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outlook

The brain, the science and the media

The legal, corporate, social and security implications of neuroimaging and the impact of media coverage

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Modern societies are increasingly dependent on complex and sophisticated technologies, the nature and workings of which are a mystery to most people. New technological developments and their potential to improve health and economic prospects are pervasive and, through media attention, arouse public curiosity or raise expectations. It is therefore the duty of stakeholders to enable public understanding of and engagement with technological progress.

The apparent ability to 'see thoughts' […] has aroused interest from the public, the commercial sector and others

Neuroimaging is a good example of a field that captures imagination. The apparent ability to 'see thoughts' and generate compelling images of physiological and biochemical processes in the brain has aroused interest from the public, the commercial sector and others. Not surprisingly, the number of applications has grown substantially in recent years and now extends well beyond clinical diagnostics and neuroscience research to law, commerce, security and politics. However, most of these applications are not supported by scientific evidence and some have gone unnoticed by the scientific community. Thus, many scientists remain ignorant of the possible misuse of brain imaging in the commercial, legal, security and political sectors, and the public remain uncertain about the reliability, interpretation and science behind the products available and the interpretation of their results. As Jennifer Kulynych from The Johns Hopkins Hospital (Baltimore, MD, USA) put it, "Neuroimaging is a field in which the technological capacity to generate brain images far exceeds scientists' current ability to interpret what imaging data reveal about the mind and the brain" (Kulynych, 2002).

…distorted reporting, commercial pressures and other factors can lead to the misuse or misapplication of neuroimaging

Despite the scientific uncertainties, the non-scientific development of neuroimaging continues and serves a wide range of interests, many of which might not be in accordance with the appropriate uses of the technology or the level of scientific understanding. These trends, in turn, influence media coverage, which then shapes public perception of the utility, acceptability and ethical use of the technology. Thus, distorted reporting, commercial pressures and other factors can lead to the misuse or misapplication of neuroimaging.

An example is the use of functional magnetic resonance imaging (fMRI), which has attracted interest from the commercial sector, the media and the public. Of the many neuroimaging techniques used to directly or indirectly image the structure or function of the brain—including structural magnetic resonance imaging, positron emission tomography, electroencephalography or computed axial tomography—fMRI has captured the imagination because it is non-invasive, easy to use and provides direct and compelling images of mental processes by highlighting areas of the brain in which blood flow is changing in response to external stimuli. As such, it is a useful research tool, but it has limitations: it is an indirect measure of neural activity, studies typically use small sample sizes and real life situations are difficult to recreate in experimental settings. Nevertheless, the use of fMRI has evolved rapidly from its original clinical role to include many new uses.

In 2006, Racine and colleagues conducted the first review of the media coverage of neuroimaging. They found an "overwhelming optimism" for the use of the technology, but also showed that many media reports fail to address the related scientific, technical and ethical issues (Racine *et al*, 2006). The authors noted three main frames to contextualize the media coverage: 'neuro-realism', in which functional neuroimaging seems to be used to give psychological observations objective 'realness'; 'neuro-essentialism', in which neuroscience would define personal identity; and 'neuro-policy', which describes the use of fMRI in the political realm.

It is premature to comment on the effectiveness of neuromarketing because the litmus test for success will not be peer-reviewed evidence, but increased revenue

Given that the public has limited knowledge of neuroscience (Herculano-Houzel, 2002) and often cannot distinguish fact from opinion in this area, distorted reports lacking technical or ethical details seem likely to provoke unreasonable ethical or social concerns or, conversely, might raise unrealistic expectations. Studies of public perception of neuroimaging therefore agree that neuroscientists should be more effective in communicating their discoveries

to the public to reduce these risks (Racine *et al*, 2010).

It remains unclear how neuroimaging will affect and influence society, what applications can be agreed on and regulated, and what future developments will be possible. To analyse the use and perception of neuroimaging in the public sphere, we define four distinct approaches for the non-scientific use of neuroimaging: for legal arguments and lie-detection; as a commercial tool; to inform political and social issues; and for military or national security purposes (Table 1; supplementary Table 1 online). To determine the extent to which neuroimaging is used in these areas and the way that this use is portrayed, we conducted a systematic review of both the media coverage of, and the specialized peer-reviewed literature about, neuroimaging applications.

