Disgust sensitivity and public opinion on nuclear energy
Anne-Sophie Hacquin, Sacha Altay, Lene Aarøe, Hugo Mercier

To cite this version:
Anne-Sophie Hacquin, Sacha Altay, Lene Aarøe, Hugo Mercier. Disgust sensitivity and public opinion on nuclear energy. Journal of Environmental Psychology, 2022, 80, pp.101749. 10.1016/j.jenvp.2021.101749. hal-03863338

HAL Id: hal-03863338
https://hal.science/hal-03863338
Submitted on 21 Nov 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY

Disgust sensitivity and public opinion on nuclear energy

Anne-Sophie Hacquin
Institut Jean Nicod, Département d’études cognitives, ENS, EHESS, PSL University, CNRS, Paris, France
Sacha Altay
Institut Jean Nicod, Département d’études cognitives, ENS, EHESS, PSL University, CNRS, Paris, France
Lene Aarøe
Department of Political Science, Aarhus University, Aarhus, Denmark
Hugo Mercier
Institut Jean Nicod, Département d’études cognitives, ENS, EHESS, PSL University, CNRS, Paris, France

Acknowledgments:
HM and ASH were funded by the ANR EUR FrontCog ANR-17-EURE-0017*, PSL ANR-10-IDEX-0001-02, and by the DGA grant CONFIRMA. SA’s PhD thesis is funded by the DGA.

Declarations of interest: none.

(9366 words)

Author note:
Correspondence should be sent to Hugo Mercier Institut Jean Nicod, Pavillon Jardin, 29 rue d’Ulm 75005 Paris; email: hugo.mercier@gmail.com.
Abstract

An increasing number of experts agree that nuclear power should be part of the solution to fight climate change as it emits little greenhouse gases, has had no negative health consequences during normal operation, and even limited consequences after accidents. However, in many countries the population is much more ambivalent about nuclear power, and tends to exaggerate the negative effects on health and the environment. We suggest that this gap between experts and the public stems in part from nuclear power triggering the behavioral immune system: a set of cognitive adaptations that aim at protecting us against pathogens by making us particularly alert to their existence, and attuned to their risks. In line with this suggestion, we find that (i) participants overestimate the risks of nuclear accidents compared to other types of disasters (Experiment 1), except for disasters that should also trigger the behavioral immune system (Experiment 2); (ii) participants were more interested in reading and sharing a news article about a nuclear accident than about other types of accidents (with the same exception, Experiment 2); (iii) participants were less willing to be in contact with an object that had been in a nuclear power plant than in a car manufacturing plant (Experiment 3); (iv) arguments showing that nuclear power plants should not elicit fears of contamination reduced the negative perception of nuclear energy (Experiment 4). This work suggests a cognitive basis for the popular rejection of nuclear power, and ways to bridge the gap between experts and the public on this topic.

Keywords: Nuclear energy; Public opinion; Behavioral Immune System; Radiation; Fear of contamination; Disgust sensitivity
1. Introduction

Nuclear energy is an efficient source of electricity that doesn’t directly emit greenhouse gases. As a result, a large number of scientists agree that it ought to play an important role in the fight against climate change (Bickerstaffe & Pearce, 1980; Cameron & Taylor, 2011; Nuclear Energy Institute, 2019; Siqueira et al., 2019). Yet, despite growing global willingness to fight climate change, widespread skepticism towards nuclear energy remains in the general public (e.g., GlobeScan, 2005). In many countries nuclear energy remains highly contested in public opinion and is opposed by political protest movements (e.g. Ho et al., 2019; Thurner et al., 2017; Wang et al., 2020).

Why does nuclear energy face such strong opposition in the general population? In this article, we investigate whether public opposition to nuclear energy is at least in part due to disgust and fears of contamination triggered by the so-called behavioral immune system (Schaller & Park, 2011; Tybur & Lieberman, 2016).

We start by briefly reviewing the scientific consensus on nuclear energy, as well as studies of public opinion towards nuclear energy. We then turn to studies on the behavioral immune system, disgust, and contamination fear, and review the evidence pertaining to the link between the behavioral immune system to public opinion on nuclear energy. Finally, we test our model across four experiments. We test whether participants are (i) particularly attuned to the dangers of nuclear energy, (ii) more interested in nuclear accidents, and (iii) more motivated to share information about nuclear accidents and to remember this information (compared to other types of accidents that should not activate fear of contamination or disgust). At the same time, we test whether disgust sensitivity helps explain the effects obtained and, more generally, opposition to nuclear energy.
1.1. The gap between experts and the public on nuclear energy

Most experts on nuclear energy agree that nuclear power has no negative health consequences during normal operation, and that even the rare incidents have only caused a limited number of casualties (Boice et al., 2003; Sermage-Faure et al., 2012; UNSCEAR, 2017). All experts also concur that nuclear power emits little greenhouse gases (Bruckner & Wiser, 2014; Kharecha & Hansen, 2013; Myhrvold & Caldeira, 2012) and most agree that nuclear power should be part of the solution to fight climate change (Budnitz, 2016; Cameron & Taylor, 2011; Nuclear Energy Institute, 2019; OECD, 2012).

Yet in many countries public opinion is largely opposed to nuclear power. In 2005, a poll conducted in 18 countries across the world showed that the risks of nuclear power as an energy source were judged to outweigh its advantages by 53% of respondents, while only 33% thought that the advantages outweighed the risks (GlobeScan, 2005). In 2014, only 20% of people in Europe supported the use of nuclear energy in their country, while 37% clearly opposed it (Eurobarometer, 2014). In the U.K., public attitudes towards nuclear power have historically been deeply divided (Corner et al., 2011), with nuclear power being at one time the least preferred of all energy sources (Pidgeon et al., 2008), and still only being supported by a minority of the public now (BEIS, 2021).

Much existing work on public opposition to nuclear energy focuses on the role of the media (e.g. Gamson & Modigliani, 1989; Koerner, 2014; Palfreman, 2006). Indeed, media coverage associated with nuclear energy tends to be overwhelmingly negative (Friedman et al., 1987; Stowers, 2017): for instance, one study in the US found that over 70% of newspaper headlines about nuclear energy or responses to nuclear incidents painted them in a negative light (Koerner, 2014). The supply of negative media stories about nuclear energy may contribute to
FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY

the development of opposition to nuclear energy in the general public. However, in the general public opposition is often accompanied by misperceptions of nuclear energy that are not found in the mainstream media. For example, in a study surveying thirty countries, 50% of respondents believed that nuclear power plants produce significant amounts of CO2 (IPSOS & EDF, 2020, see also BVA). A study on high school students found that 84% believed that radioactive waste from nuclear power is an ozone depletion factor (Pekel, 2005). Furthermore, extant data indicate that even dramatic events creating substantial negative media coverage might not have a lasting impact. In the US, even after a widely negatively covered nuclear accident (the Fukushima Daiichi accident), public support for nuclear energy only dropped by a small amount (Gallup, 2012), and it quickly reverted to its baseline level (Visschers & Siegrist, 2013). Hence, there are reasons to believe that negative media coverage cannot fully explain the opposition to nuclear energy in the mass public. Moreover, explanations that rely on biases in the media would still have to explain why the media is biased in the first place, especially since news media are strongly demand-driven, suggesting that bias in the media might be an effect rather than a cause of public opinion (see, e.g., Gentzkow & Shapiro, 2010).

