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Religious beliefs and public attitudes toward nanotechnology in Europe and the United States

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How do citizens make sense of nanotechnology as more applications reach the market and the mainstream media start to debate the potential risks and benefits of technology[1]? As with many other political and scientific issues, citizens rely on cognitive shortcuts or heuristics to make sense of issues for which they have low levels of knowledge[2]. These heuristics can include predispositional factors, such as ideological beliefs or value systems[3], and also short-term frames of reference provided by the media or other sources of information[4]. Recent research suggests that 'religious filters' are an important heuristic for scientific issues in general[5], and nanotechnology in particular[6]. A religious filter is more than a simple correlation between religiosity and attitudes toward science: it refers to a link between benefit perceptions and attitudes that varies depending on respondents' levels of religiosity. In surveys, seeing the benefits of nanotechnology is consistently linked to more positive attitudes about nanotechnology among less religious respondents, with this effect being significantly weaker for more religious respondents[6]. For this study, we have combined public opinion surveys in the United States with Eurobarometer surveys about public attitudes toward nanotechnology in Europe to compare the influence of religious beliefs on attitudes towards nanotechnology in the United States and Europe. Our results show that respondents in the United States were significantly less likely to agree that nanotechnology is morally acceptable than respondents in many European countries. These moral views correlated directly with aggregate levels of religiosity in each country, even after controlling for national research productivity and measures of science performance for high-school students.

When forming attitudes about nanotechnology, the U.S. public seems to focus mostly on novel applications or scientific breakthroughs and their potential benefits, and is not particularly interested in or concerned about specific risks of this new technology[4,7]. However, surveys tracking public attitudes and knowledge about nanotechnology have shown that levels of knowledge in the United States—measured on a battery of true/false questions—have stayed at consistently low levels since 2004 (see Supplementary Information, Fig. S1).

Recent research also suggests that religious beliefs may be part of the value systems people use when they make sense of science and technology more broadly. This may be due to perceptions that there are normative inconsistencies between science and religious beliefs[8], illustrated by the view that science interferes with nature—or is equivalent to playing God—and is therefore incompatible with strong religious beliefs[9]. For instance, researchers have found that moral issues and concerns about 'unnatural' technologies were important in explaining negative attitudes towards genetically modified (GM) organisms, which were seen as disturbing nature and natural processes, and perceived as risky and immoral[10].

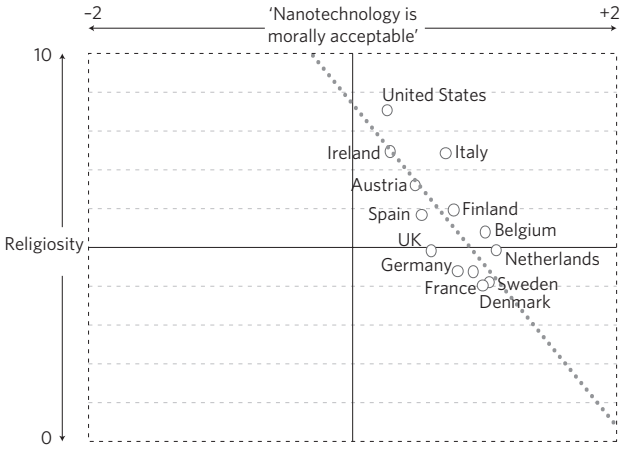

Figure 1 | Relationship between strength of religious beliefs and moral acceptance of nanotechnology. Based on country-level data, we see a negative relationship between levels of religiosity (vertical axis) and beliefs that nanotechnology is morally acceptable (horizontal axis). More religious countries cluster together at the top end of the dotted regression line, and more secular countries at the bottom end. The average responses plotted here somewhat under-represent the range of responses across all response categories. The proportion of respondents who disagreed (that is, −1 or −2) that nanotechnology was morally acceptable was highest in the United States (24.9%) and lowest in Italy (7.3%). The percentages for respondents who agreed (that is, +1 or +2) was highest in Belgium (82.4%) and lowest in Ireland (33.5%).

The potential conflict between religiosity and science has been much more salient for nanotechnology, in particular with respect to nano-bio-info-cogno (NBIC) technologies that may, in the future, enable us to create life and intelligence at the nanoscale without divine intervention[11,12]. Such threats to people's religious beliefs make them more likely to oppose further research in nanotechnology on moral or religious grounds[13].

