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The differences in perception of radiological risks: lay people versus new and experienced employees in the nuclear sector

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This paper studies the differences in perception of two radiological risks – an accident at a nuclear installation and medical X-rays – between four different groups: the general population without (1) and with experience related to radiological risks (2), new employees (3) and professionally exposed people (4) in the nuclear sector. More precisely, this study determines if differences in risk perception can be explained by the level of experiences with ionizing radiation, the knowledge level about radiological risks, the confidence in authorities, the attitude towards nuclear energy, the trust in a management of nuclear installations, gender and age. The data are gathered using computer assisted personal interviews based on the SCK-CEN Barometer of the Belgian Nuclear Research Centre. The relations between risk perception and the independent variables are tested with linear regression analysis. The risk perception of both risks differs significantly between the four population groups. The professionally exposed people and the new employees in the nuclear sector have a significant higher risk perception for medical X-rays compared to the risk for an accident at a nuclear installation. For the general population without experience, it was just the opposite. The general population with experience does not have a significant difference in risk perception between the two radiological risks. Level of experiences with ionizing radiation is determined as an important variable; people have a lower perception of radiological risks when they have higher experiences with risk.

Keywords: risk perception; radiological risks; experts; lay people

Introduction

Society is faced with several major technical and environmental risks such as nuclear energy, dangerous waste, climate change, food safety, etc. (Sjöberg 1999, 2005a). In scientific literature, the differences in risk perception between (scientific) experts and the general public is already elaborated in the fields of nanotechnology (e.g. Sjöberg et al. 2000; Siegrist et al. 2007), nuclear power (e.g. Kanda, Tsuji, and Yonehara 2012), genetically modified food and biotechnology (e.g. Savadori et al. 2004). In general, these studies conclude that the experts have significantly lower risk perceptions than lay people. However, Perko (forthcoming) indicated some inconsistencies related to different radiological risks perceived by the public and the experts.

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In order to explain why people have different risk perceptions, it is necessary to gain insight into the factors that influence the difficult and complex process of risk perception (Sjöberg 2000). In general, two dominant perspectives can be distinguished: the Psychometric Paradigm and the Cultural Theory. It is out of scope to describe and compare these theories in full detail. For a comprehensive overview of each theory, we refer to their founders: Fischhoff et al. (1978) and Douglas and Wildavsky (1982), respectively. Albeit the Psychometric Paradigm and the Cultural Theory have claimed to offer a certain value of explanation, both theories have been criticized for their limited explanatory value (Sjöberg 2000). A lot of other factors, not directly originating from Cultural Theory or Psychometric methods, were recognized as predictors of a risk perception, for instance gender, education, income and size of community (Sjöberg 2000). In addition, also the influence of mass media on risk perception was recognized within the Social Amplification of Risk Framework (Kasperson et al. 1988). Wynne (1996) also emphasized the importance of the amount of trust people have in the competences and expertise of individuals or organizations that are responsible for risk management. Consequently, no model is comprehensive and complete as risk perception is the result of people's individuals beliefs, attitudes and norms as well as wider social and cultural aspects.

The differences in risk perception between experts and lay people are often explained by differences in familiarity and knowledge about the risk and trust in government (Siegrist et al. 2007). According to Sjöberg and Drottz-Sjöberg (1994), the lower risk perception of experts is linked with responsibility as, for instance, radioactive waste experts feel responsible for the safe use of radiological applications. The gap in risk perception between experts and the public is also related to mistrusted communication and trust in experts, for instance, in the case when there is no scientific consensus (Otway and Winterfeldt 1992; Sjöberg 1999). Cohen (1998) explained the differences in risk perception by assuming that the public is misinformed about risks or misled in favour of one's advantage. However, according to Sjöberg (1999), people are not ignorant about risks, nor completely misinformed. Perko et al. (2012) also concluded that knowledge has hardly any effect on people's risk perception.

Related to radiological risks, the differences in perception of experts and lay persons have already been explored and empirically confirmed in scientific literature (for instance Sjöberg 1999; Kanda, Tsuji, and Yonehara 2012). Nevertheless, the expert populations in these studies were identified according to rather weak methodological standards (persons who were not exposed to any occupational radiation risk were included in the group of experts) and rather small population samples were compared, while the differences between the groups related to perception of non-industry related radiation risks, for instance medical use of radiation, were not investigated.