In this article we investigate the role of deep-seated cognitive mechanisms in shaping opposition to nuclear energy in the mass public. In particular we investigate whether people’s opposition to nuclear power, and their misperceptions of the pollution and health risks caused by nuclear energy could be driven by psychological mechanisms of disgust and contamination avoidance rooted in the behavioral immune system.

1.2. The behavioral immune system and disgust
Fighting diseases is one of the most important challenges faced by living organisms. In humans it has been suggested that a *behavioral immune system* evolved to supplement our physiological immune system by motivating people to avoid coming into contact with pathogens in the first place (e.g., Murray & Schaller, 2016; Schaller & Park, 2011; Tybur & Lieberman, 2016). This behavioral immune system works through psychological mechanisms that scan the environment for cues of potential pathogen threats (e.g., infected food, objects, or people). Once the behavioral immune system identifies a potential pathogen threat, it can activate a feeling of disgust that motivates individuals to retreat from potentially infected objects (e.g., Oaten et al., 2009; Schaller, 2006; Tybur et al., 2009).

The behavioral immune system regulates a number of psychological processes that aid in avoiding pathogen contact, including information gathering about sources of contaminants, attention towards avenues of pathogen transmission, and learning mechanisms. Of particular relevance here, “disgust should regulate attention (directed toward avenues of pathogen transmission),” and social communication “to corroborate suspicions of pathogen presence” (Tybur et al., 2013: 70). Thus, people might pay special attention to, want to learn more about, and share more information about potential pathogen threats.

Given (i) the asymmetry in costs of false alarm versus misses, and (ii) the difficulty of identifying infectious agents, the behavioral immune system is expected to be hypervigilant and to err on the side of treating any pathogen cue as a potential threat (Schaller & Duncan, 2007; Tybur & Lieberman, 2016). While the behavioral immune system should be observed in every normally developing individual, its sensitivity varies: some people are more easily disgusted, worry more about contamination, and avoid sources of pathogens more actively than others (e.g., Duncan et al., 2007; Schaller & Duncan, 2007; Tybur & Lieberman, 2016). These variations have
allowed researchers to study the relationship between having a particularly vigilant behavioral immune system, or having a high disgust sensitivity, and a variety of behaviors and attitudes (e.g. Aaroe et al., 2017; Inbar et al., 2009; Park et al., 2003; Terrizzi et al., 2013). For example, people with high disgust sensitivity have been shown to be more opposed to genetically modified food, and to support governmental regulation of food, air, and water (e.g. Clifford & Wendell, 2016; Scott et al., 2016; see also Karg et al., 2019 for a review).

Recent studies, however, have shown that disgust sensitivity is also associated to an increase in the perception of risks that are not plausibly related to disgust, such as flying in commercial airliners, or elevator crashes (Kahan & Hilgard, 2017), and to heightened risk perception more generally (Karg et al., 2019). These results raise the possibility that disgust sensitivity tracks risk sensitivity more generally, rather than risk associated with pathogen threat more specifically (a possibility we will take into account in our experiments).

1.3. The behavioral immune system, disgust, and perceptions of nuclear energy

Nuclear energy comes from splitting uranium atoms, which creates nuclear radiation. Radioactive particles are sufficiently energetic that they can remove electrons from atoms and molecules and ionize them. The combination of how much radiation someone is exposed to, what type, and how often will determine the effect on cells and tissues. Our cells can easily clean up any damage done by low-level background radiation. Medium doses of radiation are more likely to change cells by modifying DNA, while high doses tend to kill cells. Long-term exposure to medium doses of radiation increase the odds of getting cancer, while a single high dose will quickly cause immediate damage to cells and tissues. Very high doses like those experienced by workers after the Chernobyl incident, or nuclear bomb blasts (several thousand times higher than the
FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY

background radiation level) cause extensive damage, resulting in a range of symptoms known as radiation sickness.

Neither radiation nor pathogens can be seen, but both can make people sick. Thus, radiation might also activate the behavioral immune system. Besides their invisibility to the naked eye, however, nuclear irradiation is very different from contamination by pathogens, in particular because it is not contagious. Moreover, and again contrary to pathogens, radiation is highly dose-dependent, with low doses of radiation being innocuous, and only long exposures to relatively high doses, or short exposure to extremely high doses creating systematic health risks (Brooks et al., 2016; Socol & Dobrzyński, 2015). Yet much data suggests that people’s understanding of nuclear radiation and its risks is guided by their intuitive understanding of contagion. As noted by (Rozin, 2001, p. 33), this understanding is guided by simple principles, two of which are that contagion is permanent, and that contagion is dose insensitive. Both principles seem to be at play in the way people react to nuclear irradiation.

People exposed to the Chernobyl accident were deeply anxious that the radioactivity could have permanently contaminated them, with many developing serious psychosomatic disorders (Bromet, 2012; Havenaar et al., 1997); these symptoms could develop even when the levels of radiation exposure had been too low to create any lasting damage (Havenaar et al., 1997; Viinamäki et al., 1995).

People who have been—or who are thought to have been—irradiated also tend to be treated by others as if they had been contaminated. Evacuees from the Chernobyl accident were not welcomed by the communities where they were resettled, being instead stigmatized because of their radiation exposure (Bromet, 2012). After the Fukushima Daiichi accident, workers at the power plant were stigmatized and discriminated against (Shigemura et al., 2012). Following the
FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY

Hiroshima and Nagasaki bombing, hundreds of thousands of Japanese who had been exposed to the bombs were suspected of carrying some disease (Weart, 2012). This ‘radiation stigma’ has adverse psychological effects, which can be more significant than the actual effects of irradiation (Ben-Ezra et al., 2015; Shigemura et al., 2014). Since nuclear radiation appears to be treated psychologically as if it were contagious, it is possible that nuclear energy more generally triggers disgust and the behavioral immune system, which might help explain people’s overly negative perceptions of nuclear energy.

1.4. Overview of the studies

We conducted four experiments to test whether public opposition to nuclear energy is related to the behavioral immune system. In each experiment, we compare conditions related to nuclear energy to other conditions (e.g. an article about a nuclear accident vs. a flood), measuring whether participants react more forcefully, in various ways (heightened risk perception, increased interest, etc.), in the conditions associated with nuclear energy. We also measure participants’ disgust sensitivity.

The overall predictions, and plan for analysis, is as follows. First, the condition related to nuclear energy is compared to the other conditions. Second, we test for an overall effect of disgust sensitivity (e.g. does heightened disgust sensitivity lead to increased perceptions of risk). Third we test whether the effect of disgust sensitivity is specific to the condition related to nuclear energy.

