional que debe impregnar a todos los trabajadores de la organización con la prioridad innegociable de la seguridad. Sin embargo, si bien es cierto que los trabajadores de una organización comparten una cultura que en mayor o menor medida determina cómo éstos experimentan, sienten, dan significado e interpretan de forma similar su organización, lo que en ella ocurre y lo que ésta valora (p.e., seguridad), también existen sub-culturas que conviven dentro de las organizaciones, conformando asunciones, valores, creencias y normas compartidas entre los integrantes del grupo, que toman forma en percepciones, actitudes y comportamientos compartidos a nivel de grupo. La primera visión se enmarcaría dentro de una perspectiva integracionista, mientras la segunda, dentro una perspectiva de diferenciación (ver Martin [2002] para una distinción entre las perspectivas de integración, diferenciación y fragmentación). En el Estudio 2 de la presente tesis se tuvo en cuenta la influencia en las respuestas al SCEQ de posibles sub-culturas formadas entre distintos grupos jerárquicos (equipo de alta dirección y resto de empleados), encontrándose diferencias significativas entre las puntuaciones de ambos grupos. Como ya se ha explicado, este gap en la valoración de la seguridad en la organización se ha observado frecuentemente en la literatura (Huang y cols., 2014). Este tipo de análisis, no solo ofrecen evidencias de validez basadas en la capacidad de una herramienta de medición para discriminar entre las puntuaciones de distintos grupos que puede tener sentido teórico que difieran en sus respuestas, sino que además puede ofrecer información adicional valiosa para la interpretación de las respuestas obtenidas y las posibles acciones que se deriven de la aplicación de la herramienta de medición. Sin embargo, la mayoría de los estudios encontrados en la literatura se ciñen al estudio de cultura organizacional o de seguridad desde una perspectiva integracionista, sin considerar la influencia que otras sub-culturas puedan estar ejerciendo en resultados organizacionales, sean seguridad, innovación, calidad, etc. Por este motivo, recomendamos que futuras investigaciones profundicen (p.e., a través de modelos multinivel) en las implicaciones teórico-prácticas derivadas de una perspectiva de diferenciación en la medición de cultura de seguridad.

En segundo lugar, un desarrollo importante de esta tesis ha sido la propuesta de un modelo de cultura de seguridad y el desarrollo paralelo de un cuestionario, el SCEQ, que nos permite llegar con métodos cuantitativos de evaluación a los valores en acción. Debido a que la muestra de este trabajo está compuesta por dos plantas nucleares, como hemos señalado con anterioridad, es necesario tomar con precaución la generalización de los resultados obtenidos a la industria nuclear, así como a las HROs en general. Futuras investigaciones deberían probar la validez del SCEQ y extender su aplicabilidad a otras HROs e industrias de riesgo en general.

En tercer lugar, la evaluación de la cultura de seguridad, tema central al que se ha pretendido contribuir en esta tesis, es especialmente interesante en la medida en que seamos capaces de enmarcar la cultura de seguridad dentro de modelos más amplios, en los que se incluyan predictores y posibles resultados de la cultura de seguridad. Futuras investigaciones en este campo enriquecerían la utilidad práctica de la medición de cultura de seguridad. Un ejemplo de dicho enfoque sería el modelo de evaluación de la cultura de seguridad y sus correlatos desarrollado por el IDOCAL (Peiró, Gracia y Martínez-Córcoles, 2015) basándose en el modelo de Análisis Multifacético de Intervención en Gestión Organizacional (Peiró, 1999; Peiró y Martínez-Tur, 2008). Como señalan Peiró y cols. (2015), "si se pretende que la evaluación de la cultura de seguridad sea realmente útil para diagnosticar esa cultura y determinar vías para reforzar y mantener sus aspectos positivos y mejorar los que lo requieran, es importante medir, además de la propia cultura de seguridad otras variables organizativas, comportamentales y de *output* o resultados que son influidos por esa cultura (p.e., indicadores de seguridad en la organización). Un análisis basado en modelos teóricos validados mediante investigación empírica nos van a permitir identificar relaciones entre esas diferentes variables que ofrecen ideas sobre cómo se genera y se cambia la cultura de seguridad y cómo los diferentes componentes y situación de esa cultura influyen sobre otras variables relevantes en la seguridad de la organización (p.e., el clima de seguridad, los comportamientos de los empleados y otros actores relevantes y los propios indicadores que reflejan la seguridad de la organización)" (p. 44).