The goal of this paper is to contribute to the discussion on the differences in risk perception related to nuclear activities. Our empirical study adds on to previous research and highlights the differences in risk perception among four different groups related to two types of ionizing radiation risks: an accident in a nuclear installation and medical X-rays. However, both risk perceptions (dependent variables) are ionizing radiation risks; it can be expected that the rationality behind these two risks might be different. After all, the first can be the result of a conditional subjective risk estimation of a possibility that a nuclear accident with a radioactive release can happen and the second can be the result of a conditional subjective risk estimation of regular exposure to medical use of ionizing radiation. Four different groups are studied: (1) the general public that never has had a job in which it could be exposed to radioactivity; (2) people who have had a job that involved the use of radioactivity; (3) new employees in the nuclear sector; and (4) people who are professionally exposed to radiation.

Compared to previous studies, this paper does not use the word expert but prefers 'people who are professionally-exposed to radiation', as the latter is a broader concept, also involving non-experts who are exposed to radiation. The number of respondents in the expert population is also much higher than in any other radiological risk perception studies. Moreover, since the group of new employees is not represented in the literature, they are included in our study. Our hypothesis is that the risk perception of the new employees rather contrasts with the perception of the lay public as a result of their differences in background and studies. Nevertheless, it is expected that the risk perception of new employees is also different from the professionally exposed people, because they are lacking experience and are less familiar with nuclear applications and the use of radioactive materials. This paper not only study potential differences in risk perception, but also analyses if significant differences can be explained by the level of experiences with ionizing radiation, the knowledge level about radiological risks, the confidence in authorities, the attitude toward nuclear energy, the trust in a management of nuclear installations, gender and age.

Methods

Participants

The participants included in the study are divided into four groups: the general Belgian public (differentiating between those who have had a job that involved the use of radioactivity and those who have not; professionally exposed people of Belgian Nuclear Research Center (SCK-CEN); and the new employees at SCK-CEN.

The results for the general population are based on a public opinion survey in the Belgian population, using computer-assisted personal interviews between 25 May 2011 and 24 June 2011. The population sample consists of 1020 respondents and is representative for the Belgian (+18) population with respect to age, gender, province, region, urbanization and professionally active status. For the analysis, the general population group is split into two different samples, making a difference between those who have had a job that involved the use of radioactivity ($N = 53$) and those who have not ($N = 967$).

The population of professionally exposed people consists of 539 employees of the SCK-CEN. These employees are exposed to radiation, enter controlled areas, wear dose meters, undergo regular medical check-ups and participate at regular radiation protection trainings). For the collection of the data, the professionally exposed people were invited by email between 23 May 2012 and 11 June 2012 to fill in a digital questionnaire based on the SCK-CEN Barometer. After two reminders, 351 respondents had filled in the questionnaire but 19 of them were excluded as they had already participated in the Barometer study or in the new employees study.

The group of new employees consists of 42 people with a seniority of less than one year at SCK-CEN. The interviews based on the SCK-CEN barometer were carried out between 13 May 2012 and 18 May 2012.

Questionnaire and data analysis

In order to be able to compare the different groups, each participant of the study received the same questions based on the SCK-CEN Barometer (Turcanu, Perko, and Schröder 2011). If relevant, some additional questions were added typical for one group (e.g. years of experience). The questionnaire was available in three languages: Dutch, English and French.

The SCK-CEN Barometer contains questions related to the individual characteristics of the respondent, a list of statements to find out the respondents' risk perception and confidence in the authorities for several nuclear and industrial risks, several statements concerning science and technology, followed by statements about nuclear energy using a five-point Likert-scale. Respondents are also asked to discuss several arguments for or against nuclear energy; they can rate their public participation in the decision-making process and they are asked to give their opinion on the management of nuclear technologies and the actors operating in the nuclear field. The knowledge of the respondents according to nuclear radiation is measured making use of 10 questions. The last series of questions is related to the respondents' perception of radioactive waste.