In all the experiments, participants started by completing a consent form, and ended by completing an attention check and providing demographic information. All the materials can be found in the Electronic Supplementary Materials (ESM). All surveys were displayed on the platform Qualtrics.
2. Experiment 1

If people’s perceptions of nuclear radiation are rooted in the behavioral immune system, the hypervigilance of this system should make people inclined to exaggerate the risks of nuclear accidents, in particular the number of fatalities, compared to that of other types of accidents that are not associated with perceived contamination risk. The goal of Experiment 1 is to test this hypothesis.

2.1. Methods

2.1.1. Participants

We recruited 301 UK participants on the online crowdsourcing platform Prolific Academic, paid £0.75. As our research design asks about the number of fatalities in the Fukushima Daiichi nuclear accident and the earthquake and tsunami that preceded it, we removed 155 participants who reported that they had not heard of these events or were not sure whether they had heard of them, leaving 146 participants (101 women, $M_{\text{Age}} = 35.73$, $SD = 11.8$). The results are similar when the excluded participants are included (see the ESM, Appendix S4).

2.1.2. Design and procedure

We asked participants to estimate the number of fatalities linked to the Fukushima Daiichi nuclear accident and the 2011 Tōhoku earthquake and tsunami (which preceded and caused the Fukushima accident). Focusing on these events ensures high ecological validity in the research design. Participants were first asked if they had heard of the Fukushima nuclear accident and of the earthquake and tsunami that preceded it. Then, they were asked the following questions in a
randomized order: “According to you, in the days following the Fukushima nuclear accident, how many people died directly because of the radiation?”; “According to you, how many people in total have died and will die as a direct result of the radiation emitted in the Fukushima nuclear accident?”; “According to you, how many people have died during the evacuation of the area around Fukushima following the earthquake and nuclear accident?”; “According to you, how many people have died during the earthquake and tsunami that preceded the Fukushima nuclear accident?” These four events happened approximately at the same time (even if the second question stretches to the present), and all received substantial news coverage. On the whole—and possibly with the exception of the first few days—the news coverage was “accurate and detailed” (Friedman, 2011, p. 3), so that participants would have been unlikely to encounter widely inaccurate numbers in the news.

The best estimates of the number of victims (used to measure overestimation of the fatalities, see below) were determined as follows: according to the literature, no one died directly because of the radiation in the days following the Fukushima Daiichi nuclear accident (Investigation Committee on the Accident at the Fukushima Nuclear Power Station, 2011). When the experiment was conducted (fall of 2019), one man—who had been measuring radiation at the Fukushima Daiichi plant shortly after the meltdown—had died from cancer (BBC, 2018). We took one as the correct answer for the number of people in total who have died and will die as a direct result of the radiation emitted in the Fukushima Daiichi nuclear accident (Brumfiel, 2012). We took 1600 as the best approximation for the number of people who died during the evacuation of the area around Fukushima following the earthquake and nuclear accident (Murakami et al., 2015). We took 18500 as the best approximation for the number of people who died during the earthquake and tsunami that preceded the Fukushima Daiichi nuclear accident (Mimura et al., 2011).
2.1.3. Measures

As participants’ answers spread over a large range, all measures were log-transformed. More precisely, because participants’ answers for the number of people who died during the accident can take a value of zero, we used the log of (1 + Number of Deaths) (Cao et al., 1999). Our main outcome of interest was the overestimation of the fatalities due to nuclear accident and to radiation compared to the fatalities due to the evacuation and the tsunami. As a result, we first calculated the overestimation of the fatalities for each of these four events. We then averaged the overestimations for, on the one hand, the deaths due to nuclear accident and the deaths due to radiation, and, on the other hand, the deaths due to the evacuation and the deaths due to the tsunami. Finally, we subtracted the latter average from the former, so that higher numbers reflect a greater overestimation of fatalities linked to nuclear radiations (compared to the fatalities linked to the other events). We will refer to this measure as Nuclear Risk Overestimation Score.

To measure individual differences in disgust sensitivity, participants completed the widely used 25-item Disgust Scale - Revised (Haidt et al., 1994, modified by Olatunji et al., 2007). Examples of items include: “I never let any part of my body touch the toilet seat in public restrooms” (complete list in ESM, Appendix S1). Answers were summed to a satisfactorily reliable scale ($\alpha = .84$).

Finally, we also measured opinion on nuclear energy, asking participants to answer seven questions about nuclear energy touching on broad perceptions of nuclear energy, safety, and the effects of radiations (see ESM, Appendix S2, for complete list). For example, one of the general questions was: “To what extent do you support or oppose the use of nuclear energy as one of the ways to provide electricity in the United Kingdom?” Answers were obtained on a five-point Likert
scale ranging from “Strongly support” (1) to “Strongly oppose” (5) and summed up to form a
reliable scale ($\alpha = 0.89$).

2.2. Results

Figure 1 displays the estimates of the fatalities provided by the participants for each type
of event along with the best available number of fatalities, showing that participants vastly
overestimated the fatalities from the radiations, while underestimating the fatalities for the tsunami
and the evacuation, which should elicit no fears of contamination. As is clear from Figure 1,
participants overestimated the fatalities due to the radiations right after the accident ($Median = 40$;
best estimate = 0), as well as the total fatalities due to the radiations ($Median = 1000$; best estimate
= 1), and they underestimated the fatalities due to the evacuation ($Median = 100$; best estimate =
1600), and the tsunami ($Median = 600$; best estimate = 18500). The Nuclear Risk Overestimation
Score (computed with log values) was significantly higher than zero ($M = 4.85$; $SD = 1.84$; Welch’s
$t(45) = 31.86$, $p < .001$, $d = 2.67$).
Figure 1: Number of fatalities estimated by the participants for each event (log scale). Black crosses represent best available estimated fatalities for the different causes which were: zero due to the radiation in the days following the accident, one due to the radiation in total, 1600 due to the evacuation, and 18500 due to the earthquake and tsunami.

To test whether participants are particularly likely to overestimate the fatalities linked to radiation, we conducted a linear regression examining the effects of disgust sensitivity (as measured by the Disgust Scale – Revised), condition (conditions involving radiations versus conditions not involving radiations) and the interaction between condition and disgust sensitivity.
on the overestimation of the fatalities (estimated fatalities minus best estimate of fatalities, with negative numbers indicating underestimation), while controlling for the demographics (gender, age, and education). The overestimation of the fatalities was higher for the conditions involving radiation ($\beta = 1.52 \ [1.42, 1.62], t(79) = 28.63, p < .001$), compared to the conditions not involving radiations.

We observed no significant effect of disgust sensitivity on the overestimation of the fatalities due to radiation for the conditions involving radiations ($\beta = 0.0 \ [-0.13, 0.12], t(87) = -0.09, p = .93$, see Figure S1) but a significant negative effect of disgust sensitivity on participants' overestimation of the fatalities ($\beta = -0.13 \ [-0.21, -0.06], t(77) = -3.50, p < .001$).

