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Science Journalism, Value Judgments, and the Open Science Movement

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Science journalists face significant challenges as they seek to report on scientific research in socially beneficial ways. This study draws on recent scholarship in the philosophy of science that can help journalists navigate these challenges. It proposes that science journalists have the opportunity to contribute to the open science movement by identifying and explaining major value judgments in scientific research for members of the public. Journalists are uniquely situated to fulfill this role because they serve as gatekeepers of information for the public and because their investigative skills are ideal for uncovering value judgments. The study concludes by examining a case study of recent journalistic reporting on possible health effects associated with cell phone radiation in order to illustrate how science journalists can adopt this role.

Keywords: cancer, science communication, communication ethics, philosophy of science, science journalism, value judgments, cellphone radiation, journalism ethics

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INTRODUCTION

Science journalists face challenges that make it difficult to do their work well. On the one hand, like most journalists, they typically have the goal of providing balanced perspectives that consider all sides of the stories they are reporting (Deuze, 2005; Clarke et al., 2015). On the other hand, they have the responsibility to avoid misleading the public by reporting poor or unreliable science. Journalists have come under fire for mishandling this responsibility in the case of climate science by giving too much attention to the views of climate-change deniers who peddle misinformation (Oreskes and Conway, 2010). By trying to be "balanced" and presenting perspectives from both sides of the issue, they have provided a misleading impression of the scientific community's views (Boykoff and Boykoff, 2004). Other journalistic norms, such as the tendency to present stories in ways that involve personalization, dramatization, and novelty, can also make it difficult to characterize science accurately in some cases (Boykoff and Boykoff, 2007). A related challenge stems from the desire not to engage in hype that inappropriately glorifies or vilifies new scientific or technological developments (Angler, 2017). This goal can be difficult to achieve when journalists face pressures to make their work exciting enough to attract readers or when they are guided by press releases from institutions that want to promote the work of their employees.

This study proposes a principle that can help science journalists think through their goals and priorities when navigating these challenges. According to the principle, journalists have an opportunity to contribute to the open science movement, which is one of the most important trends in science over the past decade (Royal Society, 2012; NAS, 2018). As the U.S. National Academy of Sciences puts it, "Open science aims to ensure the free availability and usability of scholarly publications, the data that result from scholarly research, and the methodologies, including code

or algorithms, that were used to generate those data" (NAS, 2018, p. 1). In particular, journalists have unique abilities to help their readers understand important value judgments associated with scientific research. Scholars working in the history, philosophy, and sociology of science have recently emphasized that science is permeated with a host of value judgments, which can be defined as choices that cannot be settled solely by appealing to logic and available evidence (Elliott, 2017). These include large-scale choices about what topics scientists study, what questions they ask, and how they frame their findings. They also include nitty-gritty decisions about how to collect data, what procedures to use for analyzing and interpreting the data, and what approaches to use for interpreting ambiguous results. Value judgments are often among the most important pieces of information that members of the public need to know about scientific research, but it can be difficult to make this information available to them.

Science journalism provides one of the best avenues for informing people about value judgments. The vast majority of non-specialists obtain almost all their knowledge about science from journalists, who serve as the primary gatekeepers for scientific information. In addition to being gatekeepers, journalists are often particularly well-placed to clarify value judgments. They frequently have opportunities to ask multiple scientists for their perspectives on the strengths and weaknesses of new studies. They often have the skills to investigate funding sources and ideological connections that could have influenced the way a study was performed. They are frequently able to place studies in their broader scientific context, clarifying how their results compare to other research that has been done. And they can place the studies in their social context as well, discussing their potential implications for society and the ways in which the research relates to broader social trends and priorities.

VALUE JUDGMENTS AND THE OPEN SCIENCE MOVEMENT

In recent years, "science studies" fields like the history, philosophy, and sociology of science have emphasized that scientific research is value-laden. In a nutshell, this means that scientists make choices that are not settled by the available evidence but that can end up supporting different social or ethical values depending on how they are made. Philosophers of science have been particularly focused on clarifying the nature of these choices (see e.g., Longino, 1990; Douglas, 2009; Elliott, 2017). They call these choices "value judgments" because one must weigh various considerations or "values" when deciding how to make them. Values are qualities that are desirable; they could be scientific characteristics like explanatory power and predictive accuracy or social considerations like public health and economic development. Thus, even though the term "value judgment" might seem to suggest that these scientific choices always involve ethical or social considerations, this need not be the case. It is merely meant to show that scientists are forced to make choices that are not settled by evidence. Nevertheless, these choices can still end up being "laden" with ethical or social values in the sense that they end up serving or supporting particular social or ethical values over others, depending on how they are made.