The newly employed people and the general population both filled in the complete SCK-CEN Barometer. The Barometer contains many questions which were not relevant to the previously defined research questions of this research paper. Only the relevant questions to our research goal are included in the questionnaire of the professionally exposed people.

The data are analysed using the statistical program SPSS. To determine if a value is significant, the *p*-value is set at 0.05 (95%) in all cases. A Chi² is calculated to check whether the four groups in this study have a different ratio of female and male respondents. All four groups are checked separately. A cross tabulation gives a clear overview of the distribution of the respondents into the different age groups, split up by the four groups. The knowledge of the respondents is measured on a 10-item scale and a Games-Howell *post hoc* test is executed. The Games-Howell *post hoc* test does not rely on homogeneity of variance; since there is no homogeneity of variance. The correlation between the independent variables is studied with a Pearson correlation test. A one-way ANOVA is performed to see whether the differences between the groups in confidence in authorities are significant. A Bonferroni test is performed to compare these results. A paired sample *t*-test checks for significant differences within the groups. A one-way ANOVA is also performed to see whether the differences in perception for each risk between the groups are significant. Significant differences between the groups result in a Bonferroni *post hoc* test. A linear regression is applied for the regression analysis of the different groups of respondents. The dependent variable is the risk perception of an accident at a nuclear installation or the use of medical X-rays. The independent variables are level of experiences with ionizing radiation, the knowledge level about radiological risks, the confidence in authorities, the attitude towards nuclear energy, the trust in a management of nuclear installations, gender and age. Last two variables are used as controlling variables.

Items and scales

Risk perception (dependent variable) is directly measured with one item per risk. The respondents were asked to 'evaluate the risks of an accident in a nuclear installation' and to 'evaluate the risks from medical X-rays' for 'an ordinary citizen of Belgium' with possible answers ranging from 'very low' (1) to 'very high' (5). Pearson correlation coefficient between the two dependent variables is significant but is extremely low (Pearson Correlation = 0.175), thus it is justified to analyse each dependent variable separately.

Knowledge is operationalized as the number of correct answers given to a set of 10 exam-style questions about nuclear technology in general. Since the purpose of the knowledge variable is to comprise different levels of knowledge, the correct answers are indexed and the resulting absolute scale ranges from 0 to 10.

To measure the confidence in the authorities, the respondents were asked to state how much confidence they had in the authorities 'for the actions they undertake to protect the population against risks for each of the following items': *an accident in a nuclear installation* and *medical X-rays*. The possible answers ranged from 'very low confidence' (1) to 'very high confidence' (5).

The attitude towards nuclear energy is measured by their level of agreement with different statements: 'In general I believe that the benefits/advantages of nuclear energy outweigh the disadvantages', 'The reduction of the number of nuclear power plants in Europe is a good cause' and 'Nuclear power it endangers the future of our children'. The answering categories ranges from 'strongly disagree' (1) to 'strongly agree' (5). The answering categories for the question 'Are you in favour or against nuclear energy' are ranging from 'totally in favour' (1) to 'totally against' (5). Based on factor analysis with extraction method, the principal axis factoring reveals one factor with loading on all four items > 0.74 and factor explaining 75% of variances (Cronbachs alpha = 0.88). Factor scores are used for regression analysis with higher factor scores indicating more negative attitudes towards nuclear energy.

Trust in management of nuclear installations is measured by the level of agreement with the following statement: 'There is insufficient control by authorities on the safety in nuclear installations in Belgium' with possible answers ranging from 'completely disagree' (1) to 'completely agree' (5).

Results

Characteristics of the different groups of respondents

The ratio male/female is not representative in every group in correspondence with the Belgian population (51.1% female and 48.9% male) except for the general population – composed of 472 male (48.8%) and 495 female (51.2%) respondents – and the gender representation in the four groups of respondents is significantly different (Pearson $Chi^2 = 119{,}669$, $p < 0.000$, df.=3 and $N = 1394$). The gender ratios vary significantly in the three other groups compared to the Belgian population. Within the general population with experience, 35 (65.6%) male and 18 female (34.4%) participated in the study. In the group of new employees, 27 male (64.3%) and 15 female (35.7%) respondents are included. The group of the professionally exposed people contains 275 male (82.8%) and 57 female (17.2%) respondents which reflects a high male representativity among the nuclear research institute personnel.

