BACKGROUND CHARACTERISTICS, PERSONALITY, ATTITUDES AND GROUP ASPECTS INFLUENCE TECHNOSCIENTIFIC RISK ESTIMATIONS IN RADIOACTIVE WASTE MANAGEMENT

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ABSTRACT

In this article, we look for social psychological influences of risk estimates that are based on scientific methods. We consider correlations between scientific estimates on the one hand and background characteristics, group aspects, personality traits, and other scientific estimates on the other hand. Despite a methodological challenge, we find important correlations between scientific risk estimates on the one hand and the attitude 'trust in science' and the personality trait 'neuroticism' on the other hand. Such insights can increase the awareness of all participants of the decision-making process that technoscientific facts are context depended.

INTRODUCTION

In the last decennia, risk perception research has made important progress. Although some important differences remain between different risk perception schools [1-3], many significant factors have been characterised. The importance of these results for risk communication is obvious. Contrary to the notable attention of laymen risk perception, the different influences on risk estimations based on scientific methods are less studied. We make the hypothesis that these influences in risk assessment applications can also be very important, especially in cases of uncertainty. Since the nuclear waste management deals with large projects and extrapolations over huge periods, uncertainties are inextricably bound up with this field.

In this article, we will explore which types of influences are important for scientific risk estimation. In doing so, we hope to give an initial impetus to enlarge the existing risk research to science and technology. We will start from existing research on risk estimation and test some of these results with our own questionnaire. The meta-study covers many different fields: radiation protection, nuclear waste management, toxicology, nuclear power plant safety, and geology. It will provide us with hypotheses for our own web based multiple-choice questionnaire in the radioactive waste domain.

RESEARCH DESIGN AND HYPOTHESES

In order to explore different influences on risk estimation and their importance, we divide the influences in four different issues. A first group consists of the background characteristics age, gender, education and working field. Attitudes are a second group of possible influences. A third aspect that could have an effect on risk estimation is personality. Lastly, the characteristics of the group scientists work in could be important.

Estimations in Radioactive Waste Management

We start with the description of the risk estimation questions. In our introduction, we stressed the importance of the difference between risk perception and risk estimation. A clear-cut delineation, however, is difficult to make. Risk estimation, on the one hand, is a judgment in which the systematic approach of characterising and quantifying risks based on the present scientific knowledge prevails. Risk perception, on the other hand, is a judgment in which no scientific or technological knowledge at all is involved in the judgement. Ideas are based on the person's intuitive processing of risk-related information through direct observation, past experience or communication. It is clear that none of these extremes exists. Laymen will always know some technological facts. Technologists and scientists will always combine intuition with their scientific methods.

What can we expect from the link between different risk estimations? Literature does not teach us much about the links between the different scientific estimations. According to Jenkins-Smith and Bassett [4], scientists tend to associate no greater certainty with more perceived risks. Slovic and others state that they did find correlations between risk estimations. In two subsequent inquiries, Slovic *et al*. [5] and Slovic *et al*. [6] asked respectively British (N= 312, RR: 36.4%) and Canadian (N=150, RR=30.6%) toxicologists for an estimation of the level of evidence of Bromoethane's carcinogenic activity based on a summary of a two-year inhalation and genetic toxicology study of the National Toxicological Program for this chemical. A low score on the index indicated a tendency to see strong evidence for carcinogenicity. With a stepwise multiple regression analysis Slovic *et al.* [5] found that the overall tendency to judge chemical B as carcinogenic for rats and mice is correlated with seeing a high risk in another compound E.

Since we consider perception and estimation only gradually different, we expect the mutual relations of magnitude, probability and uncertainty estimation to be positive, as they are in perception studies and in Slovic's estimation study. We make the hypothesis that scientists making higher hard fact magnitude estimations will give larger uncertainties and higher probabilities too.

We want to focus on estimations as much as possible. In order to do so, we limit ourselves to scientists and technologists in the radioactive waste domain and ask them questions in their domain. We also want to avoid the perception contribution as much as possible. For this reason and in order to be able to operationalise the risk factor, we define risk (R) as magnitude (M) × probability (p). For each magnitude and probability estimation, we ask an uncertainty estimation as well (U_M and Up). In this way, we get sets of four questions. We applied these sets to four different themes: repository dose rate, isolation failure, location, and human intrusion (Table I.).

