Who feels a greater environmental risk? Women, younger adults and pro-environmentally friendly people express higher concerns about a set of environmental exposures

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Abstract.

Health-related risk perceptions concerning environmental exposures reflect the public's awareness of certain environmental issues that may compromise their health. These perceptions may trigger coping strategies and self-protective behaviors, which are key for protecting people's health. With this study, we sought 1) to assess the general public's perceptions of risk from a set of environmental exposures compared with the assessment of experts; and 2) to build predictive models of the general public's risk perceptions using a comprehensive set of sociodemographic and psycho-environmental variables. We recruited a sample of 338 inhabitants (208 women, 45.8 years on average) of Gipuzkoa (Basque Country). Participants completed a paper-and-pencil questionnaire comprising questions on general sociodemographic characteristics and on health-related behaviors, and several psycho-environmental scales assessing general environmental knowledge, nature relatedness, pro-environmental behavior, environmental concerns and place attachment. Additionally, we contacted 33 regional experts who also evaluated the risk associated with the given set of exposures. Risk scores assigned by participants ranged from 1.51 to 3.42 (out of 4) and were higher than those assigned by the experts. Nonetheless, the pattern of risk prioritization was similar in the two groups. Explanatory models accounted for small to moderate shares of the variance in environmental exposure risk (R^2 = .05 to .17). The best predictors of risk perceptions were gender, age, environmental knowledge and egoistic environmental concerns. Biospheric concerns, nature relatedness and educational level hardly made any contribution. Assessment of past experiences with each environmental exposure, affective reactions towards them and psychological traits could enrich future explanatory models.

Keywords. Risk perception, public health, regression models, experts, general public.

1

Introduction

1.1 The concept, implications and apparent paradoxes of risk perceptions

Risk perceptions are intuitive judgements about the odds of a given negative event happening (Slovic, 1987). They are rapidly formed perceptions that allow people to identify factors that may have a negative impact on them and act accordingly. From a public management and health perspective, understanding people's perceptions of risk is vital to making people aware of the adverse consequences of certain behaviours or environmental exposures, to enable them to protect themselves and manage their behaviour adequately in everyday life and moments of crisis (Oltra and Sala, 2018). For the same reasons, public bodies need to take into account how public perceptions of risk work, in order to prepare successful preventive and coping strategies and plans to respond to the manifold environmental contingencies that may affect society (Ellis et al., 2018).

Elevated risk perceptions frequently appear in response to events or situations directly linked to hazardous industries and large infrastructure such as industrial complexes (Kim & Kang, 2019) and landfill sites or waste incineration plants (Lin et al., 2018). Similarly, many activities related to the extraction and manipulation of energy resources, such as those of nuclear power plants (Ho, Oshita, Looi, Leong, & Chuah, 2019) and fracking infrastructure (Brasier et al., 2011; Schafft et al., 2013) are often sources of environmental concern. All these activities are usually thought to pollute air, water and/or soil and affect human health in several ways, and also raise concerns due to possible malfunctioning or human error that could lead to harmful events.

When worried about a given environmental exposure, people often feel stress, annoyance, fear, and anxiety or even depression (Oltra and Sala, 2018; Zeidner and Shechter, 1988). Coupled with risk perceptions, these affective reactions may lead people to employ a wide array of coping strategies or self-protective behaviours in order to reduce the odds of being affected by potentially harmful events or minimize the extent of their impact (Bubeck et al., 2012; Deguen et al., 2012; Lin et al., 2018; Oltra and Sala, 2018; Verlynde et al., 2019). These strategies may imply changes in daily behaviour (e.g. avoiding risky places and modifying commuting habits and leisure activities), the use of specific devices (e.g. wearing masks or installing anti-theft alarms), and a willingness to pay for the implementation of mitigation measures or even move house to avoid the environmental stressors. Therefore, risk perceptions are of great importance because they mediate the eventual effect of a given exposure on people's health (Ban et al., 2019; Choon et al., 2018; Spence et al., 2011; Zeidner and Shechter, 1988).

1.2 Correlates of the general public's perceptions of environmental risk

In this section, we briefly review previous literature concerning possible associations between the sociodemographic and psycho-environmental variables included in our study and the set of environmental exposures we sought to analyse.

1.2.1 Sociodemographic correlates

Women consistently express higher concerns about risk than do men (Carlton & Jacobson, 2013; European Commission, 2014, 2017; Finucane, Slovic, Mertz, Flynn, & Satterfield, 2000; Greer et al., 2018; Kim, Park, & Kang, 2018; Madrigano et al., 2018; van der Linden, 2015). Age has also frequently been associated with risk perception, although results are mixed across studies. In particular, older people have expressed higher or lower levels of concern than their younger counterparts depending on the exposures being analysed (European Commission, 2014; Gallastegi et al., 2019; Kim & Kang, 2019; Madrigano et al., 2018; Zeidner & Shechter, 1988).

In general terms, more educated people are more concerned about environmental risk (European Commission, 2017, 2014; Sun and Han, 2018; van der Linden, 2015). Nonetheless, several studies have shown the opposite or no effect (Lechowska, 2018; McIntyre et al., 2018; Slimak and Dietz, 2006; Yu et al., 2018). The literature also contains studies showing a significant correlation between political orientation and perceptions of environmental risk but again the results are inconsistent (Carlton & Jacobson, 2013; Kellstedt et al., 2008; Kim & Kim, 2018; van der Linden, 2015).

