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Deliberating the risks of nanotechnologies for energy and health applications in the United States and United Kingdom

Nick Pidgeon[1]*, Barbara Herr Harthorn[2], Karl Bryant[3] and Tee Rogers-Hayden[4]

Emerging nanotechnologies pose a new set of challenges for researchers, governments, industries and citizen organizations that aim to develop effective modes of deliberation and risk communication early in the research and development process. These challenges derive from a number of issues including the wide range of materials and devices covered by the term 'nanotechnology', the many different industrial sectors involved, the fact that many areas of nanotechnology are still at a relatively early stage of development, and uncertainty about the environmental, health and safety impacts of nanomaterials[1]. Public surveys[2–8] have found that people in the United States and Europe currently view the benefits of nanotechnologies as outweighing their risks although, overall, knowledge about nanotechnology remains very low. However, surveys cannot easily uncover the ways that people will interpret and understand the complexities of nanotechnologies (or any other topic about which they know very little) when asked to deliberate about it in more depth, so new approaches to engaging the public are needed. Here, we report the results of the first comparative United States–United Kingdom public engagement experiment. Based upon four concurrent half-day workshops debating energy and health nanotechnologies we find commonalities that were unexpected given the different risk regulatory histories in the two countries. Participants focused on benefits rather than risks and, in general, had a high regard for science and technology. Application context was much more salient than nation as a source of difference, with energy applications viewed in a substantially more positive light than applications in health and human enhancement in both countries. More subtle differences were present in views about the equitable distribution of benefits, corporate and governmental trustworthiness, the risks to realizing benefits, and in consumerist attitudes.

Public participation with nanotechnologies is often described as 'upstream' in nature, reflecting its occurrence before commercialization in real-world applications and before significant social controversy[9,10]. The past five years have seen public engagement efforts of differing forms run in the United Kingdom[3,10–12], the United States[13,14] and continental Europe[15,16]. Most engagement efforts to date have been restricted to a single topic and cultural context, but legitimate questions arise. Will different application domains of nanotechnologies lead to differential public responses in participation events? And will responses also be influenced by geographical or cultural factors? For example, the potential health and environmental risks associated with energy applications of nanotechnologies are likely to be very different from those arising in the medical domain. And beliefs about the latter might in turn be influenced by different cultural values around issues such as the body and health, or experience with different healthcare delivery systems in different countries. Here, we present a generic method for public dialogue about nanotechnologies that can be used to compare responses to different applications (energy and health/human enhancement in the present case), and also in different national contexts. Details about the workshop are given in the Methods section. We discuss the findings under four headings.

Benefit rather than risk continues to frame nanotech risk perception. Risk perception researchers have extensively documented that a technology's acceptability will depend upon people's perceptions of both benefit and risk[17,18], with the balance between the two depending upon the particular technology or the context within which judgements are formed. Nanotechnology survey research in the United States and United Kingdom to date[3,4,7,19,20] shows two clear findings. The first is that most people know little or nothing about nanotechnologies. Second, notwithstanding this, many people nevertheless feel that nanotechnology's future benefits will outweigh its risks.

The discourse of our workshop participants conformed to this general pattern, in spite of the fact that we presented information on and discussed numerous potential downsides during the sessions. An advantage over surveys of the more qualitative exploratory approach adopted here is that it yields additional insights into why benefit frames continue to dominate. In a pattern we would describe as low 'techno-scepticism', participants in both the United Kingdom and United States demonstrated almost complete acceptance of the likelihood of scientific promises being realized at a technical level; while responses ranged from acceptance to wariness to resistance, no one fundamentally questioned the viability of the technology itself. These data are compatible with an interpretation that, under conditions of low knowledge and the absence of any nano-related risk events, attitudes toward technology in general (known to be highly positive in both countries[21,22]) are being reproduced in people's judgements for the case of nanotechnology. This effect is likely involved to some degree, as a confounding variable, in all of the surveys of nanotechnology perceptions conducted to date, making their interpretation as evidence of responses to nanotechnology *per se* particularly problematic.

Past risk perception studies would also predict a likely high level of concern by people about technologies that will actually enter the human body[8,23]. Invisibility and the dependence on other high technology to convey information about embodied risks would also predict higher perceived risk. However, one surprising finding across both nations was the apparent lack of significant expressed

[1]School of Psychology, Cardiff University, Cardiff CF10 3AT, UK, [2]NSF Centre for Nanotechnology in Society, University of California, Santa Barbara, California 93106, USA, [3]Department of Sociology and Women's Studies Program, State University of New York at New Paltz, 600 Hawk Drive, New Paltz, New York 12561, USA, [4]School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK; *e-mail: PidgeonN@cardiff.ac.uk

concern about the medical risks of bodily incorporation of invisible nanomaterials, nanomedical devices and the like. Instead, even in these examples, participants expressed more concern about privacy issues and the control of their personal information rather than concern about unintended technology–body interactions.