Some of the major value judgments that scientists make include choices about what topics to study, what questions to ask about those topics, how to design studies to answer those questions, how to interpret the data obtained, how much evidence to demand, and how to frame and communicate findings (Elliott, 2017). One kind of value judgment that has received particularly detailed scrutiny is the decision of how much evidence to demand before drawing a conclusion (Douglas, 2009; Elliott and Richards, 2017). Different scientists can reach different conclusions in response to the same data if they disagree about how much evidence is needed.

The testimony that climate scientist James Hansen provided to the U.S. Congress in 1988 provides a particularly vivid example of this kind of value judgment. At that time, most climate scientists were worried about the potential for climate change, but they were typically not confident enough in the available data to claim that they could already observe it happening. Based on the work of his team, however, Hansen testified, "Global warming has reached a level such that we can ascribe with a high degree of confidence a cause and effect relationship between the greenhouse effect and observed warming. It is already happening now" (Shabecoff, 1988). Others disagreed with Hansen's willingness to draw this conclusion, but he said that even after considering the potential costs of being wrong, it was time to "stop waffling, and say that the evidence is pretty strong that the greenhouse effect is here" (Weart, 2014). This dispute between Hansen and his critics illustrates how value judgments (in this case, choices about how much evidence to demand before drawing particular conclusions) can have a significant impact on the information that scientists provide to decision makers.

Another kind of value judgment involves choosing how to interpret the available data. For example, different groups of scientists have clashed over whether to conclude that bisphenol A (BPA; a chemical found in products like plastics, food can liners, and receipts) is harmful to human beings (Resnik and Elliott, 2015). These disagreements arise in part because scientists weigh and interpret the available data differently. For example, the chemical industry funds studies for regulatory purposes that are performed according to standardized guidelines. These studies tend to indicate that BPA is not harmful at the levels to which humans are currently exposed. In contrast, many academic studies suggest the opposite conclusion (Myers et al., 2009). These differences appear to be the result of clashing views about the adequacy of particular study designs. Many academic researchers have concluded that the industry studies are not appropriate for uncovering BPA's harmful effects, while proponents of the industry studies argue that the academic studies are unreliable and not appropriately validated (Vandenberg and Prins, 2016). Another reason for differing views about BPA is that scientists disagree about how to interpret data suggesting that it might be toxic at low doses but not at higher doses. Some scientists argue that these apparent effects are likely illusory, whereas others are more likely to conclude that the apparent effects are genuine (Vandenberg and Prins, 2016).

When scientists draw different conclusions because of the value judgments involved in interpreting data and drawing conclusions, it might be tempting to say that they display different biases. Nevertheless, although values can sometimes

play the role of biases, it is helpful to distinguish biases from values and value judgments. Strictly speaking, a bias is a systematic deviation from a standard (Danks and London, 2017). So, for example, if a scientist consistently predicted the toxicity of environmental chemicals inaccurately because of the scientist's strong commitment to environmentalism, this would count as a bias. However, there are numerous ways in which environmental values could influence scientific judgments without playing the role of biases. For example, an environmentally oriented scientist might ask somewhat different questions than a scientist without such leanings, or the environmentally oriented scientist might design her studies in ways that would lessen the chance of missing important environmental effects, or she might demand less evidence before concluding that an environmental threat is present. In these cases, the scientist would be influenced by environmental values, but it seems inappropriate to call these influences "biases."

One of the major upshots of all this recent scholarship on values and science is that society needs to find ways to manage value-laden judgments responsibly. While there are disagreements about the details of how to handle these judgments (see e.g., Kourany, 2010; Intemann, 2015; Elliott, 2018; Brown, forthcoming), an important theme is that it is important to promote openness about them so they can be subjected to critical scrutiny (Longino, 2002; Elliott, 2017). If those who draw on scientific information in order to make decisions do not receive information about the value judgments associated with research, they risk not being able to make decisions that accord with their own values (Betz, 2013; Schroeder, 2017).

Consider the predictions that climate scientists are often asked to make about future changes in temperature, precipitation, and sea levels. To make these predictions, they have to make a wide range of value judgments in the course of developing, running, and interpreting their models (see e.g., Winsberg, 2012; Parker, 2014; Intemann, 2015). If information about these judgments were not communicated to those using the predictions, they could be seriously misled. For example, if the scientists made these judgments in ways that tended to err on the side of underestimating the negative effects of climate change, whereas those using their predictions were trying to err on the side of overestimating the effects of climate change, they would be hampered in their decision making (see e.g., Douglas, 2009; Elliott, 2010). However, decision makers would be less likely to be misled into making decisions that conflicted with their own values if they understood and perhaps even influenced how the available scientific information was affected by value judgments (Intemann, 2015). For example, if decision makers wanted to avoid worst-case scenarios, they could hopefully convince climate scientists to handle value judgments in a manner that made worst-case scenarios particularly clear. Failing this, it would at least helpful for decision makers to understand that the climate scientists' pronouncements did not serve as a good guide for predicting those scenarios.