The respondents are subdivided over nine age categories (<25, 25–30, 31–35, 36–40, 41–45, 46–50, 51–55, 56–60, >60). The differences in age between the four groups are significant. The group of the new employees has no respondents older than 60 years, and the group of professionally exposed people has a very small number of respondents older than 60 (3.6%). This is not surprising as the official age of retiring in Belgium is 65 years. Most respondents in the group of new employees are between 25 and 40 years old (71.5%). In the group of professionally exposed people, only two respondents are younger than 25 years old (0.6%).

The Games-Howell *post hoc* test indicates that the level of knowledge, measured on a 10-item scale, is significantly different between all groups ($p < 0.001$) except for the differences between the group of new employees and the general population with experiences ($p = 0.046$) and between the group of professionally exposed people and new employees ($p = 0.056$). The general population without experience has a significantly lower mean score compared to the other groups ($M = 6.09$; SD = 1.88). The mean level of knowledge of the general population with experience ($M = 7.21$; SD = 1.69) is significantly higher than the mean knowledge level of the general population without experience, but significantly lower compared to the professionally exposed people ($M = 8.57$; SD = 0.96). The new employees ($M = 8.02$; SD = 1.32) have a significantly higher level of mean knowledge only when compared to the general population, but not when compared to the general population with experience or the professionally exposed people.

Confidence in the authorities to protect against an accident at a nuclear installation and risks from medical X-rays differs a lot between the four groups. There is a significant difference in confidence in the authorities to protect against an accident at a nuclear installation ($(F) = 12.263$; $p < 0.001$, df.=3). A Bonferroni *post hoc* test indicates that there is no significant difference ($p = 1.00$) between the general population without ($M = 3.15$; SD = 1.15) and with experience ($M = 3.25$; SD = 1.04), but the confidence of the general population without experience is significantly lower compared to the confidence of the new employees ($M = 3.93$; SD = 0.97; $p < 0.001$) and the professionally exposed people ($M = 3.50$; SD = 1.11; $p < 0.001$). The general population with experience has only a significantly lower level of confidence compared to the new employees ($M = 3.92$; SD = 0.97; $p < 0.025$). The professionally exposed people ($M = 3.50$; SD = 1.10) do not have a significantly different level of confidence in authorities to protect against an accident at a nuclear installation compared to the new employees ($p = 0.148$), neither compared to the general population with experiences ($p = 0.789$). 42.1% of the people without experience have a 'high' to 'very high' trust in the government, compared to 50% of the general population without experience, 72.5% of the newly employed people and 56.8% the professionally exposed people.

There are also significant differences between the four groups related to the confidence in authorities to protect against risks from medical X-rays ($F = 6.079$; $p < 0.001$, df = 3). A Bonferroni *post hoc* test indicates that the level of confidence in the authorities to protect against risks from medical X-rays of the general population without experience is much higher ($M = 3.16$; SD = 1.10) and varies significantly from the confidence of the new employees ($M = 2.65$; SD = 1.08; $p = 0.019$) and the professionally exposed people ($M = 2.94$; SD = 0.93; $p = 0.007$). The general population with experience ($M = 3.23$; SD = 0.95) does not have a significantly different level of confidence compared to the general population without experience ($p = 1.000$), the new employees ($p = 0.069$), nor the professionally exposed people ($p = 0.482$). The differences between the new employees and the professionally exposed people are not significant ($p > 0.05$).

The confidence in authorities not only differs significantly between the four groups, but also within each group depending on the type of ionizing radiation risk, except for the general population without experience ($p = 0.878$; $t(949) = -0.153$)

and the general population with experience ($p = 0.816$; $t(50) = 0.234$). The new employees ($p < 0.000$; $t(38) = 6.171$) and the professionally exposed people ($p < 0.000$; $t(323) = 8.539$) have significantly more confidence in authorities to protect against an accident at a nuclear installation, compared to their confidence in authorities to protect against medical X-rays.

