Responsible use of language in scientific writing and science communication

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Abstract

Biologists increasingly utilize marketing strategies to promote their results, obtain funding and influence decision makers, but this development can compromise public perceptions of their objectivity as well as effective communication of reliable scientific knowledge. Responsible and effective communication is particularly important in this era of biotechnological innovation and global environmental change when knowledge is often uncertain, rapidly evolving, and can have huge consequences for society. While scientists and science journalists carefully evaluate scientific results, they more freely choose rhetorical elements, and in particular their metaphors, despite the value-laden judgments that often accompany these choices. We thus argue that metaphors should be carefully chosen and evaluated alongside empirical evidence, because they shape data interpretation and how science influences society. We propose guidelines for responsible use of metaphors in science writing and communication.

Keywords:

evidence-based policy, journalism, media, metaphors, science communication

Introduction

Scientists are increasingly advised to utilize marketing strategies and strong metaphors or dominant news frames to get their message across (Bubela et al. 2009, Kuchner 2011, Larson 2011, Nelder 2013), because there is growing competition for funding, public attention, and the ability to influence decision-making (e.g. Fischer et al. 2012). We think that this development creates problems to the extent that it invites scientists to undermine their objectivity by making assertions that are not based entirely on data. Instead, when scientists make public statements that build on their legitimacy as neutral and knowledgeable experts, their appropriate role is to act as "honest brokers of policy alternatives" (Pielke 2007). They can contribute to controversial debates and express their personal opinion, but to the extent possible they should explain the degree of subjectivity in their opinion and provide alternative ways to interpret the evidence.

Decision-making in our time depends on reliable scientific evidence, so neglecting or misinterpreting such evidence may impair decision-making. However, often knowledge is uncertain or incomplete. In these instances, incipient knowledge can be used to substantiate multiple conflicting views on an issue, thereby contributing to policy impasse (Sarewitz 2004, Kahan et al. 2012). As biologists we are increasingly confronted with such situations, especially in an era of biotechnological innovation and global environmental change when much knowledge that once seemed solid is fundamentally changing. This puts a great burden of responsibility on science communication, so media coverage of scientific findings is rightly expected to follow strict guidelines of good practice and ethical behavior. Trustworthy science journalism focuses on peer-reviewed literature, carefully fact-checks articles, and reports not only primary research results but also the critical assessment of peers in the research field. Scientists are equally concerned that the interpretations and limitations of their science are presented in a correct and evidence-based way.

In this commentary, however, we highlight an aspect of responsible reporting of scientific evidence that has received less attention. It appears that while scientists and science journalists carefully evaluate scientific results and ways to interpret them, they more freely choose the metaphors to communicate to their audience (see Nerlich et al. 2009). In this manner, they may communicate interpretations and weightings of scientific results that are not supported by data. While there is no such thing as value-free communication (Weber and Word 2001), we argue that scientists and journalists need to reflect carefully on their communication choices to minimize confusion and contested interpretations of uncertain knowledge.

The performative quality of language at the research frontier

We focus on metaphors here because they are linguistic choices that have been shown to shape the thinking of scientists and thus the direction of research fields (Keller 2002, Brown 2003, Larson 2011). They are in this sense ‘performative’, meaning that they lead to actual outcomes in the world. Conversely, a narrow choice of metaphorical tools can restrict the diversity of research approaches and creative thinking especially at emerging research frontiers (Larson 2010). This is of particular concern where research outputs can have huge consequences for society.