The interaction between condition and disgust sensitivity on participants' overestimation of the fatalities was significant ($\beta = 0.12 \ [0.01, 0.22], t(77) = 2.21, p = .03$; see Figure S1).

Participants had also been administered a short survey about their overall opinion of nuclear energy. This allowed us to test whether disgust sensitivity was related to a negative perception of nuclear energy. We found that individual differences in disgust sensitivity predicted Nuclear Opinion Scores, with individuals with high disgust sensitivity being more opposed to nuclear energy ($\beta = 0.34 \ [0.19, 0.50], t(41) = 4.39, p < .001$).

2.3. Discussion

In line with our predictions, participants vastly overestimated the number of fatalities due to the radiations, while underestimating the fatalities due to the evacuation and the tsunami. Disgust sensitivity was related to overall increased estimates of fatalities, except for the tsunami (see Figure S3). However, higher disgust sensitivity was associated with a more negative perception of nuclear energy, as measured by the opinion survey.
It is plausible that the Fukushima Daiichi incident received more media coverage than the tsunami and earthquake that preceded it, at least relative to the actual number of deaths in each event. However, any such difference could hardly either for the massive overestimation of the deaths due to the nuclear incident (a thousand-fold), or for the underestimation of the deaths due to the tsunami and earthquake (which did receive extensive coverage at the time).

3. **Experiment 2**

The first aim of Experiment 2 was to conduct a conceptual replication of Experiment 1 to ensure that its results were not caused by our specific focus on events related to the Fukushima Daiichi accident. Experiment 2 therefore bears on fictitious accidents, one related to nuclear energy, and three unrelated. Experiment 2 also extends Experiment 1 by testing two additional set of predictions. First, the behavioral immune system should not only lead to increased risk perception of nuclear accidents, but also to increased interest in information about this type of accidents, willingness to tell others about them, and memorization. Second, Experiment 2 included a contamination relevant accident unrelated to nuclear energy: an accident in a laboratory working on dangerous diseases. If nuclear accidents are psychologically categorized as contamination risk participants should react to the nuclear accident condition as to the contamination relevant laboratory accident. We test both predictions.

3.1. **Methods**

3.1.1. **Participants**

We recruited 206 UK participants on the online crowdsourcing platform Prolific Academic, paid £2.25 (142 women, $M_{Age} = 35.29$, $SD = 11.57$).
3.1.2. Procedure and measures

In a between-subject design, participants were randomly assigned to read excerpts from one of four news articles about a fictitious accident in Pakistan. The excerpt for the nuclear power plant read as follows:

Accident in a nuclear power plant in Multan, Pakistan.

The Pakistani nuclear power plant suffered an electronics failure, and was forced to shut down. Radiation may have escaped through the chimney and contaminated part of the surrounding area. Experts are conducting tests to determine the impact of this incident. They estimate the number of people at risk of being affected to be between 100 and 200. The surrounding area may be contaminated in a 20 km radius from the nuclear power plant.

The other three articles focused on accidents with the same background characteristics (location, estimates of people at risk, etc.), but that were, respectively, an accident in a high security laboratory working with dangerous diseases, an accident in a petroleum refinery plant, and a flood (see ESM, Appendix S5, for complete text).

To measure interest in the article and willingness to share it, participants then answered the following questions: “How interested are you in reading this article?” (on a six-point Likert scale ranging from “Not at all interested” to “Extremely interested”) and “How likely would you be to share this article with a friend or relative?” (on a six-point Likert scale ranging from “Very unlikely” to “Very likely”).
To measure participants’ estimates of the number of fatalities in the accident they were asked: “In your estimate, how many people will die because of this incident?” As in Experiment 1 we subsequently log-transformed the answers as they spread over a large range. More precisely, because participants’ answers for the number of fatalities can take a value of zero, we used the log of $(1 + \text{Number of fatalities})$ (Cao et al., 1999).

Participants completed another task, an unrelated experiment aimed at introducing a delay before the final memorization task. Then participants answered the 25-item Disgust Scale – Revised ($\alpha = .84$) (Haidt et al., 1994, modified by Olatunji et al., 2007).

Finally, to measure how much information the participants remembered about the accident from the news article, they were asked: “Imagine you meet a friend and want to tell them about the accident in Pakistan (the first article you saw when starting this survey), what would you tell them?” Each answer to this general memory question was manually coded by the first author of the article. Answers were coded according to the mention of the accident as stated in the text: 0 if the nature of the accident was not mentioned (e.g. “Pakistan has just had a terrible accident...”), and 1 if the nature of the accident was mentioned (e.g. “There was a petroleum accident in Pakistan”). To ensure the validity of the coding, an independent coder, blind to our hypotheses, coded 50 randomly selected answers. Intercoder-reliability test was conducted and showed a Cohen’s Kappa agreement score of 69% which corresponds to an ‘substantial’ agreement (McHugh, 2012, details can be found in the ESM, Appendix S6). As the final element of the memory task participants answered two specific recall questions about the effects of the accidents: “How many people were at risk of being affected by the accident?” and “How large was the area affected by the accident?”. We subsequently calculated the deviation between the answer and the numbers in the original news articles for the number of people mentioned by as being at risk, and
the area mentioned. As the recall of the area and of the number of people affected spread over a large range, we log-transformed these measures, using the log(1+x) transformation. We generated one recollection measure by adding the recall of the area and of the number of people affected.

### 3.2. Results

![Box plots showing results for estimation of fatalities, interest in reading, and willingness to share across four conditions.](image)

**Figure 2**: Estimation of the number of fatalities (panel a; log-scale, “0” answers have been transformed to 1 to allow their incorporation in the log scale), interest in reading the news article (panel b; full range of scores is 1-6) and willingness to share it (panel c; full range of scores is 1-6) in the four conditions (four different accidents: flood, biological laboratory, nuclear power plant, and petroleum plant).

Figure 2 and Table 1 display the results of Experiment 2. Since we have five dependent variables (estimation of the number of fatalities, interest in reading the news article, willingness to share the article, spontaneous mention of the accident in the memory task and recall of the area and of the number of people affected by the accident), we first ran a multivariate analysis of variance (MANOVA) on these five dependent variables, with the condition, participants’ disgust...
scale scores, and the interaction between condition and disgust scale scores participant as independent variables, and gender, age and educational level as covariates. If the global multivariate test is significant, we run linear regressions on each of the dependent variables to identify the specific dependent variables that contributed to the significant global effect.

We first tested the difference between the nuclear accident condition and the biological laboratory condition. If both conditions activate the behavioral immune system to a broadly similar extent, the answers should not be substantively different. Then, we tested whether answers in the nuclear accident condition differed from answers in flood and in the petroleum factory condition. If the behavioral immune system is more likely to be activated by the nuclear accident than the other two, we should observe differences between these conditions. We tested the moderating effect of individual differences in disgust sensitivity on the impact of condition on the dependent variables. If the behavioral immune system explains in part the different reactions to the nuclear power plant and biological laboratory conditions on the one hand, and the petroleum and flood conditions on the other, these differences should be larger among individuals with higher disgust sensitivity. Alternatively, the disgust sensitivity scale might measure a more general sensitivity to risk, in which case we would expect a main effect of disgust sensitivity.