This goal of making value judgments known accords well with the rise of the open science movement (Royal Society, 2012; NAS, 2018). As part of this movement, important initiatives are currently underway to make all the data, materials, and computer codes associated with studies openly available; to promote open-access publishing; to make the scientific peer review process more transparent; to encourage pre-registration of studies so that study designs are known in advance; to promote more systematic publication of studies (including those with negative as well as positive results); and even to report on the progress of studies in real time using software that allows other scientists to make comments and suggestions (Royal Society, 2012; Nosek et al., 2015). These efforts serve a number of purposes, including the goals of making scientific research more replicable and reliable, hastening the development of scientific advances, and making scientific information more available and relevant to members of the public.

Nevertheless, although prominent documents about the open science movement explicitly state that making information available to the public is an important goal, they provide few details about how to achieve this aspect of the movement, and they do not refer to the literature on value judgments in science (Royal Society, 2012; NAS, 2018). Most open science initiatives are directed primarily at members of the scientific community. For example, making data, materials, and computer code available can help other scientists to evaluate each other's work, but these efforts are of little use to the average member of the public. Even open-access publishing, which is supposed to assist members of the public who do not have access to academic libraries, is of little use to most citizens, who are unlikely to be able to critique scientific articles even if they have access to them. What most members of the public need when hearing about scientific results is a combination of the main "take-home lessons" associated with those results, together with the most important value judgments involved in interpreting the results. Clarifying those judgments could include providing information about important weaknesses or limitations in the results, or major disagreements among members of the scientific community about how to interpret the results, or information about whether alternative results might have been obtained if different studies had been performed.

A ROLE FOR SCIENCE JOURNALISM

The pervasiveness of value-laden judgments throughout scientific research raises a challenge for journalists but also an important opportunity. The challenge is that when scientists disagree, journalists have to figure out when the disagreements are the result of irresponsible or erroneous claims (which would be problematic to report widely in the media) and when they are the result of reasonable differences in approaches to making important value judgments (which would often be helpful to report). As noted in the introduction, this task has become increasingly difficult in recent years, in part because some stakeholders have developed organized efforts to mislead the public about hazards associated with industrial chemicals, pharmaceuticals, climate change, and other social issues (Michaels, 2008; Oreskes and Conway, 2010; Holman and Elliott, 2018). These difficulties are exacerbated by the explosion of information on the internet, including a great deal of unreliable

and even fraudulent material (Allcott and Gentzkow, 2017). Fortunately, journalists are typically trained to address these challenges by drawing from multiple sources and evaluating their reliability[1].

To the extent that science journalists are able to sort through this confusion, they have the opportunity to play a very important role in the open science movement on behalf of society. Specifically, they are in a unique position to clarify important scientific value judgments and communicate about them to broad swaths of the public who seek to make decisions that are informed by scientific information. The following principle represents this important aspect of science journalism:

> **Value Judgment Principle**: Science journalists have valuable opportunities to contribute to the open science movement by identifying and explaining major value judgments in scientific research (and the factors that could be influencing those judgments) on behalf of non-specialists.

The Value Judgment Principle (VJP) can help journalists report on controversial areas of science in a responsible fashion. When scientists disagree and controversies ensue, science journalists have the opportunity to clarify the reasons for those disagreements (i.e., value judgments) and the strengths and weaknesses of different views. In general, when journalists are deciding what details it is important for them to cover in an article or report, they can reflect on the major value judgments associated with the topic they are covering. If they are trying to figure out how to prioritize different details that they could include, it would be helpful to consider whether those details involve judgments that could hamper or facilitate people's decision making. In fact, when looking for stories worth covering, they can consider whether there are important value judgments in particular areas of science that people should know about. Of course, this principle does not capture all the goals of scientific journalism, but it does address important concerns raised by the literature on the value-ladenness of science (i.e., the potential for decision makers to be hampered in their ability to use value-laden scientific information to achieve their own goals or ends).