Cross-cultural differences: subtle and contextual. Our initial expectation was that distinct differences would emerge on benefits and risks between the United Kingdom and United States, particularly given recent differences in technological risk controversy in the two countries. During the past 15 years Britain had seen the BSE ('mad cow disease') disaster and the dispute over genetically modified organisms (GMO), placing the possible risks of new technologies and failures of government regulation into the media spotlight. As a result, a House of Lords Select Committee argued that Britain has experienced a 'crisis of trust' in science[24]. What we actually observed were more similarities than differences in the data. Using the Eurobarometer survey data Gaskell and colleagues[4] had demonstrated that nano benefit perceptions are higher in the United States than in the United Kingdom and Europe, which they attributed to greater underlying technological optimism in the United States. Our data suggest a more complex pattern. As described above, general technological optimism, expressed as perceptions of the benefits to be gained from new technologies such as nanotech, was uniformly positive in both the UK and US workshops. However, views on some specific and uncertain applications of nanotechnologies did appear to be interpreted by the UK participants against a background of their awareness of recent failures of risk governance in that country (GMO, BSE, foot and mouth disease and so on). Thus, a general high regard for science and technological development can, somewhat counter-intuitively, be accompanied by the amplification of highly specific risk perceptions linked not to the scientific discovery process or even the technology itself, but rather to perceived societal failure[25] or, as Freudenburg puts it, institutional 'recreancy' in the safe management of new technologies[26].

The US case is arguably different from this, with high technological optimism prevailing in both survey data and our own study, alongside a relative absence in our workshops of narratives linking nanotechnologies to past failures to control technology in the United States, which in turn appears to be accompanied by attenuated perceptions of risk, as compared to the UK participants. US participants also showed greater adoption of what might be called a 'consumerist stance', naturalizing the view of new technologies as almost overwhelmingly personally beneficial commodities for which they will compete with others, particularly in the domain of health technologies. In contrast, UK participants showed a greater tendency to discuss the benefits of new technologies at community, national and even at international levels.

On a more nuanced level, however, the framing of risks and benefits between the two countries was found to further differ, in subtle but important respects that interact with the specific application domain under discussion (health/enhancement or energy, respectively). For example, issues of distributional justice or equity took very distinct forms in the two national contexts when discussing the health and enhancement issue, a pattern almost certainly reflecting different cultural assumptions and experiences with health, healthcare institutions and access to care. In all groups, participants judged that, in the very short term, the wealthy would be the most likely to benefit from new health applications in nanotechnologies, with access and choice conditioned by individual economic circumstance. However, the US participants voiced faith that an eventual 'trickle down' of benefits from developments in nanotechnologies would occur over the longer term, although not necessarily in an equitable fashion by race and class. Participants in the United Kingdom voiced more scepticism, tending to focus on how the wealthy would always accrue greater benefits, particularly in the health and enhancement context. By contrast, in the discussions of the energy applications of nanotechnology both sets of participants believed that there would be eventual communal and societal benefit from developments in this area.

Application matters. Reflecting the findings of the original Royal Society/Royal Academy of Engineering[3] workshops held in the United Kingdom in 2003, participants in all of our groups thought that the impacts of nanotechnologies would ultimately depend upon the ways in which they are used. Nanotechnologies, of course, span a very wide range of applications, and our two cases (health/enhancement and energy) were selected precisely to reflect some of this diversity. It is no surprise, then, to find that the type of nanotechnology application matters a great deal to the form dialogue takes, to projected resistances, and to outcomes. As discussed above, although talk of benefits predominated over risks in all groups, participants in both countries were far more easily engaged in positive discussion of energy than of health and enhancement applications.