The MANOVA showed a significant multivariate effect for condition, Pillai’s Trace = .26, $F = 3.61$, $df = (3, 564)$, $p < .001$, and disgust sensitivity, Pillai’s Trace = .12, $F = 4.95$, $df = (1, 186)$, $p < .001$.

Univariate regression analyses for the effect of condition showed no significant difference between the nuclear accident condition and the biological laboratory condition ($p > .05$), for all five dependent variables.
Univariate regression analyses for the effect of condition showed significant differences between the nuclear condition and the petroleum plant condition on the estimation of the number of fatalities ($\beta = -0.70 \ [\text{-1.11, -0.35}], t(93) = -3.66, p < .001$), interest in reading the news article ($\beta = -0.62 \ [\text{-1.01, -0.24}], t(93) = -3.19, p = .002$), spontaneous mention of the accident in the memory task ($\beta = -0.60 \ [\text{-0.98, -0.22}], t(93) = -3.13, p = .002$), but not on the willingness to share the article and recall of the area and of the number of people affected by the accident ($p > .05$). Participants in the petroleum plant condition estimated fewer fatalities, were less interested in reading the news article, and mentioned significantly less the accident in the memory task than participants in the nuclear condition.

Univariate regression analyses for the effect of condition showed significant differences between the nuclear condition and the flood condition on the estimation of the number of fatalities ($\beta = -0.51 \ [\text{-0.89, -0.13}], t(93) = -2.67, p = .008$), interest in reading the news article ($\beta = -0.50 \ [\text{-0.88, -0.12}], t(93) = -2.56, p = .01$), willingness to share the article ($\beta = -0.41 \ [\text{-0.80, -0.03}], t(93) = -2.11, p = .04$) but not on the spontaneous mention of the accident in the memory task or recall of the area and of the number of people affected by the accident ($p > .05$). Participants in the flood condition estimated fewer fatalities, and were less interested in reading and sharing the news article than participants in the nuclear condition.

Univariate regression analyses for the effect of disgust sensitivity showed no significant differences on all dependent variables ($p > .05$), except for the spontaneous mention of the accident in the memory task ($\beta = -0.27 \ [\text{-0.40, -0.13}], t(93) = -3.84, p < .001$), with participants higher in disgust mentioning significantly less the accident in the memory task.

The interaction between condition and disgust scale scores was non-significant ($p > .05$), for all five dependent variables.
3.3. Discussion

Experiment 2 confirmed the main finding from Experiment 1: compared to other types of accidents (here, a flood and an accident in a petroleum plant), people estimate more fatalities for nuclear accidents. Experiment 2 also extended Experiment 1 in two ways. First, we observed the same pattern for two other measures besides estimated fatalities: participants were more interested in reading a news article about a nuclear accident than about a flood or an accident in a petroleum plant (and in sharing a news article about a nuclear accident than about a flood). Second, participants provided similar answers to all three questions (fatalities, interest in reading, and in sharing) in response to the nuclear accident, and to an accident in a biological laboratory working with dangerous diseases. The results are consistent with the prediction that nuclear accidents trigger the behavioral immune system, leading to increased interest and perception of risk.

Experiment 2 also provided two sets of results that do not fit this hypothesis. First, participants were not more likely to recall the nuclear accident, or to have an inflated memory of its importance compared to the two accidents that should not active the behavioral immune system. Second, the differences observed between the conditions were not modulated by disgust sensitivity.

Finally, for some of the questions, the rarity of the event might have played a confounding role: nuclear accidents and accidents in biological laboratories (such as the one described here, in particular given that the experiments were conducted pre-COVID 19 pandemic) are rare, whereas floods and, to some extent, industrial accidents, are more common. As a result, participants might have deemed it more interesting to read and share news articles related to the first two types of accidents. However, this different couldn’t explain the effect on estimated fatalities (why would
FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY

rare events be seen as more deadly?). We also note that other very rare events (e.g. catastrophic dam failures, such as the accident that caused over 200,000 fatalities in China in 1974) do not seem to attract the same attention as nuclear accidents, in spite of vastly larger death tolls, and thus that rarity is unlikely to be a very significant factor overall.

4. Experiment 3

The findings in Study 2 do not allow us to safely conclude that nuclear accidents are psychologically treated as a contamination risk that activates the behavioral immune system. To test more directly whether nuclear power triggers fears of contamination we implemented different versions of the ‘sweater test,’ some of which involved nuclear energy (e.g., Rozin et al., 1989). With the sweater test, Rozin and his colleagues have shown that even an object objectively clean, such as a thoroughly laundered sweater, could still provoke a fear of contamination if it had been previously in contact with a source that itself triggers a fear of contamination, and that people are less willing to wear such a sweater. If nuclear power triggers a fear of contamination, people should be less willing to wear a sweater that has previously been worn by an industrial working in an environment people associate with nuclear radiation.

4.1. Methods

4.1.1. Participants

We recruited 400 UK participants on the online crowdsourcing platform Prolific Academic, paid £0.75. Participants were screened for their knowledge of the Fukushima accident, and we removed 104 participants who reported that they had not heard of this event or were not sure whether they had heard of it, leaving 296 participants (189 women, $M_{Age} = 34.38, SD = 11.78$).
4.1.2. Design, procedure, and materials

To test the prediction we used the original instruction for the sweater test applied by Rozin et al. (1989), manipulating in a between-participants design whether participants were told that the sweater had been worn by an industrial worker working in an environment that should not trigger contamination fear (a car manufacturing plant), or one of three environments evoking nuclear radiation to different degrees (a nuclear power plant, the Fukushima Daiichi plant long before the accident, or the Fukushima Daiichi plant shortly after the accident). The instructions read as follows (experimental manipulations shown in brackets):

Consider a scale that runs from +100 (something that you would like extremely) to 0 (something you would dislike extremely). A rating of 50 would mean that you felt neutral. Now imagine a new unisex sweater of a style that you like. Rate how you would feel about wearing the sweater for one day after the sweater was worn by an industrial worker while he was working in a car manufacturing plant [an industrial worker while he was working in a nuclear power plant / an industrial worker while he was working in the Fukushima power plant, long before the accident / an industrial worker while he was working on the damaged reactor of Fukushima, shortly after the accident]? The sweater was thoroughly laundered after the man wore it.

Participants then answered the same questions as in Experiment 1 regarding their opinion on nuclear energy (seven questions) and the Disgust Scale – Revised (Haidt et al., 1994, modified by Olatunji et al., 2007).
4.2. Results

Figure 3. Participants’ declared willingness to wear a thoroughly washed but previously worn sweater as a function of the place it had been worn in.