Background Characteristics

Based on literature, we expect background characteristics to influence risk estimation too. We want here to look for evidence for some background characteristics that influence risk estimation: education, working field, age, and gender.

Differences in one's educational field seem to correlate with hard fact estimation. Richard Barke and others found that life scientists (biology, biomedical science and clinical medicine) perceive higher levels of nuclear and overall environmental risk than physicists, chemists and engineers. [7,8,9]

The working field or affiliation also affects people's risk perception. Scientists in universities or state and local governments tend to see the risks of nuclear energy and wastes as greater than scientists who work as business consultants or for private research laboratories. [6,8,10-13] We therefore expect people with an education in the life sciences such as biology or environmental sciences to estimate M, p, and U higher than people from the material sciences such as engineering or physics. The same goes for people working in universities or governmental organisations compared to those working in private companies.

Age and gender also seem to influence M, p, and U estimations. Barke *et al.* [9] and Mertz *et al*. [12] show that older people seem to judge risks lower than younger ones. The influence of age on a scientist's risk estimation in these studies is consistent with laymen risk perception studies. Kivimäki *et al* [14], however, did not find a significant correlation between age and risk estimation of nuclear power plant employees.

Many inquiries have been carried out to look for gender influences. According to some inquiries, women seem to judge risks higher than men do. [5-7,9,10] We expect younger people and women to make higher M, p, and U estimations.

Attitudes

We see attitudes as a second important possible group of risk estimation influences. In literature, the effect of political opinion and worldview has been looked for. We will focus in our questionnaire on 'belief in science'.

Richard P. Barke, Hank C. Jenkins-Smith and Carol Silva [9] inquired scientists for the Union of Concerned Scientists (UCS) (N=1155, RR=55%) and Sandia and Los Alamos National Laboratories (Lab) (N=1226, RR=53%) about their opinion on the correct relation between ionising radiation and carcinogenic response. We are not quite sure in how far the respondents were familiar with radiobiology or radiation protection to consider the judgements as estimations. Probably, it concerns mere perceptions since Barte *et al.* asked a broad group of scientists. They found that those who tend to believe that scientists understand the risks associated with nuclear radiation judge the radiation risk at low doses as low (Lab: $F=11.13$, $p<.0001$; UCS: $F=26.20$, $p<.0001$).

The same was found by Slovic *et al.* [6]. They found that toxicologists with a tendency to see strong evidence of carcinogenicity in animals were more likely to believe that animal reactions reliably predict human reaction ($r=-.14$, $p<.05$) or cancer causation ($r=-.28$, $p<.01$). They were more likely to disagree that risk is a subjective construct ($r=-.12$, $p<.05$)

We therefore think that confidence in nuclear research and development can also be an important aspect. People who have trust in what happens in nuclear R&D will make lower M, p and U estimations. In order to test this hypothesis, we ask for the respondents' trust in the usefulness of safety estimation methods (variable TUSEFPA) and their opinion about the knowledge of the final waste forms (variable TWSTDET) (See Table I.).

Personality

In our questionnaire, we also want to look for personality influences of risk estimation. In order to show this influence, we have to choose one of the classical approaches of personality. [15,16]: psychodynamic theories, phenomenological and humanistic philosophies, the social learning theories, and the trait approaches. For our technoscientific risk estimation purposes, we opted for the personality trait approach in general and the big five-personality questionnaire in particular.

Paul T. Costa Jr. and Robert R. McCrae define personality traits as 'dimensions of individual differences in tendencies to show consistent patterns of thoughts, feelings, and actions. This is a phenotypic definition; in essence, it tells us what traits look like and how we can recognize one when we see it.' [17] The five factors found by McCrae and Costa are neuroticism, extraversion, openness, agreeableness and conscientiousness [18].

Neuroticism (N) describes the general tendency to experience negative affects such as fear, sadness, embarrassment, guilt, or distrust. People with high N score are prone to have irrational ideas, to be less able to control their impulses, and to cope more poorly than others with stress. The concept ‘neuroticism’ might suggest that the N-scale is a measure for psychopathology. It is however a dimension of normal personality, although patients traditionally diagnosed as suffering from neuroses generally do score higher on measures of N. Individuals with a low N score are emotionally stable. They are usually calm, even-tempered, and relaxed, and they are able to face stressful situations without becoming upset or rattled.