1.2.2 *Health-related behaviours*

There is sound evidence that the overall global burden of disease is related to various behavioural, environmental, and occupational risks and there is no doubt that the level of all these types of risk contribute greatly to people's health status. On the other hand, though there are still few data concerning associations between healthy habits and levels of concern about environmental exposures, it is plausible that more health-aware people are also more concerned about environmental exposures. The authors of a cross-sectional study (Rouillon et al., 2017) of postpartum women in France suggested that perceived risk of endocrine disrupting chemicals may be related to health-related behaviours in many spheres (e.g. reduction in the use of hair dryers and insecticides and organic food consumption), but their results were unable to confirm such an association. Nevertheless, a North American study reported that pregnant women who strongly agreed that environmental chemicals were dangerous were more likely to adopt healthy behaviours like eating

organic food, choosing food in safe plastics or buying “eco-friendly” personal care products (Barrett et al., 2014).

1.2.3 Psycho-environmental correlates

Literature in environmental psychology is rich in constructs aimed at understanding the way people relate to the environment, however the application of such variables to risk studies has been scarce (Carlton and Jacobson, 2013). Both natural and human-made risks are dangers that come from, and affect to, the environment we live in. In this sense, a deeper understanding of the relation between the way we perceive and react to our environment and the way we perceive and react to risks could enrich this research area with innovative results. Therefore, in this study, we included a comprehensive set of measures, using scales assessing several key constructs related to our relationship with Nature and the place we live, seeking to explore their relation to risk perception. More specifically, we measured environmental knowledge, nature relatedness (NR), environmental concerns, pro-environmental behaviour and place bonding. The decision to focus on these variables was based on the hypothesis that the more people are aware about the importance of the environment and nature for their life, the more psychologically they are connected to it and the more they care for it, the greater their concern about environmental risks.

From an applied perspective, this endeavour might result fruitful for the design and conduction of public health campaigns and policies. If - as we expect - the selected psycho-environmental variables do show an association with perceived environmental risk, strategies aiming towards sustainability, environmental awareness and pro-environmental behaviour might serve also to raise the consciousness about the influence of environmental features on health. Additionally, if different profiles of thinking, feeling and acting towards the environment would be associated to specific levels of risk perception, the findings could be applied for identifying groups and designing messages when using a segmentation strategy in risk communication.

Environmental knowledge

Environmental knowledge refers to scientific knowledge-derived notions people have about diverse natural phenomena, the impacts of human activities on the environment, the causes and consequences of climate change and effective strategies to manage to cope with environmental exposures and to behave pro-environmentally. The role of environmental knowledge in individuals’ risk perception is not yet clear (Choon et al., 2018; Gallastegi et al., 2019; Verlynde et al., 2019), as it can lead both to an increase in awareness and protective behaviours and to an underestimation of the real implications of certain risks that might be affecting them.

Nature relatedness

This is a personality trait that varies across individuals and reflects individuals' connection with nature and other living beings on earth (Nisbet et al., 2009; Nisbet and Zelenski, 2013). NR is a valid construct to gather the affective, cognitive and physical aspects of the relationships individuals hold with nature. Recent research has found this trait significantly associated to health related worries about modern technologies and electromagnetic hypersensibility (Dömötör et al., 2017).

Environmental concerns

Schultz (2000, 2001) proposed that personal attitudes about environmental matters vary in terms of the weight that people assign to themselves, other people and other living beings when perceiving, reflecting and behaving regarding environmental issues. Subsequently, he distinguished between the following types of concern: biospheric (related to all living beings and nature as a whole), egoistic (valuing himself/herself above other people, living beings and nature) and altruistic (taking into account costs and benefits to other people).

Pro-environmental behaviour

To behave pro-environmentally implies either to cause the least damage possible to the environment or to benefit or take care of it (Steg and Vlek, 2009). Far from being a monolithic construct, it implies actions in many diverse spheres (Suarez, 2010), such as donating to green NGOs, commuting in an active way or buying local products.

Place bonding

Person-place bonding refers to the cognitive, emotional and identity ties between people and the places they inhabit or use (Droseltis and Vignoles, 2010; Hidalgo and Hernández, 2001; Lewicka, 2011; Scannell and Gifford, 2010). Previous studies have shown that such bonds are significantly linked to perceptions of environmental risks that might affect a given place; however, the evidence about the direction of such association is mixed (Bonaiuto et al., 2016).

1.3 Risk assessment by experts and the general public

Experts' risk assessments are formal and informed evaluations of environmental exposures and risks (Bonaiuto et al., 2016). Regional experts may have accurate and up-to-date knowledge about the actual environmental exposures affecting the region, place or area they are working in. On the other hand, it is well-known that there is commonly a mismatch between the criteria applied by experts and by the general public regarding environmental issues. It has been shown that, most of the time,

experts give lower risk ratings than the general public (Slovic et al., 1987; Finucane et al., 2004; Siegrist, Hübner, & Hartmann, 2018; Siegrist, Keller, Kastenholz, Frey, & Wiek, 2007). Further, it seems that experts and the general public also differ when it comes to prioritizing the importance of different environmental risks (2015).

Risk assessments of the general public and experts may differ due to the process followed to assign a certain level of risk to a given environmental exposure. In particular, experts can be expected to base their decision on actual scientific knowledge, empirical experience and official reports and records, whereas ordinary people may base it more on qualitative aspects of the exposure (Finucane et al., 2004; Siegrist et al., 2007; Slovic, 1987).

In this context, stress responses and coping strategies in relation to highly likely events or exposures are evidently adaptive, in that they help to avoid or mitigate eventual harms for the individual. Nonetheless, when triggered by unlikely events or inaccurate/false information, they may produce unnecessary negative consequences for the person in psychological and social spheres. This idea was highlighted by Vozmediano & San Juan (2010), who pointed out the adaptiveness of being concerned about a real risk and taking active protective measures or not doing anything in the absence of a threat. On the other hand, being unworried and careless about a real exposure or being worried and taking preventive measures when not affected by any exposure are ineffective and may generate negative outcomes (e.g. loss of time and effort, anxiety, and behavioural restriction).