Results are displayed in Figure 3. To test whether participants’ disgust sensitivity affected their willingness to wear the sweater in the four conditions (Fukushima after the accident, Fukushima before the accident, generic nuclear power plant, and car manufacturing plant), while controlling for demographic variables, we conducted a linear regression.
FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY

Compared to the “car manufacturing plant” condition, participants were less willing to wear the “Fukushima after the accident” sweater ($\beta = -1.30 [-1.59, -1.01], t(85) = -4.21, p < .001$), but there was no significant difference between the “car manufacturing plant” condition and the “nuclear power plant” condition ($\beta = -0.37 [-0.65, -0.09], t(85) = -1.24, p = .22$) or the Fukushima before the accident” condition ($\beta = -0.53 [-0.80, -0.25], t(85) = -0.36, p = .72$).

Disgust scale scores were negatively associated with participants’ willingness to wear the sweater ($\beta = -0.38 [-0.56, -0.20], t(84) = -4.17, p < .001$), with participants low in disgust sensitivity being more willing to wear the sweaters than participants high in disgust sensitivity.

There was no significant interaction between Condition and disgust sensitivity on participants’ willingness to wear the sweaters (see figure S4).

We found that individual differences in disgust sensitivity predicted Nuclear Opinion Scores, with individuals higher in disgust sensitivity having a less favorable opinion of nuclear energy ($\beta = 0.25 [0.14, 0.37], t(91) = 4.38, p < .001$).

4.3. Discussion

Participants’ willingness to wear a previously worn sweater decreased as the association with nuclear radiation increased, from the sweater having been worn in a car manufacturing plant to the sweater having been worn in the Fukushima nuclear power plant after the accident. Compared to the car manufacturing plant, participants were less willing to wear sweaters worn in a nuclear power plants even in the absence of accidents, and thus without any dangerous levels of radiations. Following the logic of Rozin et al. (1994), these results suggest that nuclear energy evokes a fear of contamination. Finally, we replicated the negative relationship between disgust sensitivity and opinion about nuclear energy.
5. **Experiment 4**

To further test whether activation of the behavioral immune system drives negative opinion of nuclear energy, in Experiment 4 we investigate whether an argument specifically constructed to allay fears of contamination from nuclear energy increases support for nuclear energy. As in the previous experiments, we measure disgust sensitivity, testing whether people high in disgust sensitivity are more convinced by that argument. In order to control for demand effects, which might make participants shift their opinion simply because they have been presented with an argument in favor of nuclear energy, we present all participants with an economic argument in favor of nuclear energy, and only half of the participants with, in addition, the argument allaying fears of contamination (Contamination Argument condition).

Finally, given the previous results showing associations between disgust sensitivity and risks apparently unrelated to contagion (Kahan & Hilgard, 2017), we also measure the perception of other risks besides nuclear energy.

### 5.1. Method

#### 5.1.1. Participants

We recruited 272 UK participants on the online crowdsourcing platform Prolific Academic, paid £0.88. We removed two participants who failed the attention check, leaving 270 participants (177 women, $M_{Age} = 35.72, SD = 12.01$).

#### 5.1.2. Design, procedure, and materials
First, participants were asked the following questions to estimate their perception of non-nuclear risks: “On a scale of 1-10 with 1 being ‘no risk at all’ and 10 meaning ‘extreme risk,’ how much risk you would say earthquakes pose to human health, safety, or prosperity?,” and the same question in relation to hurricanes, floods, and droughts. Then, participants had to answer six questions regarding their opinion on nuclear energy (Nuclear Opinion Scale). In order to assess in a more fine-grained manner the effects of the arguments later given to the participants we used two questions related to each of the following three themes: General opinion, Economics, and Radiation. The questions were as follows:

(General opinion 1) “On a scale of 0-10 with 0 being ‘no risk at all’ and 10 meaning ‘extreme risk,’ how much risk you would say nuclear energy poses to human health, safety, or prosperity?”

(General opinion 2) “Do you believe that nuclear power is a good source of energy generation compared to other methods such as coal, oil, gas and renewable sources?”

(Economics 1) “To what extent do you agree or disagree with the following statement? Nuclear energy costs less to produce than other energy sources.”

(Economics 2) “To what extent do you agree or disagree with the following statement? Nuclear energy helps to make us less dependent on fuel imports, such as gas and oil.”

(Radiation 1) “Do you think the escape of radioactivity into the atmosphere is a major problem connected with nuclear power plants?”

(Radiation 2) “Do you think that nuclear power plants emit dangerous levels of radiation that could lead to health problems?”
The general opinion questions were answered on ten-point Likert scale ranging from “No risk at all” (1) to “Extreme risk” (10), and the other questions on five-point Likert scales ranging from “Strongly disagree” (1) to “Strongly agree” (5), with a central measure “Neither agree or disagree” (3).

In a between-participant design, participants were then exposed either only to the Economic Argument, or to the Economic and the Contamination Arguments. We designed the Contamination Argument to address fear of contagion by tapping into the main characteristics of the “law of contagion,” representing people’s intuitions about contagion: (a) physical contact is a critical factor in determining negative reactions, (b) even very brief contact, or contact with very small amounts of material, is capable of transmitting substantial negative properties (dose insensitivity), (c) the effects of even brief contact are long lasting (permanence) (Rozin et al., 1992).

The contamination argument read as follows: The uranium used in nuclear plants is safely enclosed in sealed containers behind multiple, robust safety barriers. No worker is ever in direct contact with radioactive substances. Radioactivity is completely unlike a viral or bacterial disease: low doses of radiation are perfectly harmless, and radiation is not contagious. Radiation exposure can occur from natural sources, such as radioactivity in rocks and soil, or cosmic radiation. Radiation arising from human activities is not different from natural radiation. Medical procedures such as X-rays account for most non-natural radiation exposure. Less than 1% of exposure is due to the generation of electricity in nuclear power plants. You get more exposure to radiation by taking a plane or getting a dental X-ray than by living next to a nuclear power plant.
The economic argument read as follows:

Nuclear power is considered one of the most economically cost-efficient ways of producing electricity: A small and inexpensive amount of uranium can fuel a plant, providing enough electricity to power a city of half a million people. The operating costs of a nuclear power plant are very low. Nuclear power plants are also economically attractive because they don’t rely on fossil fuels. As a result, they are not affected by fluctuating oil and gas costs. According to the Organization for Economic Co-operation and Development, one new nuclear plant creates approximately 1000 permanent jobs, not to mention thousands of others during its construction. This is more than coal or natural gas plants. These positive effects on job creation further adds to the positive economic effects of nuclear power.

After reading the arguments, participants completed again the Nuclear Opinion Scale, and then the Disgust Scale – Revised (Haidt et al., 1994, modified by Olatunji et al., 2007).

5.1.3. Coding

We created a Nuclear Opinion Score by standardizing and averaging the scores of all the questions, reverse coding items when appropriate, and normalizing all answers to the [0; 1] range, with higher scores indicating stronger support for nuclear energy. We also calculated subscale scores, by averaging the normalized scores of the two questions of each of the three subscales: General opinion, Economics, and Radiation.