Extraversion (E) expresses sociability, assertiveness, activity and a talkative characteristic. The third factor, openness (O) consists of active imagination, aesthetic sensitivity, attentiveness to inner feelings, preference for variety, intellectual curiosity, and independence of judgement. Agreeableness (A), the fourth factor, describes altruism and sympathetic feelings towards others. Conscientiousness (C), the last personality domain in the five-factor model tells about how purposeful, strong-willed, determined people are.

We expect scientists that tend to experience negative affects such as fear, sadness, anger, and distrust to make higher M, p, and U estimations. People who are altruistic or dutiful will estimate higher risks than people who are less altruistic since it is to be expected that they feel responsible for their fellow men.

We use the NEO-FFI big five questionnaire. All five-personality traits are measured by 12 different items. We give the questions of the neuroticism factor as an example in Table I..

Group Characteristics

Our last issue of risk estimation influences are group aspects. Classical psychological research showed the importance of group norms. Salmon Asch's line judgement task showed that under group pressure, more than 25 % of individuals could be brought to always conform to a publicly stated, but blatantly wrong “group norm" and 75% conformed at least once. Muzafer Sherif showed how norms develop in small groups. He used the autokinetic effect that in darkness a motionless point of light appears to move, occasionally randomly and in various directions. The individual estimations differed from 2 to 25 centimetres. In group situations, the inquiry showed a convergence to a common but group dependent perception. [19]

The role of group aspects in science and technology has been described by Thomas Kuhn, first with his paradigm notion and later with the disciplinary matrix concept. A disciplinary matrix is regarded as a ‘constellation of convictions, values and techniques shared by members of a certain scientific community, and that are handed down in an inextricable whole.’ [20] This set of convictions influences scientific action.

One of the scarce quantitative inquiries we found in this respect is the one of Kivimaki *et al*. [14]. They found (N=428, RR=80%) a strong correlation between the nuclear power plant personnel's risk estimation and their organisational commitment ($r=-.32$, $p<.001$). The more committed people are towards their organisations goals, the lower they assess the risk of their company.

We inquire the group factor by means of the groupthink concept. It has been defined by Irvin Janis. He speaks of groupthink as 'a mode of thinking that people engage in when they are deeply involved in a cohesive in-group, when the members' strivings for unanimity override their motivation to realistically appraise alternative courses of action.' [21] The groupthink concept has been operationalised by M. Rosander, D. Stiwne, and K. Granstrom [22] in a questionnaire. It was analysed in three different factors. The first factor consists of, on the hand, morale groupthink, according to the authors describing a strong belief in the integrity of a group and a strong belief in its effectiveness. The second factor distinguishes between autonomy and lack of control in the groupthink concept. The third factor measures self-sufficiency vs. vulnerability. ‘In a broader perspective, this factor also concerns a group’s boundary regulations. Thus, a group characterised by low boundary permeability shuts itself off from outside influence and in extreme cases acts on fantasies about self-sufficiency and invulnerability. The other extreme, a group characterised by high boundary permeability, acts on the belief that the group urgently needs something from outside for development or survival.’ (Ibid., 86) We give the vulnerability questions as an example in Table I..

We make the hypothesis that group aspects are major determinants for risk judgement. As described in the previous chapters, group culture is a broad concept. Groups with high groupthink tend to have more extreme estimations. Groups with high groupthink that tend to make high M, p, U estimations will make higher estimations, whereas groups that tend to make low estimations will make even lower estimations if their groupthink is high.

Table I. Items of the radioactive waste questionnaire on estimation, 'trust in science', neuroticism, and groupthink vulnerability.

Estimation questions
At what time do you expect that the dose rate due to nuclide migration from the HLW repository will exceed for the first time a dose rate of 0,3 mSv/y, taken all possibilities (normal and altered evolution scenarios) into account? What do you think is the uncertainty on the time period you have chosen? What will be the maximum dose rate at a certain time due to nuclide migration of the HLW repository, taken all possibilities (normal and altered evolution scenarios) into account? What do you think is the uncertainty on the number you have chosen? Suppose that the high level waste repository will be closed in 2100 according to the best available techniques of that time. What will be the probability that something happens as a consequence of isolation problem due to system failure within 500 years after closure? What do you think is the uncertainty on the number you have chosen? Suppose that the high level waste repository will be closed in 2100 according to the best available techniques of that time. Suppose an isolation problem due to closure failure does occur 500 years after closure. What is a realistic number of deadly injured persons a closure failure can cause in total? What do you think is the uncertainty on the number you have chosen?