1.4 Study aim

The primary objective of the study was to assess the general public's perceptions of risk from a set of environmental exposures that may have an impact on their health and compare them with the assessment of regional experts. Secondly, we sought to build predictive models of the general public's risk perceptions using the sociodemographic and psycho-environmental variables presented in Epigraph 1.2.

2. Materials & Methods

2.1 Sample

A total of 338 adults (mean age 45.78 years; *SD* = 14.36) resident in the province of Gipuzkoa (Basque Country; Spain) formed the convenience sample that took part in the study (see Figure 1). The participants were residents of the municipalities of Donostia- San Sebastian, (the main city of the province), and from Lasarte, Usurbil Andoain, Ordizia, Beasain (Oria Valley) and Urretxu and Zumarraga (Urola Valley). The environmental characteristics of the municipalities, with the exception

of the main city, are largely shared and described below. We selected the municipalities seeking to gather information from a diverse range of municipality sizes as well as individuals with different geographical and economic backgrounds. Overall, 110 participants were recruited from the municipal censuses delivered by the local government, while the others were recruited in the street, near the entrance to local organizations: local government offices, libraries, community centres, municipal sports centres, schools and a central market. The natural environment for most municipalities of Gipuzkoa is characterized by the orographic features of the terrain: narrow valleys bordered by hills and mountains covered by autochthonous forests and conifer forest for wood and paper production, with small and medium-sized municipalities, where industries of varying sizes, roads and the urban fabric coexist. In Gipuzkoa, the industry is an important productive sector. The main environmental exposures come from the industrial activities related toiron and steel, and the machine and tool sectors scattered throughout the region. The main environmental issues for the general population during the last two decades have been related with the urban waste management and the location of the different kind of infrastructures: landfills, compost generation plants, mechanical-biological recycling plants and the incinerator plant.

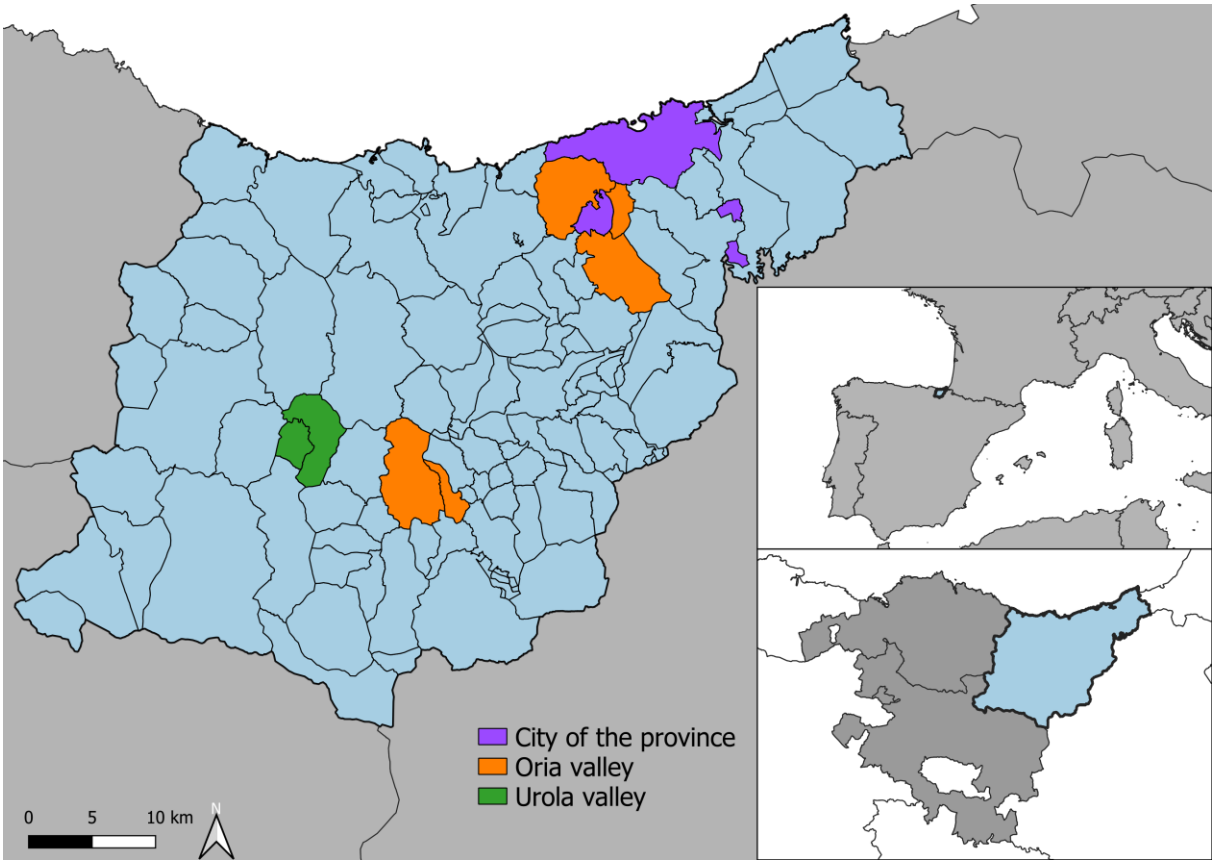

Figure 1. Spatial description of the study location.

186 Table 1 summarizes the sociodemographic characteristics of participants and their scores in
187 the main study variables. Compared to the general population of the province[1], women, those living
188 in rural areas and those with university education were slightly overrepresented, while the
189 distribution of occupational status and political orientation were similar. A notably high percentage
190 of participants were employed at the time of taking part in the study. All the participants were
191 informed of the objectives of the study and signed an informed consent from that had been
192 approved by the Ethics Committee of the Health Department of the Basque Country. The participants
193 were asked to complete a questionnaire in the presence of a field worker. All the field workers were
194 well trained and able to answer to a wide range of queries that might arise in relation to the
195 questions and scales used.