There are three interrelated reasons for thinking that the VJP is a good principle for science journalists to adopt. The first reason has already been covered in the previous section: there is a great social need for scientific value judgments to be clarified for decision makers, especially members of the public. Consider just a few of the everyday decisions people make that draw on scientific information: whether to get one's kids vaccinated, whether to limit their screen time, whether to eat genetically modified or organic foods, whether to lessen one's consumption of fats or sugars, whether to take various dietary supplements, whether to pursue alternative medical treatments, whether to engage in particular forms of exercise, and whether to engage in various actions to try to address environmental threats. Without any clarification of the value judgments involved in these areas of science, people would be unable to engage in successful decision making in ways that accord with their values. Thus, it is very important for society that the major value judgments involved in scientific research be highlighted and clarified.

A second reason for adopting the VJP is that many journalists are ideally placed to meet this crucial social need of clarifying value judgments, both because of their role in society and because of their skills. The average member of the public who has to make a decision that draws on scientific information is unlikely to be reading scientific papers or talking to scientists; instead, their primary source of information is typically science journalism. Moreover, in addition to serving as the primary source of scientific information for members of the public, journalists are often particularly well-placed to help identify and clarify value judgments. In the course of their reporting, journalists frequently talk to multiple scientists or stakeholders and ask for their perspectives on the strengths and weaknesses of new scientific results. By doing so, they often determine whether important value judgments have been made. Individual scientists are often not even aware that they are making important judgments, but the journalistic activity of talking to multiple sources can help bring important judgments to light. Journalists also frequently have the skills to investigate the "backstories" behind important scientific developments, which often involves identifying important funding sources, ideological perspectives, or social connections that could be influencing how scientists handled the value judgments associated with their research.

A third reason for adopting the VJP is that it accords exceptionally well with the way many science journalists already conceive of their work. In his recent introduction to science journalism, Angler (2017) notes that there are relatively simple, entertainment-focused forms of science journalism as well as more complex, critical forms (see also Murcott and Williams, 2013) (Of course, there are other approaches to science journalism in addition to the two that Angler discusses, but his account nevertheless represents important journalistic trends). Entertainment-oriented journalism is focused primarily on describing new scientific advances in an exciting fashion, often with a "cheerleading" attitude toward what science can accomplish (Nelkin, 1987). The critical role focuses more on identifying potential flaws or limitations of studies and providing context concerning how they relate to other scientific work (Rehman, 2013). In other words, the critical role is essentially what the VJP calls for science journalists to be pursuing.

Angler argues that while entertainment-oriented science journalism is likely to continue to be significant, the critical form is important to promote. He cites survey research indicating that many science journalists view their field as being "too uncritical" (Angler, 2017, p. 15), and he emphasizes that critical science journalism can help to promote a well-functioning democracy (Murcott and Williams, 2013). He affirms, "If done properly, science journalism questions the methods scientists employ as well as their results and how the media and the public interpret them; it also investigates and unfolds possible conflicts of interest researchers may have" (Angler, 2017, p. 3).

[1]Admittedly, as the resources available to the traditional media have shrunk, fewer journalists have been able to dedicate themselves to science journalism. Thus, their ability to evaluate the reliability of scientific sources and engage in responsible reporting has been weakened. Even if they cannot always fulfill this task successfully, however, this study assumes that science journalists should at least be striving for this ideal.

Furthermore, in accordance with the philosophical concern that we should enable people to make decision that accord with their own values, he argues that one of the important contributions of science journalists is to provide enough "context and supporting information" so that people can make informed decisions about areas of science that affect their well-being (Angler, 2017, p. 10). Thus, Angler's recommendations for science journalism are essentially the same as those found in the VJP.

Given the similarity between the VJP and the notion of critical science journalism, one might actually wonder why a new principle is needed. Why couldn't one just call for more critical science journalism and not bother to talk about value judgments or open science? The additional value of the VJP is that it provides a theoretical foundation that justifies the importance of critical science journalism and clarifies what it should involve. The work by philosophers of science and other science-studies scholars described earlier in this article explains the importance of clarifying value judgments so that people can make decisions that better align with their own values. Moreover, science journalists can turn to science-studies scholars to help identify all the different kinds of value judgments that might be important to clarify. In addition, bringing open science and science journalism into conversation with each other has the potential to enrich both domains. The open science movement has struggled to fulfill its goal of providing useful information to the public (Elliott and Resnik, 2019), and science journalists are in a perfect position to help fill this gap. Recognizing this opportunity can influence journalists' conceptions of themselves and their mission. While the VJP should resonate with journalists independently of its connection to the open science movement, the potential to contribute to open science may make the VJP a higher priority than it would otherwise be.