For instance, scientific and popular articles about research in synthetic biology often build on metaphors taken from the world of machines, computers or consumerism

(Cserer and Seiringer 2009, Keller 2009, Hellsten and Nerlich 2011). The titles of recent articles in *New Scientist,* for example, proclaim “Evolution machine: Genetic engineering on fast forward”, “Genetic code 2.0: Life gets a new operating system”, “Synthetic biology's Ikea”, and “Synthetic 'upgrade' for fruit fly's DNA”. These titles often encapsulate the core metaphor of an article, but such metaphors are usually prevalent throughout a text. Elsewhere, for example, individuals affiliated with syntheticbiology.org, initiated by students, faculty and staff from MIT and Harvard, seek to “specify and populate a set of standard parts that have well-defined performance characteristics and can be used (and re-used) to build biological systems”, “reverse engineer and re-design pre-existing biological parts and devices in order to expand the set of functions that we can access and program”, and “construct […] a genetic code with an enlarged alphabet of base pairs”. The use here of mechanistic language implies an ease of manipulation and a certainty of understanding that misrepresents knowledge of these biological systems (Boudry and Pigliucci 2013), as well as what synthetic biologists actually do in their research and how they think about associated risks (Cserer and Seiringer 2009, Marris and Rose 2012). Furthermore, the implied ability to control biological systems prioritizes an instrumental way of valuing life in contrast to an intrinsic or even sacred one (Deplazes-Zemp 2012). Given the holistic and dynamic nature of the genome and cell (Boudry and Pigliucci 2013), we recommend following ecology and evolutionary biology and instead utilizing metaphors such as ‘tangled genome’ (compare ‘tangled bank’ in Darwin 1869) or ‘tinkering’ instead of ‘design’ (Jacob 1977) because they more fully acknowledge organismal complexity (Proctor and

Larson 2005). Using such alternative metaphors could change the way research is done in synthetic biology and how it is taken up by industry and the general public.

There are many other prominent metaphors in biology that have gained disproportionate importance and which shape both research and social outcomes (see Larson 2011 for review). The metaphor of 'ecosystem services,' for example, currently dominates ecological research on human-environment relationships, thereby reinforcing a perspective from economic production that emphasizes the direct benefits that ecosystems provide to humans, while neglecting alternative conceptions that focus on stewardship and moral duties, long-term sustainability, and cultural values of ecosystems (Raymond et al. 2013). Similar examples can be given for other biological research fields such as health (e.g. Sontag 1989) or neurosciences (e.g. Slaney and Maraun 2005). The problem here is not so much that a metaphor is 'wrong', but that it is misleading to interpret a 'partial' view as the whole truth or to attribute too much importance to the view provided by one metaphor as opposed to the different insights provided by a plurality of them.

Such a tunneling of our intellectual engagement with an emerging topic is problematic for a number of reasons. It weakens creativity, threatens our ability to foresee unknown problems and risks ('unknown unknowns'), and excludes members of society who do not share the implicit values of the dominant narrative—which can lead to public opposition and controversy (Marris and Rose 2012). Excluding people in this way undermines responsible scientific conduct, which requires scientists to ensure that their research contributes to democratic deliberations that serve the common good (Kitcher 2004).

Inclusive and effective communication with the public

Effective communication with the public is a rapidly growing concern for scientific fields ranging from biotechnology to ecology (Beardsley 2006, Bubela et al. 2009, Groffman et al. 2010, Nerlich et al. 2010), and metaphors are often used to help readers connect to scientific results. While we do not question the utility of metaphors in science communication, we turn to the example of invasive species to highlight how value-laden and targeted messaging can also hinder effective communication and action.