196 We also drew up a list of 44 regional experts on environmental issues and human health and
197 all were contacted by email inviting them to participate. We obtained 33 completed questionnaires:
198 from people with a mean age of 52.7 years old (SD = 8.97) and 18 (54.5%) were women. All of them
199 had more than 15 years of professional experience and a deep knowledge of the region of Gipuzkoa.
200 They had relevant backgrounds, with qualifications and/or professional experience in health (n = 18)
201 and environment-related areas (n = 15) including disciplines such as biology, biochemistry, chemistry,
202 pharmacy, environmental sciences, geography, psychology and various specialties in medicine. All of
203 them had knowledge concerning public health and environment-related problems, several being
204 researchers and/or university academics.

205

[1] According to the Basque Institute of Statistics, population in Gipuzkoa has a 51% women rate, a 63.17% or urban residents, a 53.6% of employed citizens and a 7.7% of unemployed. Regarding political orientation, Gipuzkoa is a progressive region (centre-right parties got a 37% of the votes in the last general votation).

206

Table 1

Sociodemographic description of the general public sample

Categorical variables		N	%	Missing data
Gender	Female	208	61.54	1
	Male	130	39.46	
Place of residence	Urban	176	47.50	2
	Non-urban	161	51.90	
Educational level	University	192	56.80	1
	Secondary or vocational	146	43.20	
Occupational status	Employed	227	67.15	0
	Unemployed	15	4.43	
	Student	40	11.83	
	Homemaker	8	2.36	
	Retired	45	13.31	
	Other	3	0.88	
Political orientation	Right	9	2.70	0
	Centre	50	14.80	
	Left	202	59.80	
	No response	77	22.70	
Quantitative variables		*M*	*SD*	Missing data
Age, years [18-82]		45.78	14.36	5
Health behaviour score [0-4]		2.43	0.71	1

Nature relatedness [0-4]	2.72	0.70	1
Pro-environmental behaviour [0-4]	2.66	0.46	1
Environmental knowledge [0-13]	8.54	0.70	1
Place bonding [0-4]	3.19	0.79	2
Egoistic concerns [0-4]	3.50	0.66	2
Biospheric concerns [0-4]	3.54	0.66	5
Altruistic concerns [0-4]	3.53	0.69	6

Note: Numbers in square brackets define the range of possible scores for each variable. The "No response" answer in political orientation should not be interpreted as a missing value; rather, participants chose one of the options given which was "I do not know/I do not want to answer".

2.2 Instruments

The questionnaire began with general demographic and health-related questions. Participants were asked to indicate their gender, age, place of residence and maximum level of education attained. Smoking, alcohol consumption, unhealthy diet and physical inactivity were measured using one item for each behaviour. A general score gathering these four health-related behaviours was created by summing the four scores. This score ranged from 0 to 4, with a higher score indicating a healthier lifestyle. Political ideology was measured with a five-point semantic differential (1-right to 5-left) and responses were then collapsed into a 3-point scale: right (1-2), centre (3) and left (4-5).

The second part of the questionnaire included several scales to measure risk perceptions, nature relatedness, pro-environmental behaviour, place bonding, environmental concerns and environmental knowledge. Risk perceptions towards a set of seventeen environmental exposures were assessed with a 0 (*None)* to 4 (*High)*-point Likert scale. This list of exposures was used in previous studies (Gallastegi et al., 2016; Guxens et al., 2012) and is shown in Table 2. Participants were asked to indicate the severity of the impact of each type of exposure on the general population's health.

Nature relatedness was measured with the short version of the *Nature Relatedness Scale* (Nisbet and Zelenski, 2013, $\alpha = .75$). This scale is composed of six items rated on a 0 (*Totally disagree)* to 4 (*Totally agree)*-point Likert scale (e.g. "My ideal vacation spot would be a remote, wilderness

235 area"). Pro-environmental behaviour was assessed using nine statements reflecting environmentally-
236 friendly behaviours (e.g. "turning off the lights when leaving a room" or "consuming local and
237 seasonal products") adapted from Vozmediano & San Juan (2006; α = .60). This scale was rated on a
238 0 *(Never)* to 4 (*Always*)-point Likert scale. To measure place bonding towards the place of residence,
239 we selected two items from the *Place Attachment and Identification Scale* ("I like my city/town" and
240 "I feel I belong to my city/town") developed by Ruiz, Hernández and Hidalgo (Ruiz et al., 2011).
241 Participants were asked to rate both items on a 0 (*Not at all)* to 4 (*A lot)*-point Likert scale. The two
242 items were combined into a single score reflecting place bonding (α = .76).

243 Environmental concerns were measured with the Spanish version of the Environmental
244 Motives Scale (Sevillano, 2007; , α = .95). This scale is composed of 12 items that form three different
245 factors: egoistic (5 items; e.g. My health), biospheric (4 items; e.g. aquatic life) and altruistic (3 items;
246 e.g. My neighbours) concerns. These were rated on a 0 (*Not at all important)* to 4 (*Very important)*-
247 point Likert scale. Environmental knowledge was assessed with a list of 13 questions dealing with
248 climate change, sustainability and waste management, among other environmental issues, designed
249 *ad hoc* for this study. For each question, participants were asked to choose one option out of three.
250 The possible scores on environmental knowledge ranged from 0 to 13 points.

251 *2.4. Data analysis*

252 In order to achieve the primary objective of the study, we first conducted a descriptive analysis of the
253 risk scores assigned to each environmental exposure by the general public and expert groups
254 separately. Then, with Student's *t*-test, we assessed whether scores differed significantly between
255 the groups.