The attitudes towards nuclear energy differ significantly between the four groups of respondents ($p < 0.001$). The overall conclusion is that the new employees and the professionally exposed people have more positive attitudes towards nuclear energy than the general population. For instance, they perceive the benefits superior to the disadvantages and they more likely disagree with the statement that the reduction of the number of nuclear power plants in Europe is a good cause. The general population without experience is the most sceptical about nuclear power: they more agree that nuclear power endangers the future of their children and are more in favour of the reduction of nuclear power plants.

The differences in perception of the respondents' groups regarding trust in management of nuclear energy are strongly significant ($p < 0.001$, $t(12) = 485.07$). The general population ($M = 3.02$, SD = 1.21) is more convinced that there is insufficient control by authorities on the safety in nuclear installations in Belgium than the other groups (general population with experiences: $M = 2.745$, SD = 1.03; new workers: $M = 2.405$, SD = 0.985; professionally exposed: $M = 2.554$, SD = 1.34).

The correlation between the independent variables is measured with a Pearson correlation. The correlations are described in Table 1, the levels of significance are displayed with * ($0.001 < p \leq 0.05$) or ** ($p < 0.001$).

Risk perception

Table 2 presents the mean values and standard deviations for each perceived ionizing radiation risk, for the four different groups individually.

Based on a one-way ANOVA between groups, the risk perception of an accident at a nuclear installation significantly differs between the four groups ($F(3.1368) = 61.808$; $p < 0.001$). Tested with a Bonferroni *post hoc* test, the differences in risk perception between the general population without ($M = 2.99$; SD = 1.19; $p = 0.91$) and with experience ($M = 2.90$; SD = 1.27) are not significant ($p = 0.8$), but the general population without experience has a significantly higher risk perception of an accident at a nuclear installation compared to the new employees ($M = 1.92$; SD = 1.04; $p < 0.001$) and the professionally exposed people ($M = 2.02$; SD = 1.13; $p < 0.001$). The same post hoc test indicates a significantly higher risk perception of the public with experience compared to the new employees ($p = 0.001$) and the professionally exposed people ($p < 0.001$). However, there is no significant difference in risk perception for an accident at a nuclear installation between the new employees and the professionally exposed people.

A one-way ANOVA is performed for risk perception of medical X-rays; the differences in risk perception between the groups are also significant ($F(3.1376)$, $p = 0.011$). However, a Bonferroni *post hoc* test indicates that the risk perception of medical X-rays of the general population without experience ($M = 2.62$; SD = 1.04) does not significantly vary from the general population with experience ($M = 2.71$; SD = 0.96; $p = 1.000$) and the new employees ($M = 2.65$; SD = 0.95; $p = 0.790$), but the general population without experience has a significantly lower risk perception compared to the professionally exposed people ($M = 2.84$; SD = 0.97; $p = 0.005$).

Table 1. Correlations between the independent variables.

Correlations												
		Gender of the respondent	age_group9 _all	popgroup	Knowledge index (10 items)	conf_ accident	conf_ Xray	benefits_ disadvant	reductionNPP	opinion_ energy	future_ children	management_ nuclear
Gender of the respondent	Pearson correlation	1										
	Sig. (2-tailed)											
	N	1394										
Age_group9_all	Pearson correlation	0.006	1									
	Sig. (2-tailed)	0.818										
	N	1394	1394									
Popgroup	Pearson correlation	−0.291**	−0.045	1								
	Sig. (2-tailed)	0.000	.092									
	N	1394	1394	1394								
Knowledge index (10 items)	Pearson correlation	−0.300**	−0.059*	0.537**	1							
	Sig. (2-tailed)	0.000	0.027	0.000								
	N	1394	1394	1394	1394							
Conf_accident	Pearson correlation	−0.047	−0.039	0.141**	0.155**	1						
	Sig. (2-tailed)	0.082	0.150	0.000	0.000							
	N	137 4	1374	1374	1374	1374						
_conf_X-ray	Pearson correlation	0.022	0.016	−0.097**	0.039	0.470**	1					
	Sig. (2-tailed)	0.415	0.564	0.000	0.150	0.000						
	N	1374	1374	1374	1374	1364	1374					
Ibenefits_disadvant	Pearson Correlation	−0.190**	−0.030	0.457**	0.302**	0.284**	0.077**	1				
	Sig. (2-tailed)	0.000	0.280	0.000	0.000	0.000	0.005					
	N	1341	1341	1341	1341	1328	1328	1341				
ReductionNPP	Pearson correlation	0.188**	0.009	−0.535**	−0.335**	−0.244**	−0.029	−0.653**	1			
	Sig. (2-tailed)	0.000	0.749	0.000	0.000	0.000	0.284	0.000				
	N	1340	1340	1340	1340	1327	1328	1314	1340			
Opinion_energy	Pearson correlation	0.212**	0.034	−0.531**	−0.379**	−0.272**	−0.035	−0.720**	,704**	1		
	Sig. (2-tailed)	0.000	0.206	0.000	0.000	0.000	0.201	0.000	0.000			
	N	1374	1374	1374	1374	1358	1357	1328	1330	1374		
Future_children	Pearson correlation	0.236**	0.043	−0.550**	−0.342**	−0.265**	−0.034	−0.597**	,608**	,646**	1	
	Sig. (2-tailed)	0.000	0.117	0.000	0.000	0.000	0.221	0.000	0.000	0.000		
	N	1338	1338	1338	1338	1324	1324	1306	1303	1326	1338	
Management_nuclear	Pearson correlation	0.084**	−0.028	−0.168**	−0.124**	−0.279**	−0.151**	−0.263**	,286**	,264**	,344**	1
	Sig. (2-tailed)	0.002	0.319	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	N	1291	1291	1291	1291	1282	1279	1258	1259	1281	1265	1291