One might worry, however, that the VJP is too abstract and difficult to understand to be helpful for science journalists. For example, one might think that most journalists will find it difficult to conceptualize their work as communication about "value judgments." This is a reasonable worry, but it can be addressed by using different language to express the same basic ideas expressed in the principle. Because it is inspired by scholarship coming from the philosophy of science, the VJP uses language associated with that field. One could instead say that science journalists have an important role to play in highlighting the "major choices" made by scientists that affect the outcomes of their work. The important thing is to recognize that science-studies scholars have done important work identifying these major choices, so they can help journalists to do their work more thoughtfully and carefully.

Moreover, one can make the VJP less abstract by specifying some of the important kinds of judgments or choices that journalists can be on the lookout to identify. Philosophers of science have clarified a number of these choices (see Elliott, 2017), and one could narrow them down to a few that are likely to be especially relevant for decision makers. These might include choices made by scientists when choosing their research questions, choices made when designing studies, major assumptions involved in interpreting results, levels of evidence demanded in order to draw conclusions, and important ways in which entire areas of research are framed or contextualized. In addition, important factors or "values" that might be informing these judgments are also important to report so that decision makers can understand whether scientific judgments are likely to have been made in ways that accord with their own values. For example, if scientists had funding sources with strong interests in the outcome of their research, such as industry groups or citizen advocacy organizations, this would often be relevant information for decision makers.

One might still worry that even if the VJP is helpful in principle, it might be somewhat unrealistic in practice. For example, one might think that journalists are under so much pressure to capture the interest of potential readers that they are forced to hype their stories and make them as exciting as possible rather than providing measured discussions of value judgments (Schünemann, 2013; Angler, 2017). In addition, the norm of immediacy and speed in reporting can also make it difficult to explore value judgments in detail (Deuze, 2005; Grubenmann and Meckel, 2017). These challenges are not insuperable, however. First, as one can see from the examples discussed in the next section, there are clearly cases where journalists have been able to engage substantively with the value judgments involved in scientific research, despite the pressures not to do so. Second, discussions of value judgments in science need not be boring for readers. People seem to enjoy learning about whether they can trust the latest research, and they also like to know whether researchers might have important conflicts of interest that could affect their work. Finally, even if the VJP were in fact difficult to follow in some cases, it still provides an ideal or yardstick that journalists can use to help measure the quality of their reporting.

A related worry about the VJP is that it proposes a general principle for science journalists while failing to take account of the wide variety of contexts, norms, pressures, and responsibilities associated with different journalistic activities. For example, journalists do not have a single role in society; in various contexts, journalists can pursue the roles of watchdogs, adversaries, interpreters, or neutral sources of information. At different times and in different countries around the world, journalists have held widely different views about the relative importance of these roles and the norms that accompany them (Willnat et al., 2013; Ward, forthcoming). For many journalists, reporting with speed is likely to seem more important than performing the careful analysis of scientific research suggested by the VJP (Deuze, 2005; Grubenmann and Meckel, 2017). The rise of digital media has further complicated efforts to propose principles like the VJP, because it has provided opportunities for a wider range of people to participate in journalistic activities (O'Neill and Harcup, 2019; Wahl-Jorgensen and Hanitzsch, forthcoming). As Karin Wahl-Jorgensen and Thomas Hanitzsch put it in the introduction to *The Handbook of Journalism Studies*, "journalism as an object of study has destabilized and become increasingly slippery" in recent years (Wahl-Jorgensen and Hanitzsch, forthcoming, p. 3).

This is an important concern, and it highlights the fact that one cannot expect all journalists to apply the VJP in the same manner or even to place the same priority on it relative to other norms, demands, and considerations. Nevertheless, insofar as

the VJP encourages journalists to clarify important judgments in science that could affect the decision making of their readers, it arguably has at least some relevance to most science journalists. In her analysis of the ethics of science communication, Goodwin (2018) distinguishes four different types of speech acts: exercising authority, reporting, advising, and advocating. She emphasizes that these different speech acts have varying characteristics and generate different ethical responsibilities. Nevertheless, she argues that there are some basic ethical principles and norms that cut across these activities. For example, she argues that "All communication must be designed to respect the audience's right to think and decide for themselves, by providing them good reasons to trust what is being conveyed" (2018, p. 18). While the relative importance and interpretation of the VJP is likely to vary significantly from one journalistic context to another, most journalists are likely to find the opportunity to identify and explain major value judgments relevant to their work, precisely because it helps their readers to think for themselves about the science being reported.