How long after closure will the location of the HLW repository be known? What do you think is the uncertainty on this number? At what time do you expect that human intrusion in the repository by means of What do you think is the uncertainty on this number? Suppose the human intrusion does take place 1000 y after closure. What is a realistic number of deadly injured persons an intrusion can cause in total? What do you think is the uncertainty on this number?
Trust in science
Appropriate use of safety assessment methods and sufficient information from proposed disposal sites can provide the technical basis to decide whether specific disposal systems would offer to society a satisfactory level of safety for both current and future generations. What do you think scientists or decision-makers know about the final waste forms that have to be disposed?
Neuroticism
I am not a worrier. When I'm under a great deal of stress, sometimes I feel like I'm going to pieces. I rarely feel lonely or blue. I rarely feel fearful or anxious. I am seldom sad or depressed. I often feel inferior to others. I often feel tense and jittery. Sometimes I feel completely worthless. I often get angry at the way people treat me. Too often, when things go wrong, I get discouraged and feel like giving up. I often feel helpless and want someone else to solve my problems. At times I have been so ashamed I just wanted to hide. Caption: Questions of the questionnaire we carried out. The numbers refer to the number in the questionnaire.
Groupthink vulnerability
The development of our team is proceeding at its best in relative isolation from other teams and groups. We develop our teamwork without much need of any contact with other teams or other outsiders. Even if our team is not developing in the right direction, more contact with other teams and groups would not change anything. We evaluate our teamwork, and change it so it will work in the best possible way, without any regard to suggestions from outside the team.

Population

We looked for a broad scope of scientists and decision-makers familiar with the estimation of high-level waste disposal. These people could be members of action groups, business consultants, governmental organisations, local agencies, non-governmental organisations, private non-profit organisation, private research, public participation groups, and universities. The operational population is determined by (1) the waste link website www.radwaste.org, describing all different radioactive waste resources on the Internet and (2) contacts attained from waste experts at SCK•CEN. The questionnaire is web-based. Since we presume that all these groups have sufficient Internet access, we assume that there is low web bias on the population.

The questionnaire was sent to different countries. We decided to make the questionnaire in English and to make a translation for only a few difficult words, since it demands many extra studies on the compatibility of the translated questionnaires. Some difficult words were translated in Chinese, Czechoslovakian, Dutch, French, German, Japanese, Russian, Slovakian, Slovenian, Spanish, and Swedish.

We obtained 149 usable answers from 82 different institutes.

DATA HANDLING

We sum up the respective results of the magnitude (M), probability (p) and uncertainty (U) questions. For the personality and groupthink questionnaire, we carry out a factor analysis. Before we discuss the different correlations, we mention how we treated a 0-value issue.

0-value Issue

The questionnaire software sets the missing values default to “0”. It also put the lowest score to “0” for subquestions. This only applies to the group and individual questionnaire data, which therefore remain ambiguous. It does not apply to the estimation questions and the background information.

Since the missing values have been given a value, the traditional missing value techniques cannot be applied to restore this issue. Data augmentation analysis could have been an alternative. With the 'NORM' software, we carried out a data augmentation analysis. [23] Unfortunately, the 0-values and the variables concerned were too numerous compared with the available information and data augmentation analysis was not possible.

Nevertheless, we could deduce that the 0-value issue was not that serious. First of all, an item-factor correlation analysis gives us an idea of the seriousness of the issue. For the loading matrix after varimax rotation, we find the following number of items that correlates with the own item (Table). We can compare this number with research results mentioned in the Dutch-language NEO manual. The more items -with a maximum of 12 for the NEO questionnaire- correlate with its own factor, the better. Knowing that the number of respondents in this research is much higher, we can see a pattern correspondence for all but the openness-factor, which is much lower. Secondly, we compare the Cronbach's alphas of our inquiry with a research of comparable sample size to decide whether we continue the analysis with these data. We see that our reliabilities are strongly comparable with same size research mentioned in the manual. [24] We find an argument in favour of keeping the complete data set in the NEO-FFI manual.

Table II. Number of items that correlates with the own factor for our own research and exemplary research. (Hoekstra et al.) ; and NEO factor reliably for our data set and research from Hoekstra et al. The Pearson correlation between the cronbach's alpha's from both groups is .974 (p=.005, N=5).