256 The secondary objective was addressed by running 17 linear regression models to explore
257 the association between the predictor variables and each of the environmental exposures. These
258 analyses were performed in R and IBM SPSS version 25. The set of predictor variables was
259 consistently used for each exposure in order to quantify the number of times a given variable was
260 significantly linked to any of the exposures included in the set. We decided not to include political
261 orientation, however, due to the very uneven distribution of political views expressed and the high
262 proportion of participants in the category "No response". Similarly, occupational status was not
263 included due to the unbalanced distribution of the responses. Lastly, altruistic concerns were not
264 included in the models because, together with biospheric ones, they caused multicollinearity issues
265 when predicting risk scores (variance inflation factor scores around 3.5).

266

3. Results

3.1 Risk scores as rated by the general public and expert samples

Scores assigned by participants to the set of environmental exposures ranged from 1.51 to 3.42 (out of 4). The most severe exposures, as perceived by the general public sample, were air pollution, proximity to hazardous industry, waste incineration plants and landfills and food contamination, all of which obtained a mean score above 3 (moderate to high). Conversely, proximity to livestock farms, dirty streets, agriculture-related burning and heat waves received the lowest ratings, with mean scores lower than 2.5. Table 2 reports the means and standard deviations of the scores for each exposure.

This table also shows the risk assigned to each environmental exposure by the experts. In all cases but two, experts gave a significantly lower risk score than participants from the general public. All these differences were moderate and large in size ($d > 0.52$). Figure 2 shows the positions of each environmental exposure in the risk ranking by the two groups. As it can be observed, both groups similarly prioritized several exposures such as air pollution, food contamination and proximity to industry, waste incinerating plants and landfills. However, they differed in the position assigned to heat waves, lack of green spaces and drinking water pollution with experts highlighting the effects of heat waves and absence of greenness and the general public sample being more worried about the contamination of drinking water.

Table 2

Mean and standard deviation of risk scores for each environmental exposure as assigned by the general public and expert samples, Student's-t comparison and effect size.

Environmental exposure, range of possible scores [0,4]	Risk perception rating (*N* = 338)	Experts' risk assessment (*N* = 33)	*t*	*p*	*d*
Agricultural burning	2.47 (1.08)	1.28 (0.99)	6.03	<.001	1.15
Air pollution	3.42 (0.80)	2.94 (1.03)	3.20	.002	0.52
Dirty streets	2.38 (1.04)	1.09 (0.86)	7.99	<.001	1.35
Deficiencies in sewage systems-domestic wastewater	2.66 (0.98)	1.63 (1.04)	5.66	<.001	1.02
Drinking water pollution	2.67 (1.31)	1.33 (1.14)	6.37	<.001	1.09
External noise	2.82 (0.89)	2.70 (0.81)	0.78	.437	-
Food contamination	3.19 (1.06)	2 (1.09)	6.10	<.001	1.11
Heat waves	2.49 (1.11)	1.88 (1.16)	2.97	.003	0.54
Lack of green spaces	2.64 (1.09)	1.69 (1.09)	4.74	<.001	0.87
Proximity to agricultural pesticides	2.88 (1.07)	1.66 (1)	6.21	<.001	1.18
Proximity to livestock farms	1.51 (1.02)	1.31 (0.69)	1.48	.145	-
Proximity to high-power lines	2.66 (1.12)	1.48 (1.09)	5.76	<.001	1.08
Proximity to industry	3.33 (0.99)	2.55 (1.06)	4.33	<.001	0.76
Proximity to landfill sites	3.04 (1.01)	2 (0.98)	5.57	<.001	1.05
Proximity to radio frequency antennas	2.70 (1.09)	1.61 (1.20)	5.46	<.001	0.95
Proximity to waste incineration plants	3.07 (1.16)	1.86 (1.03)	5.41	<.001	1.10
Recreational water pollution	2.70 (0.99)	1.73(0.98)	5.34	<.001	0.98