Our search of PubMed, Google Scholar, media websites and science blogs returned 210 articles published between January 2001 and August 2010: 105 from the general media and 105 from the peer-reviewed literature (see Methods section in the supplementary information online). In addition to identifying the specific applications of neuroimaging and the sector of society in which they are applied (Table 1), we recorded the technical and ethical details in each article, as well as whether it had a positive, neutral or negative viewpoint (supplementary Table 1 online). Data were coded iteratively and initial categories were combined to produce roughly equal numbers of reporting characteristics that were associated with particular topics. For instance, we combined papers coded as having 'neutral' or 'sceptical' viewpoint values into one viewpoint category, and papers coded as having 'basic' or 'detailed' categories into one each of the technical and ethical categories, as the original categories contained too few papers for analysis.

Table 1 | Description of the sector/application coding scheme used in the systematic review

Sector	Definition	Application
Law	Articles discussing the implications of neuroimaging for the legal system	Lie-detection: neuroimaging-based lie-detection Blame: criminal mitigation using brain scans
Commercial	Articles discussing corporate interests in neuroimaging	Marketing: neuroimaging-based marketing measures Politics: use of neuroimaging to investigate political preferences
Social	Articles discussing neuroimaging issues that have social and 'human' implications	Enhancement: research to enhance cognitive abilities Diagnosis: medical diagnosis using neuroimaging Mind reading: decoding thoughts using neuroimaging Employment: neuroimaging for employee screening Policy: use of evidence from neuroimaging studies to shape social policy
Security	Research on military and anti-terrorist applications of neuroimaging	Biosecurity: neuroimaging-based identification Military: neuroscience research for military purposes
Ethics (specialized review only)	Articles focusing on the ethical debate surrounding neuroimaging practices	Neuroethics: ethical issues of neuroscience research Communication: discussion of issues of scientific engagement with the media

Our analysis of the general media and peer-reviewed literature showed nine possible or existing applications of neuroimaging outside the scientific or clinical setting.

Blame. A recent capital punishment case in the USA has brought attention to the use of neuroimaging for mitigation in criminal cases (Hughes, 2010). However, there is general agreement among experts that it is premature to use neuroimaging in courts to diagnose psychopathy or frontal-lobe dysfunction (Dressing *et al*, 2008). A related issue concerns the debate about the illusory nature of free will (Rose, 2005). Some researchers argue that evidence from neuroimaging precludes criminal blame owing to the deterministic nature of human behaviour (Greene & Cohen, 2004), whereas others regard free will as a serviceable construct for judging individuals who are assumed to be rational agents (Morse, 2006). Another aspect of this issue is whether judges and jurors might—mistakenly—interpret visually compelling brain scans as 'hard science' (Weisberg *et al*, 2008).

Lie Detection. Although preliminary results are promising, experts agree that the methodologies used to apply neuroimaging to lie dectection need to be rigorously validated in larger trials (Spence, 2008). In response to two unsuccessful attempts to admit commercial fMRI lie detection data to courts, the US Federal Magistrate court has recommended the need for further evidence of reliability (Madrigal, 2010). Nancy Kanwisher, a neuroscientist at the Massachusetts Institute of Technology, argues that fMRI lie-detection paradigms are so artificial that they have no external validity—for instance, research subjects are instructed to lie (Talbot, 2007). In addition, evidence suggests that people diagnosed with psychopathy—a significant proportion of the prison population—experience deception differently (Fullam *et al*, 2009). It is therefore not clear whether fMRI would be better or worse than other methods that are admitted in court, reflecting differences in the standards of proof in law and science (Schauer, 2010).

> **…researchers might distort their own science or over-emphasize the importance of their research to attract media interest or funding**

Neuromarketing. More than 90 marketing companies offer services using neuroimaging. The main potential is at the design stage of a product, when fMRI is used to gauge the attractiveness of the image, taste or smell of a new product (Ariely & Berns, 2010). Public fears in this area focus on guarding the privacy of inner thoughts that neuroimaging might lay bare, whereas specialists are concerned about commercial pressures on research practices, such as the patenting of methods or the trading of transparency for the marketability of results. It is premature to comment on the effectiveness of neuromarketing because the litmus test for success will not be peer-reviewed evidence, but increased revenue. A regulatory framework has been proposed by Murphy *et al* (2008), to preserve neuromarketing as a profitable enterprise by promoting the

responsible testing of participants and the dissemination of findings.