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 2. Risk perception between different groups.

	General population without experience		General population with experience		New employees		Professionally-exposed people	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Accident at a nuclear installation	2.99	1.19	2.90	1.27	1.92	1.04	2.02	1.13
Medical X-rays	2.62	1.04	2.71	0.96	2.65	0.95	2.84	0.97

The risk perception of medical X-rays of the general population with experience is not significantly different from the new employees ($p = 0.897$), nor from the professionally exposed people ($p = 0.724$). The new employees do not have a significantly different risk perception for medical X-rays than the professionally exposed people ($p = 1.000$).

The risk perception also differs within each group depending on the type of risk, exceptionally for the general population with experience ($p = 0.350$; $t(51) = 0.944$). The general population without experience has a significantly higher risk perception for an accident at a nuclear installation ($p < 0.001$; $t(951) = 8.32$) compared to medical X-rays, whereas the new employees ($p = 0.001$; $t(38) = -3.73$) and the professionally exposed people ($p < 0.001$; $t(324) = -0.667$) have a significantly higher risk perception for medical X-rays compared to an accident at a nuclear installation.

Identifying predictors for risk perception for each group

In this section, the hypothetical predictors for the risk perception of the two ionizing radiological risks are analysed based on linear regressions. Two separate models are conducted to test the following independent variables (hypothetical predictors): index of knowledge about nuclear technology in general, confidence in the authorities for the actions they undertake to protect population against risk, attitude towards nuclear energy and trust in management of nuclear installations. The variable group of respondents is taken as a scale for level of experiences ranging from general population without experiences (1) to the most experienced, since they are professionally exposed to radiological risks (4). The variables age and gender are used as controlling variables. Only the significant ($p < 0.05$) and almost significant ($0.09 > p < 0.05$) results are discussed here. Detailed results related to hypothetical predictors are reported in Table 3.

The attitudes towards nuclear energy are most strongly related to risk perception of an accident at a nuclear installation. People with more positive attitudes perceive the risks of an accident at a nuclear installation much lower than people with negative attitudes. We identified that experiences on ionizing radiation significantly influence the level of risk perception as well. People with more experiences, for instance the group of professionally exposed to ionizing radiation, the group of new employees at a nuclear installation or even the group of people with some experiences from a general public have significantly lower risk perception of an accident at a nuclear installation than the general public. Interestingly, for medical X-rays the relationship is just the opposite. People with more experience of ionizing radiation perceive medical exposure much riskier than the general population without experiences. Trust in a management of nuclear installations revealed a moderate influence on the perceptions of risks related to a nuclear accident and the use of medical X-rays. People with lower trust in a safe management of nuclear installations have rather higher perception of both risks. Since age group is not significant for the relationship with the risk perception of an accident at a nuclear installation, it is statistically significant for the relationship with risk perception of medical X-rays. How younger the person, how higher his/her risk perception. The level of knowledge revealed a significant relationship only with risk perception of medical X-rays. As expected, people that know more about nuclear technology have a lower risk perception of medical X-rays. Remarkably, the research shows that level of knowledge does not significantly

Table 3. Hypothetical predictors of risk perception of an accident at a nuclear installation and risk perception of medical X-rays.