A somewhat different worry is that the VJP will diminish public trust in science. By highlighting the complexity of the value judgments underlying scientific work, journalists might cause members of the public to develop unwarranted skepticism about the reliability of scientific research (John, 2018). This is a legitimate concern, and more empirical research is needed to investigate how discussions of value judgments affect public perceptions of science (see e.g., Elliott et al., 2017). Nevertheless, it is likely that journalists can follow the VJP without eroding public trust in well-founded scientific information. For example, an important aspect of responsibly discussing the value judgments associated with scientific research is to clarify the extent to which they do or do not throw scientific conclusions into doubt. Thus, when reporting about topics like climate change or vaccines, responsible journalists would clarify that there are not significant uncertainties about whether greenhouse gas emissions are contributing to climate change or whether vaccines cause autism. Journalists can identify important value judgments associated with these areas of research while distinguishing scientific claims that are particularly well-supported from those that are not. Moreover, by helping members of the public to understand how all scientific research involves value judgments, journalists might lessen the danger that people will assume value-laden research to be untrustworthy (see e.g., Kovaka, 2019).

Finally, a more theoretical worry about the VJP is that much of the justification for it stems from the importance of promoting people's ability to make choices that accord with their own values. One might question whether this goal is actually very important, and thus whether the principle is important to follow. This objection resonates with longstanding philosophical debates about the relative importance of promoting people's autonomy as opposed to promoting other important ethical values, such as well-being (see e.g., Beauchamp and Childress, 2012). Nevertheless, while there is room for disagreement about its importance relative to other values, it seems difficult to deny that it is indeed important to help people make decisions that accord with their own values. It would be deeply worrisome if people could not decide how much to trust the scientific information offered to them because they did not know how reliable it might be or whether it had been influenced by significant but undisclosed value judgments. An additional response to this objection is that the clarification of important value judgments can be valuable for other purposes besides assisting people's decision making. For example, talking about the value judgments or choices involved in science can help to promote more sophisticated publics that have a richer understanding of how science works (Angler, 2017; Kovaka, 2019).

A CASE STUDY: RADIOFREQUENCY RADIATION AND HUMAN HEALTH

A case study may help provide more specificity to what has been a fairly theoretical discussion of the VJP. The following case study serves a number of purposes. First, it illustrates how the VJP can be fleshed out in concrete situations. Second, it shows that the pressures to produce exciting pieces need not prevent science journalists from doing the kind of work suggested here. Indeed, the case study discussed here illustrates that journalists can highlight value judgments in truly impressive ways that empower members of the public to engage in high-quality decision making. Finally, the case study illustrates how the principle can provide practical guidance for science journalists to help make their work stronger.

Radiofrequency (RF) electromagnetic radiation is the kind of radiation that carries TV, radio, cellphone, and wireless signals. The radiation used in microwave ovens and radar also falls in this range, which has a lower frequency than that of visible light. Given that environmental exposure to this form of radiation has increased dramatically in recent decades, some scientists and citizen groups have expressed concern about its potential to have harmful effects on humans and other organisms (Bandara and Carpenter, 2018). These concerns have intensified as nations around the world prepare to roll out 5G technology, which will require placing many more antennas in close proximity to human communities and living spaces. Nevertheless, evidence for the human health effects of RF is ambiguous and difficult to interpret, which makes the topic very challenging for journalists to cover responsibly.

A piece by Schulson (2018) in the online publication *Undark Magazine* highlights the complexity of covering this topic. Schulson notes that the current evidence for health problems caused by RF radiation is fairly weak; as the FDA states on its website, "The majority of studies published have failed to show an association between exposure to radiofrequency from a cell phone and health problems" (quoted in Schulson, 2018). Thus, it would seem problematic to fan public fears by giving "equal weight to every incremental study suggesting some possible health risk" (Schulson, 2018). Nevertheless, this is a complex topic that is difficult to study both because of the nature of the subject matter and because of powerful financial interests that attempt to minimize any evidence of harm (Alster, 2015; Hertsgaard and Dowie, 2018). Some studies do in fact provide

evidence that RF radiation could have negative effects on humans or other organisms (e.g., Volkow et al., 2011; Carlberg and Hardell, 2017; Zothansiama et al., 2017; Pall, 2018). Thus, as Schulson (2018) notes, "it's sobering to think of a world where the public is simply assured that everything is definitely okay—at least until a consensus forms and enough scientists get together and tell them that it's not. Science is littered with examples of toxins and pollutants that were long thought to be safe … only to be revealed later as hazardous."

Fortunately, science journalists have demonstrated the ability to provide information about health risks from RF radiation in a manner that accords with the VJP, thereby promoting decision making that accords with people's values. Consider a wonderful piece of reporting by Belluz (2018) in *Vox*, in collaboration with epidemiologist Dylan Collins. It is noteworthy that Belluz opens her piece in an engaging fashion by connecting the topic with the new rollout of 5G networks and with personal anecdotes about how her mother worried that her brothers were "frying their testicles" with their cellphones in their pockets. After this entertaining introduction, she manages to address almost all the important kinds of value judgments discussed in the previous sections of this article.