In both countries new technology development to resolve energy issues was seen as an unchallenged good, with discussion of the potential for energy applications more consistent and more urgent, and responsibility for control being thought to lie primarily in a traditional combination of expert regulation, markets and the individual choices of consumers. With health and enhancement the discussion was, for both US and UK participants, more nuanced, more layered and more multivalent. As one might expect, and in complete contrast to the energy sessions, applications for health and enhancement were thought to raise particular 'moral' and ethical questions, while in both countries participants, unprompted, raised the possibility that responsibility for control should involve a dialogue, or some form of multi-party body, where everybody (citizens, government, business and scientists) could debate their implications. These clear cross-application differences to some extent dwarfed the more subtle cross-national differences present in our study. When discussing societal and ethical implications, nanotechnology is often compared, perhaps unfairly, with biotechnology[4,27]. In demonstrating that people are highly sensitive to the characteristics of different nanotechnology application domains, it seems far more likely that the public will draw upon a range of analogies (some positive, some less so) to help them interpret the nature and implications of specific current and future nanotechnology developments.

One methodological lesson learned, common to both the health and energy deliberations, was that our participants displayed little distinction between present, near-term or long-term application, or between these and the fantastical. This suggests that considerable care has to be exercised in the design of both general (what is nanotechnology) and more domain-specific (health, energy and so on) engagement materials for deliberating such upstream issues.

The social trumps the technological in the discussion of 'risk'. Studies of the conditions under which people's perceptions of risk escalate or amplify have focused on the specific perceived characteristics of the technological risk object[17,18] or the social-dynamics of the events, including media and other portrayals, surrounding a technology's use or misuse[25]. These past studies have all been conducted retrospectively, after technologies have become well known, and, in some cases, highly stigmatized. In contrast, nanotechnologies so far do not appear to elicit beliefs about physical risk as such; rather, they stimulate discussion of social conditions. It is notable that this pattern was consistent across both nations in spite of numerous obvious political, cultural and social differences between the participants. Indeed, in spite of many expectations about public interest in and concern about the science and technology of nanomaterials and nano-enabled products, and the provision of scientific expertise and informational materials about a diverse

range of applications, participants in all of the workshops displayed a marked tendency to veer towards discussion of the social or societal implications of technologies rather than the technologies *per se*. For example, a US participant argued, regarding new nanotech medical diagnostics, that 'ethics in medicine for instance has had thousands of years to develop and be tested and so forth, but I'm not sure we have the luxury of time, nanotechnology is changing so fast, the capabilities are increasing so rapidly, that maybe our ethical foundation isn't sufficiently developed to observe, analyze and make recommendations on what's happening'.

Allied to this, discussion of potential risks often focused on societal factors that could limit realization of benefit, as when a US participant argued, regarding nanotech energy benefits, 'I don't think that adding a new technological silver bullet is going to make people any more likely to make changes in terms of conservation and efficiency [of energy] just because it has some new buzz word attached to it', a theme paralleled in the UK group during a lengthy discussion about how use of nanotechnologies for energy efficiency might simply result in greater consumption.

Consistent with academic analysis of public discourses about new technology[28,29], and other qualitative studies of nanotechnologies in both countries[3,30], the issue of trust, and the potential activities of institutions such as government, regulatory agencies and corporations were discussed as a source of risk. UK participants in particular displayed a far more detailed sense of potentials for misuse, and hence were more pessimistic about the eventual realization of potential benefits of health and energy nanotechnologies, for themselves, for the United Kingdom and for global society. They also appear to have a far more explicit understanding of how politics affect investment in technology R&D and innovation and how that in turn affects likely realized social benefit. Regarding specific institutions, the US participants show far more ardent anticorporate sentiments, citing corporate greed, environmental exploitation and complete lack of control as important factors for nanotechnology regulation. The UK participants show more antigovernment and antiscientist feelings (again in line with the recent history of regulatory failures in the United Kingdom), while acknowledging self interest and profit motives of corporations as a problem. At the same time, as a theme of technological saturation and ambivalence, both US and UK participants sought to impugn everyday people's laziness and unwillingness to take advantage of available knowledge and educational opportunities, and saw technological development as colluding with this less desirable side of human nature.

Discussion. The study sought to develop and evaluate a novel form of deliberative workshop using a generic structure capable of being used for comparing complex public discourses about different nanotechnology applications, and in different national contexts. In this task we believe we have broadly succeeded. In more substantive terms, one inference to draw from all of the workshops is that benefit framing currently dominates understandings of the future of nanotechnologies in both the United States and United Kingdom, and persists even when participants are provided with the opportunity for balanced engagement with a range of information and perspectives regarding potential risks. Where downsides are discussed they are, in large part, restricted to more generic concerns about the trustworthiness of the institutions charged with managing and regulating nanotechnologies. It is impossible to say currently whether this pattern of perceptions is likely to be an enduring one, or might prove fragile were any significant health, environmental or safety issue with a nanotechnology material or product to occur in the near future in either of these two countries. Any such event, if significantly amplified through media coverage, would likely provide the (currently missing) 'mental model' or narrative allowing people to connect nanotechnology risks in more concrete terms to their everyday lives.