Predictor	1. Model risk perception of an accident at a nuclear installation		2. Model risk perception of medical X-rays	
	β	S. E.	β	S. E.
Gender	0.042	0.071	0.041	0.064
Age group	0.001	0.013	−0.063*	0.012
Group of the respondents/level of experiences	−0.175***	0.035	0.201***	0.032
Index of knowledge	−0.033	0.021	−0.084*	0.019
Confidence in the authorities	−0.050	0.031	−0.114***	0.028
Attitude towards nuclear energy	0.215***	0.046	0.096*	0.040
Trust in a management of nuclear installations	0.095**	0.028	0.098***	0.025
Constant	$B = 2.949$***	0.245	$B = 2.833$***	0.218
		$N = 1197$		$N = 1201$
		R^2(adj) (full model) = 0.19		R^2(adj) (full model) = 0.06

Note: Linear regression analysis, Dependent variables: Risk perception of an accident at a nuclear installation and risk perception of medical X-rays.
***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

influence the level of risk perception of an accident at a nuclear installation, although the influence was expected.

To summarize, the perception of both ionizing radiation risks is influenced by the level of experiences that a person has and consequently, the group of the respondents that they belong to. However, the explanatory value of the first model was moderately strong ($R^2 = 0.19$) whereas the second model was lower ($R^2 = 0.06$).

Discussion

This study analyses the differences in risk perception of two ionizing radiological risks among four population groups (the general population without and with experience, the new employees and the professionally exposed people working in the nuclear sector). The hypothesis was that new employees have a significantly lower risk perception for an accident at a nuclear installation compared to the general population without experience, but higher compared to the professionally exposed people. However, the empirical results reveal that the latter was not the case as the difference in risk perception between the new employees and the professionally exposed people is negligible. Related to the perception of risks due to the use of medical X-rays, the results are slightly different. Here, the only significant difference in risk perception between the groups is found between the general population and the professionally exposed people who have a significantly higher risk perception. This result is surprising as in a previous study, Sjöberg et al. (2000) found that experts have a systematic lower risk perception for risks concerning radiation and nuclear technology than the general public. Although the two radiological risks included in this paper make use of ionizing radiation, it seems that these two technologies are perceived quite differently by the different groups. The professionally exposed people in our study have a lower risk perception for an accident at a nuclear installation than for medical X-rays. This difference can be explained by the differences in confidence in the authorities and the trust in the management of nuclear installations. Professionally exposed people has less confidence in the authorities to protect them against the risks of medical X-rays, and the general population is more convinced that there is insufficient control on the safety in nuclear installations in Belgium. However, the regression analysis revealed that trust in management of nuclear installations only have a moderate influence on the risk perception, but confidence has a significant relationship with the risk perception of medical X-rays: the higher the confidence in authorities, the lower the perception of the radiological risk. This corresponds to previous studies, such as Sjöberg (1999). The significant differences in confidence in authorities between the groups can be attributed to different knowledge levels. According to Siegrist et al. (2007), the higher the knowledge of the respondents, the more insight they have into the effectiveness of the actions performed by the authorities to protect them against these risks. In order to explain the differences in trust in authorities of the professionally exposed people, it is also plausible that these respondents consider that different actors are responsible for their protection; i.e. the federal government for protecting against risks related to an accident at a nuclear installation and hospital management for protecting against risks in the use of medical X-rays. However, the questionnaire does not differentiate this actor issue. The general population might also have more confidence in hospitals (for medical X-rays) than the authorities (for an accident at a nuclear installation) as Sjöberg (1999) found that the public has less trust in experts who are working for the authorities compared to experts who are considered as independent.