Metaphors of war are often used when reporting about non-native invasive species (Larson 2005, 2011), as well as in other environmental sciences (Hamblin 2013). Popular and scientific articles abound that include terms such as enemy, eradication, fight and war, or which liken biological invasions to bioterrorism. However, there is a growing consensus in the literature about invasive species that such language hinders effective engagement with diverse stakeholders and nature conservation practitioners (Young and Larson 2011), especially in situations were scientific information is ambiguous, uncertain or incomplete (Larson et al. 2013). Indeed, researchers in the field think about the problem in diverse ways, which leads to differing assessments of the negative effects of non-native species and the urgency of the problem (Humair et al. 2014). In particular, the positive effects of non-native species are increasingly acknowledged (e.g. Schlaepfer et al. 2011), so popular scientific articles portray them as beneficial and encourage readers to “embrace invasives” (Vince 2011) or “welcome weeds […that] could save the Earth” (Hamilton 2011). Trapped within an either-or duality, these titles overstate this alternative view so it becomes as misleading as the view that “all non-native species are bad”. The extreme of “battling invasives” may encourage managers to take rigorous action under all circumstances without considering alternative options and balancing implementation costs, opportunity costs, and benefits (Larson 2005), just as the other extreme of "embracing invasives" may encourage them to ignore the problem rather than seeking solutions. Using such hyperbole to report on an issue—which is actually quite nuanced—can lead to confusion and hinder the responsible and effective use of scientific evidence in decision-making and the media. In contrast, neutral and balanced language will help to ensure that policy makers and scientific advisors are not in the difficult situation of needing to overcome stereotypes when seeking solutions adequate to the socio-political and biological complexities of the problem.

The metaphors in scientific texts should be used to help readers understand scientific findings, not as a means to convince them without explaining the reasons. IUCN has for instance recently listed the giant salvinia (*Salvinia molesta*) as one of the world's 100 worst invasive species, and reported this in *Nature* in a letter entitled "Monster fern makes IUCN invader list". We consider this choice to be undesirable, because it merely expresses a value judgment of the authors ("the species is like a monster because it is as bad as a monster") rather than illustrating the science. The metaphor devalues this plant species in its entirety (like a monster that is always bad) rather than specifying which aspects of its behavior are problematic. In short, the monster metaphor implies an absolute value judgment, which may undermine the public's perception of science as a critical and balanced form of inquiry and ultimately their trust in it. Given their societal role, scientists should make value statements such as this one in a more explicit way—for example, by calling the fern a "problem fern". Or they might use a metaphor to explain the underlying science rather than to express an opinion—for example, by calling an aquatic fern that rapidly proliferates in water polluted by nutrients a “gourmand fern”.

Strong messaging can undermine the credibility of science in particular when contradictory facts become available and thus scientific uncertainties become visible to a broader public. For instance, ecologists adopted apocalyptic warnings in the “Waldsterben” (dying forest) debate in the 1970s and 1980s in Europe, and this choice still undermines their expert status several decades later (Horeis 2009). It might seem that engagement with uncertainties will reduce the capacity for science to contribute to decision-making, and there is undoubtedly political demand for clear and fixed answers. In the long-run, however, scientists and science journalists need to reiterate that science is not so much a collection of established facts as a process of inquiry, and thus, especially in the case of contested and complex societal issues, responsible science communication entails stating the facts in neutral language and acknowledging areas of uncertainty (Pielke 2007). Conversely, a major concern for scientists is that journalists tend to portray a scientifically undisputed case—such as the anthropogenic causes of climate change—as an unresolved issue by giving unjustified space to extremists’ views (e.g. Boykoff and Boykoff 2004). Using loaded language may invite such media coverage by giving the impression that the inclusion of an opposing view is needed for a well-balanced story.

Another problem with promotional communication by scientists is that they are seldom trained in how to appropriately or effectively communicate. Accordingly, their choices may be counter-productive to their intended outcomes. Invasive species and climate change scientists still tend to resort to fear-based language about negative impacts of non-native species or climate disasters even though there is evidence that such language is ineffective or even counterproductive (Nerlich et al. 2010, Larson 2011, Kahan et al. 2012). To change environmental attitudes, a focus on solutions and cultural values, not danger and loss, is often more effective. As another example, Pigliucci and Boudry (2011) argued that the use of machine-information metaphors in biology—such as in synthetic biology as discussed above—can play into the hand of proponents of 'intelligent design' because they "bolster design-like misconceptions about living systems" that are pivotal to the intelligent design argumentation of creationists.