5.2. Results
5.2.1. Opinion Change

A linear regression was conducted to compare the main effects of Condition (Economic Argument; Economic and Contamination Arguments), disgust sensitivity, and their interaction on Nuclear Opinion Score after being presented with the arguments, while controlling for Nuclear Opinion Score before being presented with the arguments (initial attitudes), age, gender and education.

Nuclear Opinion Scores post-arguments were highly correlated with Nuclear Opinion Scores pre-arguments ($\beta = 0.70 \ [0.61, 0.80], \ t(62) = 4.19, \ p < .001$). Participants in the Economic and Contamination Arguments became more favorable to nuclear energy than participants in the Economic Argument condition ($\beta = 0.41 \ [0.24, 0.59], \ t(62) = 4.68, \ p < .001$). Disgust sensitivity was not associated with participants’ shift towards more positive opinions of nuclear energy ($\beta = 0.08 \ [-0.01, 0.18], \ t(62) = 1.83, \ p = .07$). There was no significant interaction between Condition and disgust sensitivity on participants’ change in Nuclear Opinion Score ($\beta = 0.02 \ [-0.16, \ 0.19], \ t(62) = 0.22, \ p = .83$, see Figure 4).

There was a significant correlation between disgust sensitivity and Nuclear Opinion Scores, measured before the arguments were provided to the participants, such that participants with higher disgust sensitivity had a more negative opinion of nuclear energy ($\beta = -0.01, \ t(64) = -3.78, \ p < .001$). The correlation was, descriptively, stronger between disgust sensitivity and answers to the Radiation questions ($\beta = -0.01, \ t(64) = -3.78, \ p < .001$), than between disgust sensitivity and the Economics questions ($\beta = -0.004, \ t(64) = -1.71, \ p = .09$).
Figure 4. Effect on Nuclear Opinion Change of the interaction between Disgust Scores and Condition. Nuclear Opinion Change is the difference between the Nuclear Opinion Scores after and before being presented with the argument, with higher scores reflecting a shift towards more positive opinions of nuclear energy. The full range of Nuclear Opinion Change is [-1; 1].

5.2.2. Risk perception and nuclear energy opinion

We tested the correlation between disgust sensitivity and the risk perception of nuclear and non-nuclear risks (earthquakes, hurricanes, floods, and droughts). There was a significant positive effect of disgust sensitivity on risk perception of nuclear energy ($\beta = -0.21 [-0.33, -0.10]$, $t(64) = -3.59, p < .001$), as well as between disgust sensitivity and risk perception of non-nuclear risks ($\beta = 0.14 [0.02, 0.26]$, $t(64) = 2.21, p = .03$). The effect of disgust sensitivity on risk perception of
nuclear energy remains when controlling for risk perception of non-nuclear risk ($\beta = -0.16 [-0.27, -0.05]$, $t(67) = -2.91, p = .004$).

### 5.3. Discussion

The argument allaying fear of contamination was effective, making people more supportive of nuclear energy (compared to when participants only received an argument about the economic advantages of nuclear energy). However, this argument was not more effective, relative to the other argument, among participants higher in disgust sensitivity. The messages were not pretested for other differences, such as valence, affect, or interest, which could in part account for condition differences.

We observed the expected positive correlation between disgust sensitivity and nuclear risk perception, and negative opinion of nuclear energy, in particular because of the increased fear of radiations. However, we also observed correlations (albeit weaker ones) between disgust sensitivity and the perception of non-nuclear risks unrelated to contamination. In line with previous results (Kahan & Hilgard, 2017), this suggests that the disgust scale might be tracking risk sensitivity generally.

### 6. General Discussion

We presented four experiments using very different paradigms to investigate whether public opposition to nuclear energy is at least in part due to fear of contamination triggered by the behavioral immune system.

Across the four experiments, two very consistent patterns emerge, while other results are less consistent. In each experiment, the main manipulation had the predicted effects. In Experiment
participants vastly overestimated the number of fatalities due to an actual nuclear accident (Fukushima Daiichi), while they underestimated the fatalities due to the preceding tsunami and the concurrent evacuation.

Experiment 2 confirmed and extended this finding using a hypothetical accident. First, as in Experiment 1, compared to other types of accidents (a flood and an accident in a petroleum plant), people estimated more fatalities for nuclear accidents. Second, besides this measure of estimated fatalities, we also measured interest in reading and willingness to share news article about these accidents, and observed the same pattern: participants were more interest in reading and sharing a news article about a nuclear accident than about a flood or an accident in a petroleum plant. Third, participants provided similar answers for the nuclear accident and for an accident in a biological laboratory working with dangerous diseases, suggesting that both accidents might have triggered the behavioral immune system, leading to increased perception of risk. The only variable which was not affected by the manipulation was participants’ recall of the accidents.

In Experiment 3, participants’ willingness to wear a previously worn but thoroughly washed sweater decreased as the association with nuclear radiation increased, from the sweater having been worn in a car manufacturing plant to the sweater having been worn in the Fukushima nuclear power plant right after the accident, even if only the most extreme comparison was statistically significant. Following the logic of Rozin et al. (1994), these results suggest that nuclear energy evokes a fear of contamination.

Experiment 4 showed that when an argument that specifically addressed fear of contagion due to nuclear energy was added to an economic argument in favor of nuclear energy, participants became more supportive of nuclear energy.
Finally, in Experiments 1, 3, and 4, we found that higher disgust sensitivity was associated with more negative opinions of nuclear energy. Moreover, Experiment 4 revealed that heightened disgust sensitivity was particularly strongly associated with fear of radiations.

In spite of this last result, the second consistent pattern emerging from our experiments is that none of the main effects were significantly modulated by disgust sensitivity. One possible explanation for this lack of modulation might be that we used the Disgust Scale Revised (Olatunji et al., 2007) to measure individual differences in disgust sensitivity. On the one hand, the Disgust Scale – Revised boasts good reliability, both in terms of internal consistency Revised (Olatunji et al., 2007) and test-retest reliability (Olatunji et al., 2012), and its factor structures has been found to be invariant between men and women, and across several countries (Olatunji et al., 2007, 2014; Olatunji & Wolitzky-Taylor, 2009). Moreover, self-report measures of disgust appear to exhibit convergent validity with some behavioral measures (see Rozin et al., 1999; Viar-Paxton & Olatunji, 2016). On the other hand, researchers have criticized disgust scales for being overly general, falling outside the scope of disgust as an emotion specifically targeted at avoiding the ingestion of toxins (Armstrong et al., 2020; Royzman et al., 2017). In particular, some reactions attributed to disgust—such as rejection of GMOs—have been attributed instead to more general fear mechanisms (Royzman et al., 2017, although see Blake et al., 2017), in line with the work mentioned earlier showing that disgust sensitivity is associated with a wide range of fears that should not elicit disgust (Kahan & Hilgard, 2017) and predicts heightened risk perception (Karg et al., 2019).