To explore this relationship, we first examined individual-level relationships in the United States between religiosity and agreement with the idea that 'nanotechnology is morally acceptable.' (See Supplementary Information, Table S1, for a full list of the questions in the survey.) We found a significant negative correlation between religiosity and agreement that nanotechnology is morally acceptable (see Supplementary Information, Table S2). This relationship holds even after potential mediators of the link between religious beliefs

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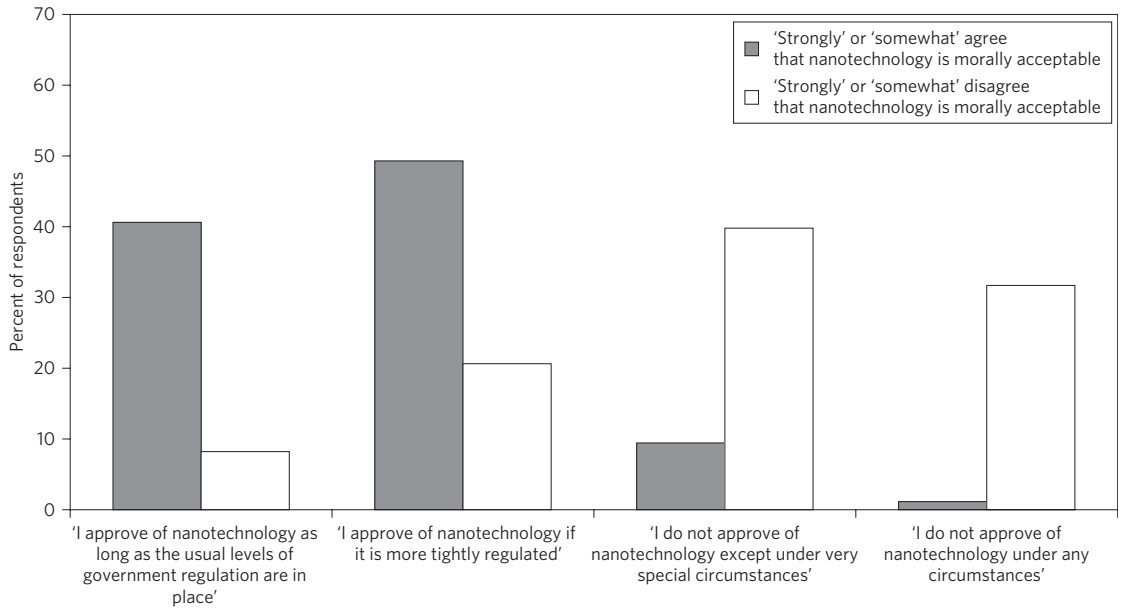

Figure 2 | Link between views on moral acceptability of nanotechnology and support for regulations. Breakdowns are shown for four different regulatory scenarios across levels of moral support for nanotechnology, with percentages calculated across all countries (United States and Europe). The data show that the majority of respondents who saw nanotechnology as morally acceptable (dark columns) also support nanotechnology under existing or tighter regulations. In contrast, a vast majority of respondents who disagreed with the statement that nanotechnology is morally acceptable (pale columns) did not approve of nanotechnology 'under any circumstances,' or only approved 'under very special circumstances.' For multivariate analyses of this relationship, see Supplementary Information, Table S2.

Table 1 | Similarities between moral acceptability of and support for nanotechnology in the United States.

		'Overall, I support the use of nanotechnology'	Religiosity	Knowledge about nanotechnology (based on true/false questions outlined in the Supplementary Information, Fig. S1)
Agreement with the following statements	'Overall, I support the use of nanotechnology'	—	−0.23*	0.28*
	'Nanotechnology is morally acceptable'	0.71*	−0.25*	0.21*

Overall support for the use of nanotechnology and moral support for nanotechnology are strongly related. At the zero-order level, both show similar negative correlations with religiosity and positive correlations with knowledge about nanotechnology. All coefficients are zero-order correlations for the U.S. data, which was the only data set for which all of these measures were available at the individual level. *$p \leq 0.01$.

and attitudes towards nanotechnology, such as trust in scientists, knowledge about nanotechnology, or attention to science content in various media, are included as control variables.

But how typical is the United States with respect to the link between religiosity and science? Historically, many countries in Western Europe have shown a quicker transition than the United States into more secularized societies as levels of education and literacy have increased. In other words, the United States provides an interesting anomaly among affluent nations in recent history, with behavioural indicators of religiosity having changed little since the 1950s[14]. This pattern was confirmed in a recent cross-country comparison by The Pew Global Attitudes Project that showed a fairly stable aggregate-level relationship between a country's wealth and levels of secularism, with the exception of the wealthiest country in the data set, the United States, where citizens were 'considerably more religious than their level of prosperity would predict'[15]. These findings are consistent with the patterns we found in our data set when we examined the relationship between religiosity and nanotechnology at the country level. In particular, respondents in the United States were significantly less likely to agree that 'nanotechnology is morally acceptable' than respondents in many European countries. And, at the country level, we found a negative relationship between aggregate levels of religiosity (that is, the overall religious climate) in each country and aggregate beliefs that nanotechnology is morally acceptable (Fig. 1).