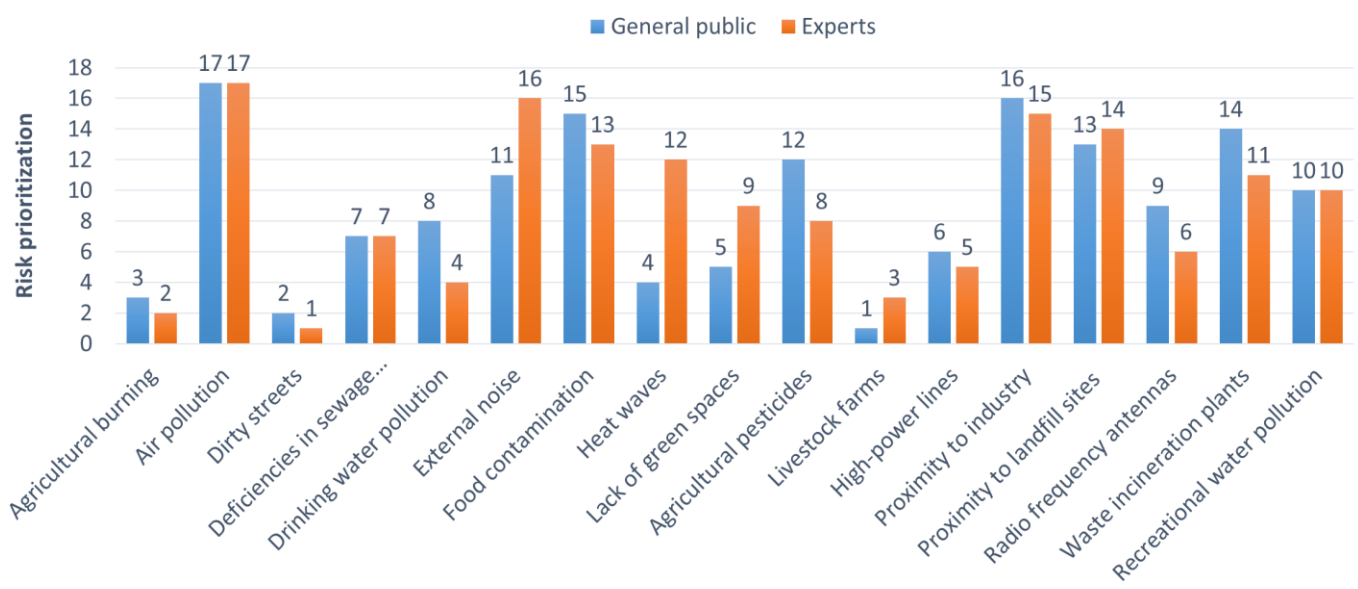

Figure 2. Prioritization of environment exposures in terms of risk for health for the general public and experts samples. Numbers on the bars indicate the position of each exposure in the ranking (17 – highest; 1 – lowest).

3.2 Prediction of general public's risk scores

As explained in the data analysis section, all the predictor variables except occupational status and political orientation (see Epigraph 2.4) were entered into multiple linear regression models. All the models were found to be significant at $p < .001$ and explained small to moderate shares of the variance in environmental exposure risk (R^2 = .05 to .17). Table 3 lists the predictors that were significant for each environmental exposure model, their β (95%CI) and the total variance explained.

Sociodemographic variables

Gender was a consistent predictor (all the models but one) of perceived risk of environmental exposures, with β-values ranging from 0.09 to 0.29, indicating that women showed greater concerns about exposure than men. Age was the second most common sociodemographic predictor in the models (8/17 models). The size of the β-values was comparable to those for gender, but indicated a negative association between age and risk perception (β = -0.12 to (-0.26)). The only exception to this pattern was the model for external noise risk, with age being a positive predictor (β = 0.11). Living in an urban environment, rather than a non-urban one, was negatively associated (β = -0.12 – (-0.20)) with risk perceptions but only for three of the environmental exposures considered. Level of education was only related to risk ratings regarding agricultural pesticides (β = 0.12) and noise (β = 0.09). Finally, the health behaviour score was a significant predictor in two models, being associated negatively with perceived risk from livestock farms (β = - 0.10) and positively with perceived risk from deficiencies in sewage systems-domestic wastewater (β = 0.10).

Psycho-environmental variables

Within the set of psycho-environmental variables, reported pro-environmental behaviour was the most consistent predictor, being significantly associated with the outcome variable in eight of the models and the association was always positive (β = 0.10 – 0.19). Environmental knowledge significantly predicted risk perceptions for five environmental exposures. In most cases, the association was positive (β = 0.12 – 0.17), meaning that the more environmentally knowledgeable, the greater the level of risk perceived. On the other hand, in the case of radio frequency antennas, this variable was a negative predictor (β = - 0.13). Egoistic and biospheric values remained in six and two models each and showed similar predictive powers (β = 0.12 – 0.21 and β = 0.16 – 0.19 respectively). Place bonding only reached statistical significance in two, being a positive predictor of perceived risk ratings for food contamination (β = 0.10) and heat waves (β = 0.12). Nature relatedness did not act as significant predictor in any of the regression models.

Table 3.

Linear regression models for environmental exposures included in the study.

Environmental exposure	F (11,227)	*p*	Significant predictors	β (95% CI)	Adj. R^2
Agricultural burning	5.94	> .001	Gender***	0.21 (0.1 , 0.32)	.14
			Age***	-0.24 (-0.34 , -0.13)	
			PEB**	0.19 (0.08 , 0.3)	
Air pollution	5.95	> .001	Gender †	0.09 (-0.02 , 0.2)	.14
			Age*	-0.14 (-0.24 , -0.03)	
			Knowledge*	0.12 (0.01 , 0.22)	
			PEB †	0.11 (0 , 0.22)	
			Egoistic*	0.16 (0.02 , 0.29)	
			Biospheric*	0.16 (0.02 , 0.29)	
Dirty streets	5.27	> .001	Gender***	0.29 (0.18 , 0.4)	.13
			Egoistic*	0.14 (0 , 0.28)	
Deficiencies in sewage systems-domestic wastewater	4.54	> .001	Gender***	0.29 (0.18 , 0.4)	.11
			Health behaviour score†	0.10 (-0.01 , 0.2)	
			Egoistic†	0.14 (0 , 0.27)	
Drinking water pollution	5.25	> .001	Gender***	0.24 (0.13 , 0.35)	.13
			Age**	-0.17 (-0.27 , -0.06)	
			Knowledge**	0.17 (0.06 , 0.28)	
External noise	6.96	> .001	Gender***	0.24 (0.14 , 0.35)	.17
			Age*	0.11 (0 , 0.21)	
			Knowledge*	0.12 (0.02 , 0.23)	
			PEB*	0.12 (0.01 , 0.23)	
			Egoistic**	0.21 (0.08 , 0.35)	
Food contamination	5.09	> .001	Gender***	0.28 (0.17 , 0.39)	.12
			Age***	-0.19 (-0.3 , -0.08)	
			Knowledge**	0.15 (0.04 , 0.26)	