Factor	**Number of items that correlates with its own factor**		***Own research***	***Hoekstra* et al. *Research A (N=351)***
	Own research (N=149)	***Hoekstra et al. (N=2415)***		
N	10	12	α_{neo_n} = .78	α_{neo_n} = .80
E	9	9	α_{neo_e} = .75	α_{neo_e} =.73
O	8	12	α_{neo_o} = .59	α_{neo_o} = .57
A	9	10	α_{neo_a} = .65	α_{neo_a} = .66
C	9	10	α_{neo_c} = .82	α_{neo_c} = .79

These results give courage to continue. We are aware that, in doing so, we include the 0-values and their problematic interpretation. Because the manual reliabilities are very comparable with our research ones, we conclude that the importance of the interpretation problem is sufficiently small to continue our analysis.

Correlations

We first inquire the correlations between the uncertainty, magnitude, and probability factors. Our hypothesis that R, M, p, and U are positively correlated is confirmed. This result goes against the conclusion of Jenkins-Smith and Bassett [9] that risk and uncertainty are correlated for laymen, but not for scientists. All relations between R, M, p, and U are statistically significant. Higher hard fact estimation of one factor means a higher estimation of another factor. The strong correlations between M, p, and U seem to indicate that these estimations have a fundamental characteristic in common. We will show with the discussion of gender results that this is not necessarily the case.

The risk estimation factor correlates negatively with our trust-items. This confirms Barke *et al.*'s [9] findings and our hypothesis that high confidence is correlated with low risk estimation.

The negative correlation between risk and age confirms research of Barke *et al.* [7] and Mertz *et al.* that elder scientists estimate risks lower. The correlations between education and affiliation are not significant and therefore do not confirm our hypothesis.

Whereas Barke *et al.* [7], Mazur *et al.* [10], Slovic *et al.* [6] find that male scientists estimate risk lower than women, Barke *et al.* [9] and our research find no statistically significant gender influence for risk estimation. Since we gave 'female' the value 1 and 'male' the value 2, this means that men make a higher U estimation. This is a contrast with all perception inquiries and our hypothesis that women make higher uncertainty perceptions and estimations.

The neuroticism factor (cronbach's alpha= .78) correlates significantly with magnitude, probability, and risk estimation. Scientists scoring high on the N-scale make a high estimation of the M, p, and R. The other correlations between personality traits and the scientific estimations are not statistically relevant. We confirm our hypothesis that scientists who tend to experience negative affects such as fear, sadness, anger, and distrust to make higher M, p, and U estimations. The hypothesis that scientists who are altruistic or dutiful will estimate risk higher than people who are less altruistic cannot be confirmed.

R correlates negatively with the vulnerability factor (cronbach's alpha= .68). A significant correlation exists between scientists' group vulnerability assessment and low risk estimation. Since we postulated that groups with high groupthink or organisational commitment made more extreme estimations, we do not confirm or disconfirm a hypothesis with these results (See Table III).

Table III. Correlation matrix for risk (p×M), magnitude (MSUM), probability (pSUM), and uncertainty (USUM) with statistically significant other estimations, attitudes, background characteristics, personality traits and group aspects. R-p and R-M correlations are not indicated because R is a function of p and M.

Variable		R	MSUM	PSUM	USUM
R	Pearson Correlation	-	-	-	**,305****
	Sig. (2-tailed)				,001
	N				106
MSUM	Pearson Correlation	-	-	**,387*****	**,258****
	Sig. (2-tailed)			,000	,008
	N			121	106
PSUM	Pearson Correlation	-	**,387*****	-	**,264****
	Sig. (2-tailed)		,000		,006
	N		121		106
TUSEFPA	Pearson Correlation	**-,201***	-,077	**-,250****	-,128
	Sig. (2-tailed)	**,027**	,400	**,004**	,191
	N	**121**	122	**132**	106
TWSTDET	Pearson Correlation	**-,427*****	**-,360*****	**-,299****	-,168
	Sig. (2-tailed)	**,000**	**,000**	**,001**	,090
	N	**118**	**119**	**128**	103
AGE	Pearson Correlation	**-,202***	-,151	**-,231****	,023
	Sig. (2-tailed)	**,026**	,096	**,008**	,817
	N	**121**	122	**132**	106
GENDER	Pearson Correlation	-,026	-,028	,026	**,246***
	Sig. (2-tailed)	,781	,760	,767	**,011**
	N	121	122	132	**106**
NEO_N	Pearson Correlation	**,299****	**,334*****	**,212***	-,011
	Sig. (2-tailed)	**,002**	**,000**	**,022**	,914
	N	**110**	**111**	**117**	97
GTVULSUM	Pearson Correlation	**-,226***	-,080	-,173	-,039
	Sig. (2-tailed)	**,019**	,410	,061	,704
	N	**108**	109	117	95