Some of the more religious countries (including Italy, Austria and Ireland) cluster around the upper end of the regression line in Fig. 1. At the other end of that line are more secular countries, such as Denmark, Sweden, France and Germany, which also tend to show higher aggregate agreement with the idea that nanotechnology is morally acceptable. This clustering is consistent with findings on religiosity reported by Inglehart and Norris, which show that historic trends toward secularization have differed markedly across countries, 'producing contrasts such as the continuing hegemonic grip of the Catholic Church in Ireland, and the far more secular society evident in Protestant Denmark'[16].

These country-level analyses corroborate the link between religiosity and attitudes towards nanotechnology that we found in the individual-level U.S. data, and in fact suggest that the religious climates in each country may play an important role in predicting levels of support for nanotechnology. Of course, these analyses raise a number of related questions.

First, what is the practical importance of people's moral views of nanotechnology with respect to their potential impact on regulatory

Table 2 | Predicting moral acceptance in Europe and the United States (country-level data).

	Pearson's *r*	Standardized β	Unique R^2	Total Model R^2
Ratio of publications over public funding (€)	−0.00	−0.07	0.4%	
PISA knowledge scores	0.22	0.09	0.7%	
Strength of religiosity	−0.75*	−0.73*	51.1%*	55.7%*

Religiosity is the dominant predictor of moral acceptance of nanotechnology at the country level. Four different statistical measures are shown in this table. Standardized β values from ordinary least-squares (OLS) regressions show the relative impact of each independent variable. The religious climate in different countries accounted for almost half of the variance in moral acceptance (see Total Model R^2), even after controlling for each country's ratio of publications to the public funding (which is a measure of productivity relative to investment) and each country's PISA score (see main text). Unique R^2 values are calculated as the variance in moral acceptance explained exclusively by a predictor variable, with all other variables in the model controlled for. *$p < 0.01$.

views or policies? Our data suggest that there is in fact a link between the two concepts. Figure 2, for instance, illustrates respondents' preference for one of four regulatory scenarios. Over 70% of respondents who disagreed with the statement that nanotechnology is morally acceptable also did not approve of nanotechnology 'under any circumstances' or only approved of it 'under very special circumstances.' Among respondents who felt that nanotechnology was morally acceptable, the pattern was reversed, with almost 90% of respondents approving of nanotechnology 'as long as the usual levels of government regulation are in place' or 'if it is more tightly regulated.'

A second question about our individual-level and country-level analyses relates to the relationship being potentially a function of the "moral" terminology used in the operationalization of our dependent variable. In other words, is it possible that the 'moral' terminology in the question inflated the link with religiosity? The zero-order correlations based on the U.S. individual-level data suggest that this was not the case (Table 1). In fact, levels of general support for nanotechnology were strongly and significantly correlated with moral views towards nanotechnology. In addition, both attitudinal measures showed consistent relationships with religiosity and levels of knowledge about nanotechnology.

A third question about our country-level analysis relates to the level of measurement. Ideally we would have parallel individual-level measures across all countries for critical variables—such as levels of information, religiosity and different dependent variables—but, unfortunately, the nature of our data collection only allowed us to coordinate a small subset of questions with the ongoing Eurobarometer data collection. In part, this concern is addressed by the fact that the relationships we found at the country level were consistent with individual-level analyses (see Supplementary Information, Table S2).

However, it is still possible that the impact of religious climates on attitudes toward nanotechnology in different countries is a function of other aggregate-level differences. In order to address the first concern, we calculated a series of ordinary least-squares (OLS) regressions that examined the relationship between religiosity and perceptions of moral acceptability, controlling for two potential confounding factors (Table 2). The first was the ratio of academic nanotechnology publications to the public/government funding for each country. There was no significant link between this productivity index and beliefs about the moral acceptability of nanotechnology, either at the zero-order level or after including multivariate controls. The second potential confounding factor was a measure of the science performance of high-school students in each country, based on the 2006 OECD Programme for International Student Assessment (PISA; see Methods). There seemed to be a moderate positive relationship between PISA scores in each country and beliefs about the moral acceptability of nanotechnology at the zero-order level but, given the limited statistical power of our country-level sample, this relationship was not significant in the OLS regression models. However, after controlling for productivity index and PISA scores, we found a strong correlation between religiosity and the moral acceptability of nanotechnology (Table 2). We also included the unique R^2 values for each variable as an assessment of the relative contribution of each variable to people's perceptions of the moral acceptability of nanotechnology, after controlling for all other variables in the model. All of these coefficients show a strong and stable link between religiosity and moral concerns about nanotechnology.