			Bonding†	0.10 (-0.01 , 0.2)	
Heat waves	3.66	> .001	Gender***	0.27 (0.16 , 0.38)	.08
			PEB†	0.10 (-0.02 , 0.22)	
			Bonding*	0.12 (0.01 , 0.23)	
Lack of green spaces	4.83	> .001	Gender***	0.20 (0.09 , 0.31)	.11
			PEB**	0.18 (0.07 , 0.3)	
			Biospheric**	0.19 (0.06 , 0.33)	
Proximity to agricultural pesticides	3.80	> .001	Gender**	0.18 (0.07 , 0.29)	.09
			Age**	-0.15 (-0.26 , -0.04)	
			Urban residence *	-0.12 (-0.23 , -0.02)	
			Level of educational†	0.11 (0 , 0.22)	
Proximity to livestock farms	3.18	> .001	Gender*	0.12 (0.01 , 0.23)	.07
			Health behaviour	-0.10 (-0.21 , 0.01)	
			score†	0.15 (0.03 , 0.26)	
			PEB*	0.17 (0.03 , 0.31)	
			Egoistic*		
Proximity to high-power lines	3.12	> .001	Gender**	0.19 (0.08 , 0.3)	.07
Proximity to industry	4.33	> .001	Age***	-0.26 (-0.37 , -0.15)	.10
			Urban residence*	-0.13 (-0.23 , -0.03)	
			PEB*	0.13 (0.02 , 0.25)	
Proximity to landfill sites	2.42	.007	Gender**	0.19 (0.07 , 0.3)	.05
Proximity to radio frequency antennas	4.07	> .001	Gender***	0.20 (0.09 , 0.31)	.09
			Knowledge*	-0.13 (-0.24 , -0.02)	

			Egoistic†	0.12 (-0.02 , 0.26)	
Proximity to waste incineration plants	3.15	> .001	Gender* Age* Urban residence***	0.11 (0 , 0.23) -0.12 (-0.23 , -0.02) -0.2 (-0.31 , -0.1)	.07
Recreational water pollution	3.83	> .001	Gender*** PEB**	0.19 (0.08 , 0.3) 0.16 (0.04 , 0.27)	.09

Note: PEB: pro-environmental behaviour; † = p <.10, * = p <.05, ** = p <.01, *** = p <.001. All the predictor variables – as explained in section 2.4 – were included in the regression models. For the sake of efficiency, we only included in the table the variables significantly associated to each outcome (p < .10).

4. Conclusions

This study aimed to improve our understanding of perceived risks related to seventeen specific environmental exposures among the general population in a region of the Basque Country and compare them with those of a group of regional experts. In brief, we found that the general public assigned higher risk scores to every environmental exposure than the experts. The size of these differences was large in most cases.

There are many reasons why lay people may show higher and experts lower levels of concern. First, the general public resort mainly to affective evaluation mechanisms triggered by mental representations of environmental exposures (Slovic, 1987) which in the case of subjects such as industrial factories, electromagnetic fields or waste incineration plants are likely to be negative. Second, it may be that merely thinking about health-related risks will boost their perceived magnitude this potentially leading participants to award scores higher than their usual level of worry. On the other hand, experts' scientific knowledge and awareness of official data may reduce the incidence of such affective heuristics and in turn reduce perceived risk (Choon et al., 2018; Finucane, Alhakami, Slovic, & Johnson, 2000). Nonetheless, it must be recognised that more information or knowledge could also lead to underestimation of the potential risk due to an associated increase in perceived control and the emergence of feelings of overconfidence.

Despite the aforementioned differences, both groups showed a relatively similar pattern of risk prioritization for most exposures but heat waves, lack of green spaces and drinking water pollution. On the other hand, it is evident from our data that the general public participants

expressed considerable levels of concern for most of the exposures and significantly superior to the ratings given by the experts. In the light of our previous discussion about the adaptiveness or maladaptiveness of risk perceptions and subsequent self-protective behaviours (not measured in this study; see section 1.3), evidence obtained here might be a matter of concern for public health professionals and government bodies. Given that human resources are limited and activation of all the energy and interest people are able to dedicate to protecting themselves from environmental harms, from numerous potentially damaging events (as perceived by the individual), could lead to feelings of defencelessness and inefficient self-protective behaviours. Given this, professionals, academics and government bodies should work effectively to deactivate unnecessarily over-inflated risk perceptions and focus people's attention and behaviour on exposures that might actually have deleterious effects on them. This reflection is relevant for decision making on communication strategies when providing objective information of environmental risks, and our results could offer some insights for designing such strategies, as we will elaborate below.

With this study, we also sought to explain risk perceptions among the general public through the analysis of a comprehensive set of sociodemographic and psycho-environmental predictors. These variables differed markedly in terms of predictive consistency with some playing a significant role in several models (e.g. gender or age) and others making hardly any contribution (e.g. health behaviour score or level of educational). In our study, when significant, being a woman was a positive predictor of risk perception ratings which goes in line with gender-based explanations of risk perception (Davidson & Freudenburg, 1996; Finucane et al., 2000; McCright & Xiao, 2014). This effect has been usually explained by the role of gender socialization processes that direct women towards health and care related cognitive and behavioral tendencies both within the family and the community. On the other hand, when age was found to be a significant predictor, it always contributed to lower risk assessments except in the case of external noise risk, where it had the opposite influence. It might be that older participants are less worried about exposures whose outcomes may develop in the long term (e.g. air or water pollution) and less easily observable but increasingly worried about the ones with immediate consequences and directly perceivable as it is the case of noise. This is consistent with mixed results shown in previous studies (Gallastegi et al., 2019; Kim et al., 2018; Madrigano et al., 2018 Zeidner & Shechter, 1988). The finding that living in an urban environment was associated with a lower perception of risk from industrial, waste incineration, waste management, and agricultural pesticides activities is coherent with the fact that such types of infrastructure tend to be located outside urban areas. On the other hand, it was somewhat surprising to us to find that environmental exposures usually related to urban life – external noise, air pollution or a scarcity of green spaces – were not, as might be expected by the

same logic, less evident in non-urban dwellers' minds. Level of educational only remained a significant predictor in two models, this being consistent with the mixed results in previous studies (European Commission, 2014; Lechowska, 2018; Lee, 2018; McIntyre et al., 2018; Slimak and Dietz, 2006; Sun and Han, 2018). The health behaviour score was a significant predictor in only two models – Deficiencies in sewage systems-domestic wastewater and proximity to livestock farms – which lends only limited support to the view that there is a relationship between healthy habits and environmental risk assessments, as had been expected based on previous research (Barrett et al., 2014; Rouillon et al., 2017).