*** Correlation is significant at the 0.001 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

The most important result is *that* there is contextual influence for technoscientific risk estimation. We see many correlations, ranging from weak ($p<.05$) to strong ($p<.001$). Among these, we see 'trust in science' and 'neuroticism' as the two most important factors. Science trust and estimation questions are not influenced by the zero value issue, the strong correlations between trust and magnitude and R are therefore very strong results for scientific estimations! The correlations between the neuroticism-factor and M and R are also very important. These results are subjected to the zero value issue and as such, we cannot use them to confirm our hypothesis. However, these results are that strong that we consider them as very promising. Personality and attitudes do indeed importantly influence hard facts. The other correlations are important as well. However, the zero value issue makes some interpretations less stringent.

The role of gender is particular. Gender does not correlate with any estimation except uncertainty. Uncertainty does not correlate with any background characteristic or personality trait but gender. And, above all, women estimate lower uncertainty compared with men. What do these results mean for our hypotheses? First of all, we implicitly expected a more or less parallel correlation between background characteristics and M, p, and U estimations. This is not the case. M and p are more or less parallel. U follows a completely different pattern with regard to the background characteristics. This result contrasts with all risk perception inquiries. A possible explanation could be that our population of women is not representative for all women. The women that work in the radioactive waste management, a typical men's world, fought against the male group culture and could maintain themselves. Maybe there is an a priori selection, maybe the women change their behaviour (and personality?) to cope with this situation.

CONCLUSION

In this article, we have demonstrated that background characteristics, attitudes, personality, and group aspects influences technoscientific risk estimations. Especially neuroticism and trust in science show important correlations with scientific risk estimation. We consider this as a very important result in many discussions: the differences in risk judgements between expert and laymen; philosophy of science; risk based decision-making including precautionary approaches, and so forth. Hard facts interact with other components.

We can draw many conclusions from these results.

First of all, the results do give an initial impetus to enlarge the existing risk research to science and technology. Since personality, attitudes, or background characteristics do influence both risk estimation and perceptions, it is worthwhile to look for similarities and differences in a symmetric way. This means that risk inquiries should not compare laymen's risk perception with the scientific and therefore 'right' risk estimations. They should compare risk estimation and perception with respect to each other.

Secondly, we see an important difference between uncertainty estimation and the other estimations probability and magnitude with respect to correlations. Risk and uncertainty estimation research should therefore make specifications between different estimations.

Thirdly, we could deduce rules to compose technoscientific safety assessment teams. We could make a plea for a team that is mixed in 'neuroticism' and 'trust in science'. We could recommend decision-makers who talk about robust and conservative decision-making to choose for technoscientists that are more neurotic than average. We could advise to measure 'neuroticism' and 'trust in science' in order to determine the ranges in which the safety assessment could have been if it were another group of technoscientists that had performed the research. These measures are probably both too delicate and too immature for application in technoscientific groups. The most realistic proposition doubtlessly is to increase the awareness of all participants of the decision-making process that technoscientific facts are context depended.

This is what we hope to have achieved here: technoscientific risk estimations in radioactive waste management correlate with background characteristics, personality, attitudes, and group aspects. In argumentations on safety, technologists and scientists should take this into account.