In summary, our analyses show a robust relationship between levels of religiosity and public support for nanotechnology across all countries. These results have important implications for how we think about the emerging public dialogue about nanotechnology. First, our findings reinforce the idea that public attitudes toward issues such as nanotechnology are increasingly driven by personal values and beliefs[3,6]. Of course, values are not the only heuristic, but likely go hand-in-hand with other shortcuts, such as affective reactions to new technologies[17] or trust and deference toward scientific authority[18,19]. Second, and more importantly, they highlight the need for a more granular look at the role that religiosity plays within and across different societies. In particular, it is important to keep in mind that our cross-country comparisons do not say anything about the differential strength of the religion–attitude link in different countries. Future research should explore this issue further.

This second point also echoes Leiserowitz's[20] call for a more nuanced investigation of the role of religiosity in public perceptions about technological and environmental risks. He argues that religiosity is part of a package of cultural and social values that is often correlated with levels of scepticism about technological and environmental risks. Although some of our nano-specific findings may appear at odds with Leiserowitz's results, the two studies are consistent in their conclusion that public attitudes about environmental and technological risks are significantly correlated with a package of larger cultural attributes that include religiosity.

The role of religiosity is not just linear. In fact, recent research[6] suggests that levels of religiosity can shape people's perceptions of risks and benefits, but also citizens' information-seeking behaviours. In other words, some sub-publics, even if they are highly knowledgeable, may choose to discount certain information when forming attitudes about nanotechnology; that is, these publics are not looking for more scientific information, but rather for a debate about the moral or religious concerns that shape their interpretation of this information.

Methods

The U.S. survey was conducted by the University of Wisconsin Survey Center under the auspices of the Center for Nanotechnology in Society at Arizona State University. Data collection for the study began on 15 February and ended on 27 June 2007, using a dual frame method of national random digit dial and listed household phone survey. The total sample size was 1,015, with a response rate of 30.60% (calculated using AAPOR's formula for RR3; ref. 21).

The Eurobarometer public opinion surveys were conducted on behalf of the European Commission. Using a multistage national probability sampling technique, the Eurobarometer 64.3 provides opinion data collected from 29 countries through face-to-face interviews of 29,193 Europeans aged 15 and above. The fieldwork was conducted between 5 November and 7 December 2005. We excluded interviewees under 18 in order to make the U.S. and European samples comparable. Also, there were slight variations in wording for scale anchors across countries, that is, 'strongly disagree' and 'strongly agree' were used in the U.S. survey, and 'totally disagree' and 'totally agree' in the English version of the Eurobarometer. Undecided respondents were coded into a middle category in all countries to make metrics comparable.

In this study, we compared the United States and the 12 top funders of nanotechnology research in Europe in terms of public/government funding.

It should be noted that the data for each country do not include about €370 million sponsored by the European Commission[22]. In addition, we collected national-level data from several sources to account for the influence of possible covariates in the country-level data. In particular, we used four additional data sources.

First, we imputed aggregate responses on religiosity for each country from the World Values Survey[14]. Possible responses ranged from one to ten, with one indicating that religious guidance was 'not at all important' and ten indicating 'very important' in respondents' lives. For more information, see http://www.worldvaluessurvey.org/.

Second, we included a measure of per-capita GDP. This was calculated as the ratio of each country's GDP over its population size.

Third, we controlled for aggregate levels of science performance in each country, based upon the 2006 PISA survey conducted by the Organization for Economic Co-operation and Development (OECD). PISA is an international standardized assessment of various dimensions of science competency and the 2006 survey was administered to 15-year-olds in schools across 57 countries. For more information, see http://www.pisa.oecd.org/.

Finally, data on the number of publications about nanotechnology in each country was generated by Youtie and colleagues, who provided us with access to their data on international publication records on nanotechnology from 1990 to 2006[23]. For the sake of comparability with our other data sources, we relied on the 2006 data for the analyses presented here.

It is important to note that the country-level analyses allowed us to impute variables from other data sources from each country that were not available as individual-level responses in the various surveys conducted in Europe and the United States. This includes PISA scores, the number of nano-related publications relative to public funding, and religiosity measures that were consistent across countries. In future studies, it would be useful to include consistent measures of religiosity, nanotechnology attitudes and so on, across countries in order to allow individual-level analyses or Hierarchical Linear Modelling (HLM) of these relationships.

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Author contributions

D.A.S. and E.A.C. led the study design and data collections and took responsibility for planning and writing the manuscript. D.A.S., E.A.C. and T.S. analysed the data. T.S., K.E.D. and S.S.H. contributed at different stages of data collection, analysis and writing.

Additional information

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