Por último, para comprender adecuadamente la cultura de seguridad y poder actuar sobre ella es importante analizar sus cambios y evolución temporal. Identificar las mejoras o deterioros de la cultura de seguridad o de los indicadores de seguridad de la organización es básico para desarrollar planes y actuaciones que permitan su gestión y su mejora (Peiró y cols., 2015). Por ello, investigaciones futuras, enmarcadas en los modelos más globales comentados anteriormente, deberán obtener medidas en varios momentos temporales de la cultura de seguridad y de sus correlatos más importantes. De esta forma será posible avanzar en la identificación de las 'palancas de cambio', es decir, los factores organizativos y humanos que tienen mayor capacidad para incidir sobre los cambios en la cultura de seguridad. La identificación de los factores más relevantes en la mejora de la cultura de seguridad y de su impacto sobre la propia seguridad, resultaría en información muy valiosa para la gestión y mejora de dicha cultura de seguridad.

CHAPTER X.

CONCLUSIONS /

CAPÍTULO X.

CONCLUSIONES

The main conclusions of this thesis are presented in the following five paragraphs:

1. A large variety of meanings and connotations have been given to safety culture. However, the following 10 points, concluded from 40 definitions of safety culture, seem to reasonably reflect the agreement reached by experts on the term: safety culture refers to a high value priority given to safety; it is embedded in organizational members' assumptions, values, beliefs, and norms; it is manifested in organizational policies, practices, and procedures, as well as in members' attitudes, perceptions, and behaviors; it must be shared by all members of the organization; it is stable and enduring; it requires the responsibility and commitment to safety of all organizational members; it determines the safety performance of the organization; leaders play an important role in channeling safety culture; training/learning and reward systems play a crucial role in safety culture; and lastly, the goal of safety culture is to promote and guarantee safety in the organization, thus protecting the workers, public, and environment from risks, accidents, and illnesses.

2. The model of safety culture of the International Atomic Energy Agency (IAEA) has been accepted by the nuclear industry without prior empirical validation. Our results suggest that the model could be unidimensional instead of being composed of the five dimensions the IAEA proposes. On the other hand, several attributes of the model do not seem to be related to their corresponding dimensions. Moreover, evidence was not found for content and face validity of the model. Changes in the model and further validation processes seem necessary to maximize the usefulness of the model in the nuclear industry and its positive impact on the safety of operations in nuclear power plants (NPPs).

3. Questionnaires are a recurring strategy to assess safety culture in High Reliability Organizations (HROs). Management/leadership, training/learning, communication, risk, and support are the most common dimensions of safety culture included in these questionnaires. The assessment of safety culture, besides focusing on dimensions of safety culture, could also be nourished by wider organizational models, whose elements make it possible to identify the fundamental sets of actions in the functioning of HROs, where the value of safety is constructed and embedded.

4. Existing safety culture questionnaires typically provide information about the organizational artifacts and, at best, the culture reflected in its espoused values. Strategies must be developed to reach the level of enacted values through quantitative methodologies because the enacted values determine the safety performance and safety outcomes of HROs to a greater extent. The Safety Culture Enactment Questionnaire (SCEQ) proposed in this thesis is designed to capture the extent to which safety is an enacted value in HROs, particularly in NPPs. The SCEQ is based on a safety culture model that covers the main components of the functioning of any NPP or HRO where the value of safety must be put into practice: strategic decisions, human resources practices, and day-to-day operating behaviors. Empirical support is provided for the final 21 items of the SCEQ and the model on which it is based.

5. The analysis and comparison of the Safety Culture Enactment Questionnaire (SCEQ) and the Organizational Culture Inventory (OCI) provides valuable information about the use of (domain-specific) safety culture questionnaires and (general) organizational culture questionnaires in the nuclear

industry. A 113-item version of the Spanish OCI is proposed as a result of the validation process. A longitudinal study supported the power of the SCEQ and the OCI to predict safety performance, as measured by safety compliance, safety participation, and risky behaviors. The use of both questionnaires at the same time to predict safety performance is preferred over the application of each of them separately. Further evidence of validity for both assessment tools is provided. Results suggest a preferred OCI cultural constellation for NPPs, which should mostly be characterized by the presence of a 'constructive' cultural style and some degree of a 'perfectionistic' culture, and by the absence of the 'avoidance', 'oppositional', and 'power' cultural norms.