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REFERENCES

[1] P. SLOVIC, "Perception of risk", In: Science, 236, 280-285 (1987).
[2] L. SJÖBERG, "Perceived risk and tampering with nature.", In: Journal of Risk Research, 3, 353-367 (2000).
[3] M. DOUGLAS and A. WILDAVSKI, "Risk and Culture: An essay on the Selection of Technological and Environmental Dangers", University of California Press, Berkeley (1982).
[4] H. JENKINS SMITH and G.W. BASSETT, "Perceived risk and uncertainty of nuclear waste – differences among science, business, and environmental group members", Risk Analysis, Vol. 14 (5), 851-856 (1994).
[5] P. SLOVIC, T. MALMFORS, D. KREWSKI, C.K. MERTZ, N. NEIL, and S. BARLETT, "Intuitive Toxicology. II. Expert and Lay Judgments of Chemical Risks in Canada", In: Risk Analysis, Vol. 15 (6)**,** 661-675 (1995).
[6] P. SLOVIC, T. MALMFORS, C.K. MERTZ, N. NEIL, I. PURCHASE, "Evaluating chemical risks: results of a survey of the British Toxicological Society" In: Human & Experimental Toxicology, 16, 289-304 (1997).
[7] R.P. BARKE, H.C. JENKINS-SMITHS, and P. SLOVIC, "Risk Perceptions of Men and Women Scientists" In: Social Science Quarterly, 78 (1)**,** 167-176 (1997).
[8] R.P. BARKE and H.C. JENKINS-SMITH, "Politics and scientific expertise – scientists, risk perception, and nuclear waste policy", In: Risk Analysis, 13 (4), 425-439 (1993).
[9] R.P. BARKE, H.C. JENKINS-SMITHS, and C. SILVA, "Translating Scientific Knowledge into Policy Recommendations: The Role of Scientists' Value", Personal copy (2000).
[10] A. MAZUR, S. ROTHMAN, and S.R. LICHTER, "Biases about man-made cancer among researchers", In: *Social Studies of Science*, 31 (5), 771-778 (2001).
[11] P. MURPHY, "Affiliation bias and expert disagreement in framing the nicotine addiction debate", In: Science, technology & human values, 26 (3), 278-299 (2001).
[12] C.K. MERTZ, P. SLOVIC, and I. PURCHASE, "Judgments of Chemical Risks: Comparisons Among Senior Managers, Toxicologists, and the Public", In: Risk Analysis, 18 (4), 391-404 (1998).
[13] N. KRAUS, T. MALMFORS and P. SLOVIC, "Intuitive Toxicology: Expert and Lay Judgments of Chemical Risks", In: Risk Analysis, Vol. 12 (2), 215-232 (1992).
[14] M. KIVIMÄKI, R. KALIMO, and S. SALMINEN, "Perceived nuclear risk, organizational commitment, and appraisals of management – A study of nuclear-power-plant personnel", In: Risk Analysis, 15 (3), 391-396 (1995).
[15] D.A. BERNSTEIN, A. CLARKE-STEWART, E.J. ROY, and Ch.D. WICKENS, Psychology, Houghton Mifflin Company, Boston (1997).
[16] H.L. ROEDIGER, E.D. CAPALDI, S.G. PARIS, J. POLIVY, and C.P. HERMAN, "Psychology, An introduction", Thomson Publishing (1996).
[17] R.R. McCRAE and P.T. COSTA JR., "Personality in Adulthood. Second Edition. A Five-Factor Theory Perspective", The Guilford Press, New York (2003).
[18] P.T. COSTA Jr. and R.R. Mc CRAE, "Revised NEO Personality Inventory (NEO-PI-R™) and NEO Five-Factor Inventory (NEO-FFI). Professional Manual", Psychological Assessment Resources, Florida (1985).
[19] S.S. BREM, S.M. Kassin & S. Fein, "Social Psychology", Houghton Mifflin Company, Boston (1999).
[20] T.S. KUHN, "The structure of scientific revolutions, International Encyclopaedia of Unified Science", University of Chicago press, Chicago, page 176 (1970).
[21] I.L. JANIS, "Groupthink. Psychological Studies of Policy Decisions and Fiascoes", Houghton Mifflin Company, Boston, page 9 (1982).

[22] M. ROSANDER, D. STIWNE, and K. GRANSTROM, "'Bipolar Groupthink': Assessing groupthink tendencies in authentic work groups" In: Scandinavian Journal of Psychology, 39 (2), 81-92 (1998).
[23] M. GROVES, "Survey nonresponse", Wiley Interscience, New York (2002).
[24] H.A. HOEKSTRA,, J. ORMEL, F. DE FRUYT, "NEO-P-IR and NEO-FFI. Big five persoonlijkheidsvragenlijsten. Handleiding. [NEO-P-IR and NEO-FFI. Big Five Personality Questionnaires. Manual]", Swets Test Services, Groningen, page 45 (1996).