Diagnosis. Direct-to-consumer services increasingly offer diagnosis of neurological and psychiatric disorders to detect conditions such as autism (Farah *et al*, 2009)—a practice that is not accepted by clinicians (Flaherty *et al*, 2005; Nuffield Council on Bioethics, 2010). However, press coverage might further invoke unrealistic public expectations and demands for services that claim that "[f]or the first time, a quick brain scan that takes just 15 minutes can identify adults with autism with over 90% accuracy" (Medical Research Council, 2010). Fears that insurance companies might use genetic information to drive up policy premiums have led to a moratorium on genetic testing; however, fMRI is not included in this decision (Sample, 2003).

Policy. The use of neuroimaging to support the agenda of political groups is referred to as 'neuropolicy' (Racine *et al*, 2006). For example, UK MP Iain Duncan Smith cited evidence from neuroimaging to argue that child deprivation issues were being neglected by the government—a conclusion that the authors of the study regarded as a distortion of their results (Lewis & Boseley, 2010). Neuroscientist Susan Greenfield has also been accused of publicizing spurious claims in the press regarding the possible detrimental effects of social-networking sites on neural development (Sample, 2010).

The 'blogosphere' also acts as a watchdog when members of the public and experts comment on the quality of research and the interpretation of results

Employment. The possibility of using neuroimaging to predict personality and intelligence has raised fears that prospective employers could use the technology to screen job applicants. In fact, a recent study promotes the use of neuroimaging for vocational guidance by measuring underlying abilities (Haier *et al*, 2010). The paper has been heavily criticized for over-interpreting the data, which the authors have publicized widely in the media. Nevertheless, there is some evidence that neuroimaging could measure complex social behaviours such as sexual preference, teamwork and response to racial groups (Phelps & Thomas, 2003). In the UK, it would be legal to use neuroimaging, provided that employers prove that it is related to performance and safety issues of the job (Shivers, 2004).

Mind reading. The ability to decode mental activity forms the basis of many of the non-scientific applications of neuroimaging. Covert mental states represent a highly sensitive form of information that is not open to the subjective control of the person, and have therefore been the subject of considerable ethical debate in both public and specialized forums. However, proponents of these approaches emphasize that decoding is limited to basic types of behaviour, such as visual representations of object and lower-order intentions (Bles & Haynes, 2008).

Military. Governments have turned to neuroscience to improve national security and the combat effectiveness of soldiers (Moreno, 2004). The US Defence Advanced Research Projects Agency (DARPA) has launched a US$24 million programme to develop neuroimaging technology for military applications. A main output of this research has been the Cognitive Technology Threat Warning System, which monitors brain activity for the unconscious detection of threat. However, reports caution that, "the time frame for augmenting human-system cognitive capabilities may be longer than is sometimes appreciated" (DARPA, 2003).

Biosecurity. Neuroimaging is also being explored for use in airport security. However, research findings so far suggest that the capabilities of the technology claimed in the media are overstated. DARPA, for instance, highlighted the limits of remote imaging methods such as near infrared spectroscopy (NIRS; DARPA, 2003). Nevertheless, two Israeli private security firms are offering NIRS airport security services. Findings from studies of neuro-security services show moderate levels of accuracy (over 80%) for identifying people from EEG signals (Poulos *et al*, 2001). A recent study reports the ability of EEG methods to identify terrorist intentions, but has been criticized for lacking real-life validity as it examined the brain responses of college students, not terrorists (Meixner & Rosenfeld, 2010).

During the course of our study, we also recognized several other themes in the general media that were not suitable for quantitative analyses. Many journalists fail to report how factors such as sample size can affect both the interpretation of results and the extent to which the findings might apply in different subjects or contexts. Moreover, journalists might distort the interpretations of the researchers. As one scientist complained in regard to an article on neuromarketing on the *Forbes* website (Burkitt, 2009), "It is unfortunate that the quote gives little context regarding my comments." In this case, as well as others, online discussion forums provided by newspapers at least enable scientists to clarify misrepresentation or misinterpretation of their research; "Our test was never designed to screen the entire population of the UK," replied Christine Ecker of King's College Institute of Psychiatry in London, UK, to a potentially misleading article in *The Guardian* about her study on the diagnosis of autism (Jha, 2010).