At a much finer grained level of analysis, our experiment suggests that discursive complexities are significant for the ways that ordinary people approach this topic; qualitative differences in perceptions were found between the two technological domains studied, alongside more subtle shades of cross-national difference too. This implies that, as nanotechnology risk perceptions emerge, context matters. In particular, much will depend upon whether early risks are adequately managed to avoid major incidents, and whether appropriate systems of risk governance can be evolved in parallel. This also suggests that a 'one cap fits all approach' (across applications and/or nations) for the social oversight and regulation of nanotechnology risks is unlikely to prove entirely satisfactory.

The present research is only the starting point in the critical task of understanding how nanotechnology risk perceptions are emerging, and how they will further evolve over the coming decades. This task will require a range of methods that are both interdisciplinary in scope and genuinely sensitive to contextual and cultural nuances arising in the future interpretation and framing of nanotechnology, its risks and benefits.

Methods

The research team developed an effective deliberative workshop format that allowed people from different age, class, educational, occupational, ethnicity and gender positions to participate. Essential components of each workshop include: (1) a quasi-representative group of the public; (2) a focus on specific nanotech application domains (energy, human health and enhancement). Following extensive piloting, a total of four parallel deliberative workshops were conducted in February 2007, two in the United States (Santa Barbara) and two in the United Kingdom (Cardiff). In each country one of the workshops focused upon energy applications of nanotechnologies and the second on human health and enhancement. The generic structure of a workshop, which lasted for about 4.5 hours, included several stages, beginning with initial open-ended discussions of understandings of energy and health, respectively, before the term 'nanotechnology' was ever introduced. This was followed by systematic introduction to the idea of nanotechnologies in general and energy or health applications in specific. A series of 'World Café' table groups then followed to prompt, very successfully, open-ended exploration and discussion amongst subsets of 4–5 participants organized around increasingly complex technologies and applications. The culmination was a guided dialogue with the whole group, once again about issues of benefit and risk, trust and responsibility, societal issues and individual preferences. Sessions were audio- and video-recorded, and full verbatim transcriptions made of all conversations. Systematic qualitative data analysis of the transcripts was conducted using NVivo software and independent cross-cultural assessment to validate identification of themes and interpretations.

Recruitment of participants took place through a neutral third party and involved advertisement, screening and construction of a sample for each group that matched local area demographics as closely as possible. Because initial identification necessarily took place through an open invitation, widely advertised to the public, rather than a randomized procedure, the resultant samples are best described as 'quasi-representative'. Screening eliminated those employed in the health or energy industries, limited student participants to ensure a diverse sample, and determined race, class, gender, education and other characteristics for sample construction. Workshops were held in public spaces within the communities, rather than on university campuses, and participants were compensated $100 in the United States and £80 in the United Kingdom for giving up most of a weekend day and obtaining transportation to the site, and were provided a meal and coffee/tea breaks. The costs of the workshops in both countries were funded by the United States National Science Foundation.

In developing the procedure considerable effort was expended to ensure the materials on nanotechnologies in general, and on energy and health applications in particular, were as accurate as possible in scientific terms. Powerpoint presentations were prepared by an interdisciplinary team at the Center for Nanotechnology in Society at University of California at Santa Barbara that included nanoscale science and engineering (NSE) experts, and these were then vetted by other NSE experts for accuracy during the pilot process. NSE experts also assisted in the selection of the publications and informational materials offered at the World Café.

Other distinctive elements of these workshops included small group size suitable for focused discussion-based interaction ($n = 12–15$), a cross-culturally comparable, well piloted, detailed protocol that enabled uniform facilitation across sites, and self-directed learning and interaction opportunities in the sub-groups supported by an extensive array of informational materials. Informational materials used included short journal, newspaper and web-based articles that provided information and analysis of nanotechnologies in general, and energy and health applications in particular. Materials included extensive information on the benefits and risks of the technologies, and participants made their own selections among

these articles, which they discussed in small ($n = 4–5$) table groups in the World Café stage. In addition, we made every attempt to frame the discussion in a balanced way that presented valid information and current arguments about nanotechnologies, including a carefully calibrated range of potential benefits and possible risks.

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Author contributions

All authors contributed to the design and piloting of the workshop procedure. N.P. and T.R.H. collected the UK data, and B.H.H. and K.B. collected the US data. All authors contributed to data analysis. Manuscript preparation was primarily the work of N.P., B.H.H. and K.B.

Additional information