She begins with the take-home message that "You can make two good arguments about cellphones and cancer based on the best-available research: that the radiofrequency radiation they emit doesn't increase the risk of brain tumors, and that the data is too poor to know that for sure" (Belluz, 2018). By making this claim central to her paper, she highlights the judgments that scientists and decision makers need to make about how much evidence to demand before drawing a conclusion. Some people might conclude based on the existing evidence that cellphones do not cause cancer, whereas others might regard the evidence as insufficient to draw a conclusion.

She also provides a wealth of information about specific studies, emphasizing many of the judgments involved in interpreting them. For example, she clarifies that the available evidence does not come from randomized controlled trials (RCTs), which would provide particularly high-quality information. She also discusses the weaknesses of case-control epidemiological studies, which look backward in time and require people to remember their activities in the past. She explains that cohort epidemiological studies are stronger but still have a number of weaknesses. Finally, she illustrates the decisions that scientists need to make about how to weigh many different studies with somewhat different conclusions. In particular, she discusses the mixed results coming from (relatively low quality) systematic reviews on cellphones and brain cancer, as well as higher-quality individual studies that generally show no increased evidence for cancer, and animal studies that provide some evidence for possible health effects.

Belluz (2018) also contextualizes this information in a number of different ways that are likely to help decision makers make sense of its strengths and weaknesses. First, she notes that the World Health Organization (WHO) has declared cellphone radiation to be a possible carcinogen, but she clarifies that many other things (including pickles, aloe vera, and being a carpenter) also fall in this category. She also notes that brain cancer rates have not been going up in recent years, which one would expect if cellphone radiation were truly harmful. Nevertheless, she points out that 5G technologies will expose us to new forms of RF radiation that have not been studied for their biological effects, and she notes that current safety standards for RF radiation are decades old and were developed primarily just to prevent the heating of tissue. (She also could have noted that some of those who are worried about cellphones causing cancer have argued that there can be long temporal delays between exposure to cancer-causing agents and the development of disease, so noticeable increases in cancer rates might not occur for an extended period of time.) Belluz also discusses how telecommunications companies have tried to influence the science on this issue, although she emphasizes that many of the individual studies showing no evidence for cancer were funded through independent sources.

In addition, she highlights the fact that one's conclusions in this area could be influenced significantly by the kinds of questions that one asks. Most discussions of RF radiation have focused on cancer, and that is where Belluz (2018) focuses most of her attention, but she notes that one could explore many other health effects. As an example, she reports fairly strong evidence that cellphone radiation negatively affects human sperm, although the overall implications for fertility are still unclear (see Adams et al., 2014). She emphasizes that there is a general lack of evidence regarding many potential biological effects, especially for new 5G technologies.

In sum, Belluz's reporting (Belluz, 2018) follows the VJP very well, insofar as it highlights important value judgments in a way that equips decision makers to formulate decisions that accord with their values. She provides those who want to understand the mainstream views of the scientific community with the understanding that most studies do not provide cause for alarm. Nevertheless, for those who are more risk averse and more willing to take protective measures, she clarifies how one could make interpretive choices that generate concern. Those who are particularly risk averse might fault her for not discussing more of the evidence indicating that RF radiation interacts with biological systems in general, which could increase one's prior inclination to think that it could be harmful (see e.g., Bandara and Carpenter, 2018). Nevertheless, by providing information about sperm quality, which is one of the best established adverse effects of RF radiation, she at least alerted interested readers that there is more to be concerned about than cancer alone.

The VJP can also help to clarify the weaknesses in other journalistic discussions of RF radiation. Consider a piece in *Popular Science* by Chodosh (2017) that has been the subject of controversy (Schulson, 2018). Chodosh (2017) frames her piece as a critical response to the decision by the California Department of Public Health to provide guidelines for decreasing one's exposure to cell phone radiation. She makes it very clear where she stands, claiming at the beginning of the piece that "there's no evidence that cell phones are dangerous to your

health. Period." At the end of the article, she vividly reiterates her position: "So go ahead and leave your phone in your pocket. Talk on it for hours. Heck, you could duct-tape it to your face if you so choose" (Chodosh, 2017).

There are clearly some strengths to this reporting style. It draws in readers and provides a straightforward message that will not leave them confused. Moreover, tucked between these catchy claims, Chodosh (2017) provides some helpful education about the methodological weaknesses of many of the studies performed on cellphone safety. Like Belluz (2018), she also contextualizes the WHO's claim that cell phone radiation is a possible carcinogen by pointing out that coffee is listed in the same classification. Finally, she directs interested readers to further information provided by the U.S. Food and Drug Administration and the National Cancer Institute.