The general population might also feel certain voluntariness concerning the risk related to medical X-rays and it is quite reasonable that they overestimate the benefits while being blind to the disadvantages (see also Slovic et al. 2007; Siegrist et al. 2007). Moreover, one can decide whether one will be exposed to medical X-rays or not, but one cannot choose to be exposed or not to an accident at a nuclear installation.

The results of the study show that the general population (with and without experience) has less knowledge of the amount of radiation and the radiation risks of medical X-rays. However, it is remarkable that although the knowledge level related to radiological risks between the groups significantly differs, knowledge does not play a significant role in the risk perception. This finding confirms previous research conclusions of Wildavsky and Dake (1990) and Perko et al. (2012), but is opposite to the findings of Siegrist et al. (2007) claiming that more knowledge decreases the risk perception.

The gender was not in either of the linear regressions a significant independent variable for an accident at a nuclear installation and medical X-rays. Although there are no significant results, there is an interesting relation between gender and the risk perception of the professionally exposed people for an accident at a nuclear installation. This finding suggests that the female respondents have a higher risk perception for an accident at a nuclear installation than their male colleagues. One should notice that the male–female ratio is different in all groups and not always representative compared to the Belgian population. The groups of the professionally exposed people and the new employees consist of many more male than female respondents. Given the findings of Sjöberg (2000, 2005a) that women are more risk-averse, the difference in male–female ratio might have an effect on the risk perception of groups with a limited amount of female respondents.

The group of new employees is under-represented in the scientific literature. Their level of knowledge is comparable with the professionally exposed people. Of all the groups, they have the lowest confidence in authorities to protect against medical X-rays, but the highest confidence to protect against an accident at a nuclear installation. It would be very interesting to further study the risk perception of the new employees, including more respondents and a better diversity of new employees who are confronted with radiological risks, since they seem to have a rather different opinion. Another recommendation for future studies is to follow the risk perceptions of experts in the long term. The public's risk perception increases after an accident, but decreases after a period without an accident. It is not clear whether the risk perceptions of experts are also influenced by accidents/incidents. It might be that experts are less influenced by accidents like Fukushima.

The discussion ends with a reflection of the limitation of our study. Related to the groups of employees (new workers and professionally exposed), only employees at the SCK-CEN participated in the study which might have an influence on the results. It is plausible that the results would have been different if the selection of the respondents was less concentrated, for instance, also taking into account professionally exposed employees at hospitals. It is desirable that future research would focus on the differences between several types of experts, like experts in nuclear power, experts in radiology, experts in transport of radioactive material, the processors of radioactive waste, etc. Also the number of risks included in this study is limited as only risk perceptions of an accident at a nuclear installation and medical X-rays are studied. The last remark is a methodological one. In the present paper, linear regression is used to look for significant relations between the dependent variables (risk perceptions of an accident at a nuclear installation and medical X-rays) and the independent variables. The choice not to use a multinomial logistic regression is debatable.

Conclusions

In life, people are directly or indirectly exposed to different radiological risks. Medical X-rays and accidents at a nuclear installation are just two of them. Previous studies (Sjöberg 1999, 2000, 2005a, 2005b; Siegrist et al. 2007; Perko forthcoming) showed that there is a gap between the risk perception of the general population and the risk perception of experts. In this study, the concept 'expert' is replaced by professionally exposed people'. Two new groups are also added in the empirical survey: (1) the general population with experience in the nuclear field (people from the general population who already have had a job that involved the use of radioactivity) and (2) the new employees of the Belgian nuclear research institute SCK-CEN. These two groups are added because they have a slightly different background compared to the general population without experience and the professionally exposed people. The results of the study reveal significant differences in risk perception of an accident at a nuclear installation and medical X-rays between the groups. The largest differences in risk perception are between the general population without experience and the professionally exposed people. The general population (with and without experience) have a higher risk perception for an accident at a nuclear installation, but the new employees and the professionally exposed people have a higher risk perception for medical X-rays. The four groups are different from each other: it is clear that the new employees and the professionally exposed people have more experience with radiological risks and their level of knowledge is higher. However, in this study, knowledge is not identified as a significant predictor for risk perception whereas the level of experiences influences the perception of ionizing radiation risks. Confidence in authorities is determined as an important predictor for the risk perception of medical X-rays.

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