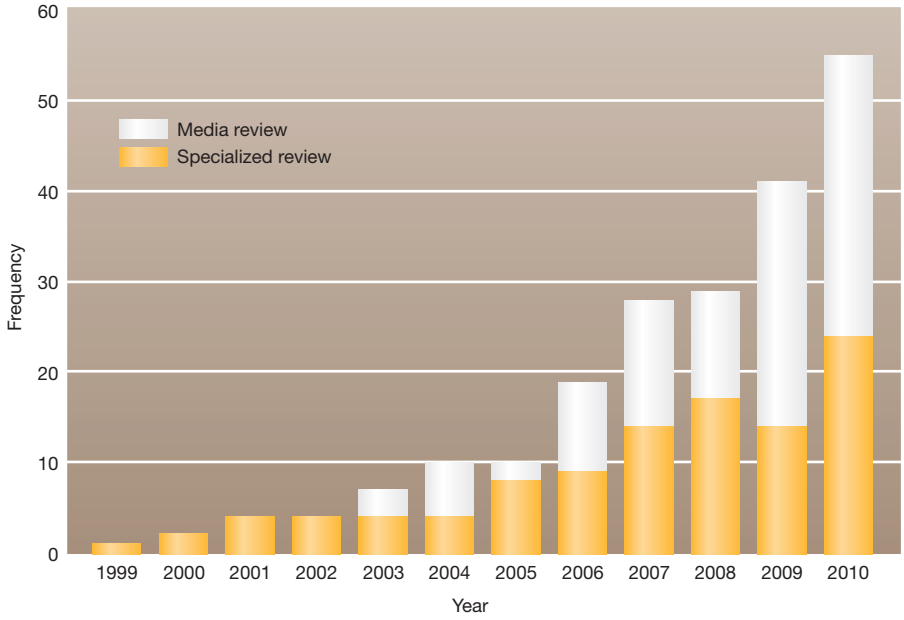

Fig 1 | Stacked bar chart of articles published in the media and specialized reviews per year.

…neuroscientists need to be made accountable for the way their research is presented to the public

Conversely, researchers might distort their own science or over-emphasize the importance of their research to attract media interest or funding. For instance, Iacoboni *et al* (2007) circumvented the peer-review system when they published their findings about the application of neuroimaging to the realm of politics in *The New York Times*. As one critical commentator wrote on the discussion forum of the newspaper, "Unfortunately, the results reported in the article were apparently not peer-reviewed, nor was sufficient detail provided to evaluate the conclusions."

Challenging tenuous claims made by either journalists or scientists should help to dispel public misinterpretation. The 'blogosphere' also acts as a watchdog when members of the public and experts comment on the quality of research and the interpretation of results. A series of interviews conducted by the British Psychological Society with leading bloggers has shown that they have gained authority within the neuroscience research community.

Individuals affiliated with commercial neuroimaging—for instance, for neuromarketing or direct-to-consumer imaging diagnoses—receive a disproportionate amount of media attention as a result of deliberate marketing to increase business revenue. This might lead to a polarized, positive view in the media, as "much of the media coverage of health news stories is based on public relations efforts on behalf of the companies that sell the products" (Zuckerman, 2003). Even if preliminary findings are positive, commercial neuroimaging companies rarely concede that the reliability of these methods are uncertain owing to the under-developed evidence base on which claims are made. "There is a great deal of variation between the findings described and, crucially, there is an absence of replication by investigators of their own findings" (Spence, 2008).

Given the influential role of media coverage, we have considered the way in which the aims, activities and public perception of the 'grey' areas of neuroimaging and their associated societal sectors influence their representation in the media. First, in support of the view that new applications of neuroimaging are gaining in media appeal, the frequency of published articles on this topic increased three-fold during the past two years (Fig 1). The most prominent foci of media articles were lie-detection (26%) and marketing (12%), with a minority focusing on employment, military use and biosecurity (Fig 2).