Engage early with audiences

There is now widespread recognition among communication scholars that the limiting step for greater scientific understanding is not simply more science communication to inform the public (Bubela et al. 2009, Kahan 2010, Kahan et al. 2012), as many scientists tend to assume (Peters 2013). This view is known as the "deficit model" of public understanding of science and it has been discounted for numerous reasons, not least that knowledge is only one element of how people come to decisions. This realization does not devalue effective science communication, but instead places it in more appropriate context as part of a broader suite of engagement with the public about the production and utilization of scientific knowledge. Evolving models of science communication incorporate citizens much earlier in the process, even insofar as designing a research program itself (Bubela et al. 2009, Kueffer et al. 2012). Interactions between scientists and stakeholders can be productive not only to improve our understanding of a problem but also about how a problem should be framed, formulated, and integrated into the sociocultural environment. Scientists should thus engage earlier with diverse audiences through participatory processes to facilitate effective use of metaphors, whether in the context of basic or applied research (see Larson 2011), and to reduce the risk of pervasive outcomes in science communication such as those mentioned above.

Many metaphors used in ecology and environmental studies, such as ‘disturbance’, ‘ecosystem health’, ‘restoration’, and ‘wildlife’, imply a preferred state of nature and they are therefore implicitly normative (Carolan 2006, Larson 2011). Recently, new terms such as ‘novel ecosystem’ and ‘Anthropocene’ have gained prominence in biodiversity conservation to denote the dominant role of humans in nature. These new terms shift the normative stance within the field, and indeed they divide experts and stakeholders who feel that they are at opposing ends of a contested issue: is the pervasive human presence in nature “bad” or “good”? Some conservationists fear that these terms could endorse human domination of the planet (Crist 2013) and exacerbate the shifting cognitive baseline whereby humans tend to become accustomed to new, and often degraded ecosystems, and thus forget the nature of the past (Caro et al. 2012). Conversely, others propose that associating widespread anthropogenic ecosystems with positive values will be the only way to ensure that people will still care for nature and the ecosystems around them (Marris 2011). But this is not really about choosing between two alternatives: it is instead a complex and ambiguous question that touches upon fundamental worldviews. It should therefore be seen as an issue requiring the engagement of the whole conservation community (Kueffer and Kaiser-Bunbury 2014). Such questions about how we put our scientific concerns into a cultural context cannot therefore be left to biologists alone, but most be elaborated with the assistance of partners from the social sciences and humanities, including ethicists (Rose et al. 2012, Sörlin 2012), as well as the engaged public (Yung et al. 2013).

Towards responsible and balanced science communication

We have argued that scientists should—with the help of journalists and social scientists—find ways to communicate (often uncertain) results in an engaging way that explicitly attends to its metaphors and values. How can the situation be improved in practice? We certainly do not suggest that scientists can or should abandon metaphorical and engaging language in science communication. We instead propose that they adopt criteria to help distinguish problematic from fruitful ways of doing so (Textbox 1), although this distinction will be sensitive to scientific and societal context, must evolve over time, and will never be perfect. Thus, we also propose procedural guidelines and training for scientists, science journalists, and the editors of scientific journals to work collaboratively to report scientific results using frames and metaphors that speak to diverse experts and stakeholders (Textbox 2). Scientists and journalists must continuously strive to get both the facts *and* the story straight because it is as unscientific to communicate with inappropriate language as it is to present bad data.

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Textbox 1: Criteria for assessing the appropriateness of metaphors for science communication

Factual correctness

Every metaphor simplifies by illustrating certain aspects of a scientific object while neglecting others. Scientific metaphors can nonetheless be interpreted in terms of their factual content, and in this respect they can be considered wrong. At the start of the genomic era, for instance, geneticist John Avise (2001) proposed alternative metaphors to replace prior mechanistic ones (e.g., the blueprint metaphor) that he felt misrepresent new insights about the nature of the genome (also see our discussion of synthetic biology above). Metaphors should be consistent with the state of knowledge to the degree of scientific accuracy required in a particular context (e.g., research, popular science writing, or science-based decision-making).