CONCLUSIONES

Las conclusiones principales de esta tesis se presentan en los siguientes cinco párrafos:

1. El término de cultura de seguridad ha presentado un gran número de significados y connotaciones. Sin embargo, hay diez puntos, extraídos del análisis de 40 definiciones de cultura de seguridad, que parecen recoger de forma razonable el acuerdo entre expertos sobre el concepto: la cultura de seguridad hace referencia a una prioridad máxima concedida a la seguridad; está integrada en las asunciones, valores, creencias, y normas de los miembros de la organización; se manifiesta en políticas, prácticas, y procedimientos organizacionales, así como en las actitudes, percepciones, y comportamientos de estos miembros; debe ser compartida por todos los miembros de la organización;

es estable y duradera; requiere el compromiso y responsabilidad de todos los miembros de la organización hacia la seguridad; determina el desempeño de seguridad de la organización; los líderes desempeñan un rol importante en la canalización de la cultura de seguridad; la formación/aprendizaje y los sistemas de recompensas juegan un papel determinante en la cultura de seguridad; y finalmente, el objetivo de la cultura de seguridad es fomentar y garantizar la seguridad en la organización, protegiendo así a los trabajadores, público, y medio ambiente de riesgos, accidentes y enfermedades.

2. El modelo de cultura de seguridad de la Agencia Internacional de Energía Atómica (IAEA) ha sido aceptado en la industria nuclear sin haber sido validado de forma empírica previamente. Nuestros resultados sugieren que el modelo de IAEA podría ser unidimensional en vez de estar formado por las cinco dimensiones que la IAEA propone. Por otra parte, la mayoría de los atributos del modelo parecen no estar relacionados con dimensiones correspondientes. Adicionalmente, no se encontraron evidencias para apoyar la validez de contenido y aparente del modelo. Nuevos procesos de validación, y un consiguiente replanteamiento del modelo, parecen necesarios para maximizar su utilidad en la industria nuclear y su impacto positivo en la seguridad de la operación de las centrales nucleares.

3. Los cuestionarios son una estrategia recurrente de medición de la cultura de seguridad en Organizaciones de Alta Fiabilidad (HROs). Las dimensiones de cultura de seguridad incluidas en estos cuestionarios con mayor frecuencia son: gestión/liderazgo, formación/aprendizaje, comunicación, riesgo, y apoyo. La evaluación de cultura de seguridad, además de basarse en dimensiones de cultura

de seguridad, podría también nutrirse de modelos organizacionales más generales, cuyos elementos permitan identificar las actuaciones fundamentales en el funcionamiento de las organizaciones, alrededor de las cuales la cultura de seguridad se construye y se cristaliza.

4. Los cuestionarios de cultura de seguridad existentes recaban normalmente información sobre los artefactos de la organización y, en el mejor de los casos, sobre la cultura reflejada en los valores expuestos. Es necesario trabajar en el desarrollo de fórmulas que permitan alcanzar el nivel de los valores en acción a través de cuestionarios, ya que estos valores en acción determinan en mayor medida el desempeño de seguridad y los resultados de seguridad de las HROs. El Cuestionario de Cultura de Seguridad en Acción (Safety Culture Enactment Questionnaire [SCEQ]) propuesto en esta tesis está diseñado para capturar el grado en que la seguridad es un valor en acción en HROs, en particular en centrales nucleares. El SCEQ se sustenta en un modelo de cultura de seguridad que cubre los principales componentes del funcionamiento de una HROs, donde el valor prioritario de la seguridad sebe poner en práctica: decisiones estratégicas, prácticas de gestión de recursos humanos y comportamientos diarios operativos. La versión final del SCEQ de 21 ítems y el modelo en que este cuestionario se sustenta, obtuvieron apoyo empírico.

5. El análisis y comparación entre el SCEQ y el Inventario de Cultura Organizacional (Organizational Culture Inventory [OCI]), ofrecieron información valiosa sobre la utilización de cuestionarios (específicos) de cultura de seguridad y cuestionarios (generales) de cultura organizacional en la industria nuclear. El proceso de validación de la versión española del OCI llevó a trabajar sobre una

versión de 113 ítems del OCI. Un estudio longitudinal apoyó el poder del SCEQ y del OCI para predecir el desempeño de seguridad, medido por las variables cumplimiento de la seguridad, participación en seguridad y conductas arriesgadas. La utilización de ambos cuestionarios de forma simultánea para predecir desempeño de seguridad es preferible que la aplicación de cada uno de los cuestionarios por separado. Se ofrecieron evidencias adicionales de validez de ambas herramientas de medición. Los resultados sugieren una constelación cultural del OCI preferida para la industria nuclear, que se caracteriza principalmente por un predominio del estilo cultural ‘constructivo’, cierto grado de presencia de la norma cultural ‘perfeccionista’, y la ausencia de normas culturales de ‘evitación’, ‘oposición’ y ‘poder’.

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