One of our aims was to establish whether there were relationships between psycho-environmental variables and risk perception. The set of psycho-environmental predictors yielded a heterogeneous picture, where pro-environmental behaviour was positively linked to eight environmental exposure risk perception scores, egoistic concerns to six, environmental knowledge to five, biospheric concerns to three and place bonding to only two. In line with our expectations, these associations were mostly positive. That is, the present evidence seems to indicate that the greater individuals' environmental awareness or responsibility, the greater their sensitivity to possible effects of environmental issues on health. Pro-environmental behaviour, which appeared as predictor on the higher number of models, was associated with an increased perception of human-made risks. It is a reasonable result, since it is easily conceivable that people aware about the consequences of their behaviour in the environment would be also sensitive to the impact that the environment may have in their health (Corral et al., 2014).

These results not only add knowledge to a possible profile of highly worried citizens, but also suggest that further research on the relation between psycho-environmental variables and risk perception will continue to be fruitful. It could be the case that in cultures highly polarized on environmental issues where two opposed belief systems about relationship with nature are present, people with ecocentric beliefs and behaviours would perceive ceratin human activities and industries as more dangerous, and this could not happen in cultures more flexible when thinking about Nature and human interests (Corral-Verdugo et al., 2008). If this would be the case, promoting pro-environmental concerns and behaviour could be influencing an increased risk perception, and this could be a non-desired outcome for some of the risks.

Therefore, these first results could be useful when designing both environmental awareness campaigns and information campaigns on environmental risks, both in relation to the direct findings and the future research lines they suggest. If the objective was to increase the awareness on a given risk and promote protective or healthier behaviours, it would be advisable to develop policies and

strategies aiming both at the increase of environmentally-friendly behaviours and self-protection against environmental exposures. But when facing situations where a specific risk perception is excessive and could be promoting unnecessary or even damaging behaviours for protecting oneself, communication strategies should consider the relation between pro-environmental behaviours and risk perception.

Our results, and future studies for a deeper understanding on the role of psycho-environmental variables, could also be useful when designing communication strategies on environmental risks that involve message framing (i.e. emphasizing the benefits/risks present in the closest, most significant environment, like one's city or region, and the range of behaviours that might protect it) and group segmentation (i.e. designing the appropriate messages for older or younger people; or using messages about health protection for people focused on egoistic concerns and messages about the impact on Nature for those with biospheric concerns and pro-enviromental behaviours).

Nevertheless, psycho-environmental predictors did not work consistently through all the models and some contributed very little to explaining the variance, and contrary to our expectations, nature relatedness scores were not associated with any risk score. Hence, future studies should investigate more thoroughly which psycho-environmental variables make relevant contributions to which specific environmental risks for health

Study strengths, limitations and future lines of research

In our opinion, one of the main strengths of this research is the consideration of a wide and diverse set of environmental exposures. We included, among others, questions regarding: 1) the contamination of resources key to human life, such as air, water and food, 2) the hazardous effects of waste management infrastructure (e.g. landfill sites and waste incineration plants), 3) the presence of electromagnetic fields (e.g. radiofrequency antennas and high power lines), a physical exposure that has attracted considerable attention in the mass media and the scientific literature on environmental epidemiology and is among the environmental exposures about which the general public is known to have concerns; and 4) various other human activities and climatic phenomena with adverse consequences for human health, such as use of agricultural pesticides and heat waves.

This study's novelty lies in the inclusion of psycho-environmental variables. Two previous studies used one measure of ecological worldviews (Carlton and Jacobson, 2013; Slimak and Dietz, 2006), but, to our knowledge, none have used a comprehensive set of psycho-environmental variables. Here, we sought to incorporate nature relatedness, pro-environmental behaviour, place

436 bonding and egoistic and biospheric concerns. As explained above, our results showed that these
437 variables acted as significant predictors in different numbers of models. Nonetheless, overall, our
438 findings suggest that consideration of these types of variables could contribute substantially to our
439 knowledge of how environmental risk perceptions work.

440 This study is not without limitations. The use of a convenience sample where women, rural
441 inhabitants and highly educated people were overrepresented, even though it did not compromise
442 our ability to address the research questions that inspired the study, makes it more difficult to
443 generalize our results to other populations. Besides, the obvious drawback of including up to
444 seventeen environmental exposures is that it was difficult to include predictor variables specific to
445 each of them. For instance, we used a general measure of environmental knowledge instead of
446 measuring knowledge referring to each exposure, which in the light of recent publications might be
447 insufficient (Rouillon et al., 2017). Had we focused on fewer environmental exposures, we would
448 have been easily able to include knowledge questions concerning particular risks, specific causes,
449 concrete effects on human health and effective protective strategies. This could be addressed in
450 future studies by adding environmental knowledge questions for each of the environmental
451 exposures included in the design. Similarly, if possible, we would like to include past experiences with
452 each environmental exposure (McClure et al., 2015), reactive affective responses (van der Linden,
453 2015) and even psychological traits such as environmental sensitivity (Aron and Aron, 1997; Belsky
454 and Pluess, 2009; Pluess, 2015), to increase the amount of variance explained by the regression
455 models.

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