The viewpoints taken by media articles were mostly positive about the aspects of neuroimaging they described (44%). Articles particularly likely to have positive viewpoints included those on marketing (77%), biosecurity (57%) and employment (60%), whereas articles on lie detection were most likely to have a neutral or sceptical viewpoint (74%). Moreover, grouping applications according to their affiliated sector had little effect on predicting whether the article expressed a sceptical or neutral viewpoint. The most prevalent finding from the media review is a tendency for positive articles to take an uncritical stance on proposed applications of neuroimaging and to lack discussion of ethical issues (68%), compared with neutral or sceptical articles ($\chi^2 = 17.384$, $p < 0.001$). As we later discuss, this trend seems to suggest the influence of commercial interests on the reporting of research.

The effective communication of scientific discoveries requires technical information to be reported in a comprehensible manner. However, 41% of media articles gave little or no technical detail of the neuroimaging methods; this was particularly notable in articles on marketing (77%) and diagnosis (73%). Both applications propose to use neuroimaging commercially by measuring previously intangible mental states—consumer preference and mental illness respectively. However, as stated, neuroimaging is far from being validated as a reliable

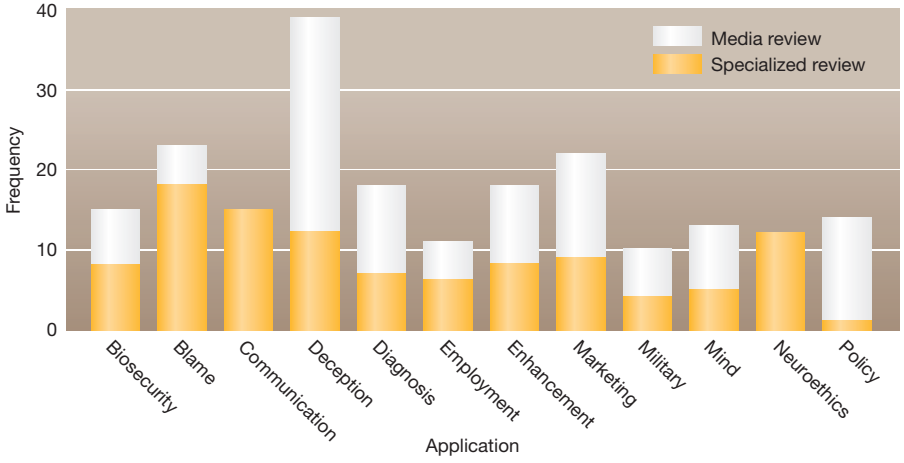

Fig 2 | Stacked bar chart of the neuroimaging application foci of articles in the media and specialized reviews.

marketing or diagnostic tool (Ariely & Berns, 2010; Flaherty *et al*, 2005). Thus, avoiding discussion of technical issues would favour acceptance. The identified association between positive viewpoints in articles and a paucity of technical reporting strengthens the view that media coverage is polarized by biased sources.

Similarly, and despite the intense ethical debate about neuroethics in the specialized literature, ethical issues were reported in only a minority of media articles (43%), most often in articles about lie detection (63%). Our analysis of the influence of a specific use of neuroimaging on its media coverage revealed that the type of application allowed us to predict 71–74% of the depth of technical and ethical detail in an article. It could be argued that the lack of ethical discussion in the reporting of neuroimaging applications to marketing, employment and biosecurity is a result of financial pressures to report positively and omit negative information. Although biosecurity might not seem ostensibly commercial in comparison with other applications, the increasing privatization of security might blur the division between biosecurity and other commercial sectors (Klein & Smith, 2008). Indeed, the ethics of biosecurity technology is inherently disconcerting, as it represents a threat to privacy and could lead to unjust imprisonment and interrogation. Generally, the commercialization of neuro-technology represents a growing field that, if left unregulated, might establish its own standards for professional conduct (Eaton & Illes, 2007). The fact that these standards will probably be different from those of the scientific community will not necessarily be apparent to the public.

The aim of our analysis is to assimilate as much information as possible about the new, non-traditional applications of neuroimaging, to determine the difference between public and scientific viewpoints and to identify any issues arising from this misalignment (supplementary Table 2 online). In this sense, our work could help to improve scientific communication and guide new regulations for the use of neuroimaging technology. Our results provide evidence for a relationship between the intensity of media coverage and the discrepancy between science and society about the appropriate application of neuroimaging. More generally, the viewpoint expressed in media articles is influenced by the purpose of a given neuroimaging method, although discussions of the source of this bias remain speculative.