Discrimination

The same rules that apply to everyday life concerning discriminatory language also apply to science. Metaphors that are racist, sexist, or in other ways discriminatory should be avoided. Herbers (2007), for example, condemns references to 'slave-making' and 'negro' ants, or reference to rape in animal behavior studies.

Neutrality

It is often difficult to assess the neutrality of a metaphor. Science communication should nonetheless seek to avoid language that is generally recognized to be loaded with emotion, such as apocalyptic warnings and dramatic hyperbole. This language can detract from the perceived neutrality of a scientist who is expected to present research results that invite open and critical discussion. One rhetorical function of such metaphors is to convince where evidence is missing or ambiguous, yet this is inadvisable insofar as it seeks to substantiate scientific statements with rhetoric instead of facts.

Transparency

When a metaphor is used it should be introduced as such, and its connection with specific aspects of a scientific concept should be illustrated. At least in longer texts, authors should explicitly reflect on the connotations and performativity of their chosen metaphors. When metaphors are replaced by similes (i.e., using an "is like" statement), there is a lower risk that they will be taken literally (Carolan 2006).

<u>Textbox 2: Procedural guidelines and training for scientists and science journalists</u>

Collaboration between scientists and journalists

Close and continuous interaction between scientists and journalists is needed in the formulation of news stories, not only to get the facts right, but to ensure they are well-balanced, honest, and compelling to a culturally diverse audience. When new stories are written, journalists and editors are under enormous time pressure, and they are constrained by existing news frames and expectations (Smith 2005). Rhetorical stereotypes will be difficult to replace at those times. Long-term partnerships among journalists, editors and scientists are therefore critical, and may be facilitated by regular interactive workshops.

Modern biologists require humanities education

It is the responsibility of scientists to understand the historical, cultural and normative connotations of key terms and concepts that they use (see our discussion of invasive species above). Therefore, closer collaborations between scientists and humanists are essential (Forêt et al. 2014, Sörlin 2012). To this end, graduate students in biology should take courses on the broader social and cultural context of scientific research, including science communication and the science-policy interface (Forêt et al. 2014, Sörlin 2012). Training in professional ethics should go beyond ethical practices within research (e.g., animal welfare and fraud) to address larger questions about the socio-ethical implications of research (Kitcher 2004).

Ensure diversity of communicators and metaphors

In some phases of research, a focal metaphor can help to direct inquiry, but at other times it may stymie it. In these instances, a plurality of metaphors may help to inspire new ideas and thus enhance scientific inquiry and communication (e.g., Avise 2001). These metaphors can originate through interactions with people of diverse backgrounds (both scientific and non-scientific). It is laudable, for example, that scientists increasingly engage with artists about their research and how to communicate it (e.g., Scott 2006).

Peer review of rhetoric and metaphors

Our recommendations apply not just to public communication but also to original scientific articles. We welcome the more creative and engaging style of many contemporary scientific articles, but scientists should be aware that these rhetorical flourishes can be problematic and misleading (Nelkin 1994; Larson 2011). During peer review referees should check not only the content of articles but also the language and metaphors used to communicate and illustrate concepts and arguments. This requires that journal editors extend their review guidelines accordingly to improve referees' awareness of these issues.

Democratic deliberation and audience studies

Metaphors influence the type of inquiry that is pursued both in basic and applied research, so their selection will often have socio-political implications. Participatory processes can help to increase democratic deliberation about metaphors in research in order to legitimate their use and ameliorate their consequences for science and society. For instance, focused communication campaigns rely upon audience studies that seek to understand the implications of particular value-laden metaphors for communication, such as the National Academies of Science have utilized for communication about evolution (Nisbet 2009).