Some of our findings suggest that the Disgust Scale - Revised may pick up a more general risk aversion, as we observed correlations between disgust sensitivity and the perception of risks unrelated to contamination (albeit smaller correlations than with nuclear risk). Still, the results in
Experiments 1 and 2, where we observe no statistically significant main effect of disgust sensitivity on the estimated number of fatalities from accidents (or even a negative effect in Experiment 1), argue against the notion that the DS-R primarily tracks general risk sensitivity. The non-significant main effect of disgust sensitivity on interest in and willingness to share news articles about accidents and recall in Experiment 2 also go against this interpretation.

Unfortunately, we realized after conducting the experiments that the most relevant subscale of this scale (Contamination-Based Disgust) had a very poor internal consistency (all Cronbach’s alpha < .6, by contrast with the overall scale, which had good internal consistency, all Cronbach’s alpha < .8). As a result, even though they are reported in ESM, we could not trust the analyses conducted using only that subscale.

Given the mixed findings for disgust sensitivity in our study, we suggest that, conceptually, the construct of pathogen avoidance motivation directed by the behavioral immune system might be more relevant than that of disgust, especially when studying people’s reaction to stimuli that cannot be ingested (such as radiations), and that a scale specifically designed to test the sensitivity of the disgust related to pathogens (such as the pathogen disgust scale from the Three Domain Disgust Scale, Tybur et al., 2009, or the Germ Aversion factor for the Perceived Vulnerability to Disease scale, Duncan et al., 2009) constitute a more direct measure to test the predictions.

We invite future research to further explore these possibilities in cross-cultural studies using different measures of individual differences in the sensitivity of the behavioral immune system and general risk sensitivity across countries with different types of media coverage of nuclear energy.

7. Conclusion
FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY

Compared to expert opinion, the public’s perception of nuclear energy is overly negative. In this study we have investigated whether this gap might be partly explained by the triggering of the behavioral immune system by nuclear energy. The behavioral immune system is a set of adaptations that aim at protecting us against pathogens by making us particularly alert to their existence, and attuned to the risks they represent (Murray & Schaller, 2016; Schaller & Park, 2011; Tybur et al., 2009; Tybur & Lieberman, 2016). Nuclear radiations could be perceived by the behavioral immune system as pathogens, leading to misunderstandings about the nature of radiations (e.g. the fact that, unlike pathogens, they are innocuous at small doses), and to an exaggerated negative reaction to nuclear energy. In our experiments, we explored different facets of this exaggerated negative reaction.

First, objects that trigger the behavioral immune system should be perceived as more dangerous. In Experiments 1 and 2, we showed that participants overestimate the risks of nuclear accidents compared to other disasters.

Second, people should pay more attention to objects that trigger the behavioral immune system. In Experiment 2, participants were more interested in reading and sharing a news article about a nuclear accident than about other types of accidents—except for the other accident that should also have activated the behavioral immune system.

Third, the behavioral immune system should lead us to refuse any contact with objects perceived as being contaminated, which we observed in Experiment 3: participants declared to be less willing to put on a thoroughly laundered sweater that had been previously worn by someone working in a nuclear power plant after an accident than in a car manufacturing plant.

Fourth, if the negative reaction to an object is due to the activation of the behavioral immune system, it should be possible to reduce this negative reaction by providing good reasons
why the object should not, in fact, trigger the behavioral immune system. In Experiment 4, arguments showing that nuclear power plants should not elicit fears of contamination were effective at reducing the negative perception of nuclear energy.

Moreover, we observed that people with high disgust sensitivity held more negative opinions of nuclear energy. However, contrary to our predictions, disgust sensitivity did not modulate our main effects, and it was also associated (albeit less strongly) with increased fears of objects that should not evoke any fear of contamination.

As noted in the introduction, observational evidence strongly suggests that the people who were in the vicinity of nuclear accidents, or of nuclear bombings, have often been treated as if they had been permanently contaminated, and were themselves contagious. Our results extend these observations by suggesting that the behavioral immune system might affect perceptions of nuclear energy even in contexts in which high doses of radiations are indeed emitted (i.e. in accidents or bombings).

Our study had several limitations. First, the failure to observe any modulations of our results by the participants’ disgust sensitivity might be in part due to our use of the Disgust Scale – Revised, as discussed above. Another limitation comes from our sample, which is non-representative and coming from only one country – the United Kingdom. Nuclear energy has been part of the energy production in the United Kingdom since 1956 (the first in the world). The only major nuclear accident in the UK dates from 1957 (the Windscale fire), and caused an estimated number of 100 deaths. Since then, the only other significant incident only caused material damage (at the Sellafield nuclear site in 2005). Replications in different countries with different histories with nuclear energy should be conducted before strong theoretical conclusions can be drawn, and
representative samples should be used before practical implications are derived (e.g. about whether
to use messages such as those of Experiment 4 to communicate around nuclear energy).

Besides adopting potentially more suitable instruments and more diverse samples, future
research could test our hypotheses further, for instance by attempting to elicit disgust and
observing the effect on support for nuclear energy (the opposite of Experiment 4, see Kam & Estes,
2016).

An increasing number of experts agree that nuclear energy, because it emits very little
greenhouse gazes, should play an important role in fighting climate change. However, public
opinion is, in many countries, ambivalent at best about nuclear energy. We hope that by better
understanding the sources of people’s distrust of nuclear energy, we can help bridge the gap
between the public and experts on this crucial topic.

8. Supplementary materials

Dara and codes used to analyze this data can be found online at
https://osf.io/yaxqh/?view_only=17187162882b4585bb5c762fbcb2f389.

9. References

political intuitions: Why and how individual differences in disgust sensitivity underlie
https://doi.org/10.1017/S0003055416000770

Armstrong, T., Wilbanks, D., Leong, D., & Hsu, K. J. (2020). Is There a Measurement Crisis in
Disgust Research?
FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY


https://doi.org/10.1016/j.jpsychires.2014.10.006


FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY


FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY

https://doi.org/10.1016/j.evolhumbehav.2007.05.001


https://www.cas.go.jp/jp/seisaku/icanps/eng/05IVfinal.pdf

IPSOS, & EDF. (2020). *Observatoire COP 2020, Mobilisation, inquiétude ou indifférence des citoyens de 30 pays envers le changement climatique.*

https://www.edf.fr/sites/default/files/contib/groupe-edf/obs-
FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY

cimat/2020/obscop2020_principauxresultats_1a_fr.pdf


FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY


Palfreman, J. (2006). A tale of two fears: Exploring media depictions of nuclear power and...

https://doi.org/10.1023/A:1023910408854

https://doi.org/10.5012/jkcs.2005.49.5.503


https://doi.org/10.1371/journal.pone.0087516


https://doi.org/10.2203/dose-response.14-034.Socol


http://large.stanford.edu/courses/2017/ph241/stowers2/


https://doi.org/10.1016/j.evohumbehav.2012.10.003


https://doi.org/10.1787/9789264991897-en
FEAR OF CONTAMINATION AND PUBLIC OPINION ON NUCLEAR ENERGY


https://doi.org/10.1016/j.energy.2020.117290