…the commercialization of neuro-technology represents a growing field that, if left unregulated, might establish its own standards for professional conduct

An obvious cause could be the use of biased sources by journalists attempting to establish the reliability of a given application. Indeed, leading proponents of commercial neuroimaging regularly use media outlets to promote their research and services in the form of solicited op-ed features, personal websites and merchandizing. By contrast, neuroscientists are not usually as media savvy and thus fail to communicate their 'balanced' version to the public. An example of the effective marketing of neurotechnology is media coverage that emphasizes the positive implications of controversial research—such as using 'mind-reading' methods to communicate with patients in persistent vegetative states. This might reflect commercial strategies to facilitate social acceptance by associating the application with clinical benefits (Racine *et al*, 2006).

Expectations about scientific discoveries need to be carefully framed in the context of their limitations to avoid abstracting findings beyond scientifically acceptable limits. However, we found that marketing and direct-to-consumer neuroimaging services provide little or no detail of technical limitations; as stated, neuroimaging has not been validated as a tool for marketing (Ariely & Berns, 2010), lie-detection (Langleben & Datillio, 2008) or diagnosis (Flaherty *et al*, 2005). Several instances indicate that, along with commercial figures, neuroscientists share the blame for inflating the reported capabilities of neuroimaging in the media. As the interaction between neuroscience and the media increases in the future, it will become necessary to establish guidelines for the professional conduct of neuroscientists participating in dialogue with the media and industry.

In contrast to these alarmist views, the findings presented here convey some hope that the public is sufficiently informed to decide on some aspects of the wider use of neuroimaging, such as the scepticism and ethical concerns expressed about fMRI lie detection. Of all the 'grey' areas of neuroimaging, this has received the most media attention and is therefore probably the topic most embedded in public awareness. The negative tone of many media articles might reflect public scepticism or disapproval, suggesting that groups aiming to profit from these methods will have to provide considerable reassurance in order to gain wider acceptance, particularly on issues of reliability, human rights and the potential punitive risk of false findings.

Neuroethics groups have reached a consensus that increased interaction between the media and science is imperative to improving public awareness (Illes *et al*, 2010). However, the same review cautions that overly enthusiastic or haphazard engagement can, in fact, be counterproductive and damaging. On the basis of the evidence gathered here, we propose

a need for refinement in scientific communication. Specifically, neuroscientists need to be made accountable for the way their research is presented to the public. Moreover, blogs and discussion forums are promising approaches to combating poor reporting or the spurious claims of scientists or companies who seek publicity. Yet, future approaches need to emphasize that neuroscience has a dual responsibility to be both open to new developments and explicit in the interpretation of those results in relation to accepted scientific knowledge.

The field of neuroethics is now at a stage at which its proposed strategies need to be subjected to public critique to ensure that they reflect the concerns and needs of society

Strong industrial ties to research are important for economic growth. Yet the societal implications of neuroimaging place an onus on neuroscientists to morally justify their involvement in commercial avenues of research. Daniel Langleben, a neuroscientist at the University of Pennsylvania (Philadelphia, PA, USA), has repeatedly cautioned against the premature adoption of fMRI for lie detection (Wolpe *et al*, 2010). He also holds a patent for the method used by a lie-detection company and has threatened to withdraw their right to use the technology if it is used in a non-validated manner. However, subsequent attempts by the company to admit fMRI lie-detection evidence in court have cast doubts over how even ethically aware scientists can ensure the proper use of their research in commercial contexts. This case illustrates the importance of neuroscientists realistically assessing the possibility that their research might be misused and whether their involvement in commercial enterprises might compromise their responsibility as scientists.

A review of media and specialized literature gives only an indirect, and therefore limited, understanding of how the public absorbs information about scientific discoveries. To address this limitation and to determine the way that science-related information in the media is shaping public dialogue, we are conducting a separate survey of members of the public and experts to investigate individual understanding of the uses of neuroimaging. Our hope is that this survey will help to inform awareness campaigns to combat the misuse of neurotechnology. Empirical approaches such as these are vital for translating issues highlighted by ethical discussion into policy (Northoff, 2009). The field of neuroethics is now at a stage at which its proposed strategies need to be subjected to public critique to ensure that they reflect the concerns and needs of society. Recognizing the ways in which science can interact with society will determine the effectiveness of those strategies.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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