Unfortunately, Chodosh's article also has some significant weaknesses. The most obvious problem is that it makes some highly questionable claims. For example, she asserts that testicles are "totally unharmed by phone radiation" (Chodosh, 2017), whereas the available evidence suggests that this is probably not true (Adams et al., 2014; Pall, 2018). Her claim that people could safely duct-tape their phone to their face, while clever, is also misleading. For example, the legal disclosure provided with iPhones reports that they are tested for their compliance with safety standards at a 5 mm separation from the body. Thus, even if one were to regard the current cell phone safety standards as adequate (which is questioned by some experts, as noted in Belluz, 2018), they would not support placing cell phones directly against one's body.

But most of the weaknesses of the article are more subtle, and this is where the VJP becomes helpful. The central weakness of Chodosh's (2017) piece is that it treats the available science as if it were totally straightforward, without the need for value judgments. She helpfully clarifies that the best available studies either find "no link" or a "weak link" to cancer, but she treats those results as decisive evidence that "cell phones don't pose a health hazard." This is one conclusion that many experts have drawn from the available data, but she fails to note that other experts have drawn conflicting conclusions based on their differing interpretive assumptions and standards of evidence. For example, Belluz (2018) notes that some experts have taken the weak links to cancer observed in some of the human epidemiological studies more seriously, given the animal studies that also provide some evidence for health concerns. In contrast, Chodosh (2017) completely fails to mention a widely discussed (albeit somewhat ambiguous) animal study produced by the U.S. National Toxicology Program (NTP). Admittedly, the final NTP report did not appear until 2018, after Chodosh published her piece, but the preliminary results released in 2016 were already enough for *Scientific American* to conclude that cancer concerns from cell phones were being "reignited" (Maron, 2016).

By reporting about cell phone safety as if there were no value judgments at play, Chodosh deprives decision makers of the ability to make decisions for themselves that accord with their own values. In the cell phone radiation case, for example, Chodosh's article seriously hampers readers who want to take a risk-averse approach to environmental threats. This is especially unfortunate because there are relatively easy steps that these readers could take to protect themselves, such as using hands-free technologies.

One might defend Chodosh by arguing that the media needs to stop trying to be "balanced," providing all sides of scientific controversies. After all, we have learned from the case of climate change that this can result in irresponsible reporting that misleads the public (Boykoff and Boykoff, 2007; Oreskes and Conway, 2010). With this in mind, one might conclude that it is helpful for journalists like Chodosh to provide a clear, decisive message that does not leave the public confused by any ambiguity. As noted earlier, however, one can follow the VJP without making it sound like all perspectives on scientific controversies are equally defensible. Consider the reporting done by Belluz (2018). She does not make it sound like cell phones are definitely harmful. In fact, she makes it clear that the majority of evidence does not provide cause for concern. Nevertheless, she alerts her readers that there are complexities surrounding this area of science and room for different conclusions, so they can pursue the issues further or take precautionary actions if they wish. Belluz's approach has much in common with the suggestion that journalists should pursue "evidentiary balance" (Clarke et al., 2015). In other words, science journalists should typically strive to clarify where the strength of evidence lies rather than simply providing all sides of a controversy without clarification.

This kind of thoughtful reporting about value judgments has become all the more important now that evidence is emerging that science journalism is one of the avenues through which interest groups have been trying to mislead the public. It is increasingly recognized that powerful tobacco, petroleum, food, pharmaceutical, and chemical companies have used front groups, public-relations firms, think tanks, and academic scientists to spread misleading messages about scientific issues related to their products (Michaels, 2008; Oreskes and Conway, 2010; Holman and Elliott, 2018). Now evidence is appearing that journalists are also being used by these companies. For example, documents emerging in the course of litigation over Monsanto's herbicide glyphosate reveal that the company paid a consulting firm to help produce favorable news articles and to "plant" fake journalists at news events to try to influence other reporters (Gillam, 2019). Unfortunately, there is also evidence that Monsanto used front groups to generate scathing responses to reporters who published articles that were critical of their products (Gillam, 2019). While the VJP may not protect journalists from these attacks, it encourages journalists to identify and discuss the activities of these interest groups so the public can hold them accountable.

It is important to remember, however, that even well-intentioned journalists may not have space in their articles (let alone the time, energy, autonomy, and resources) to discuss value judgments in the extensive way that Belluz (2018) does. Thus, they will undoubtedly have to make difficult decisions when deciding how to implement the VJP. Different journalists will come to different conclusions about which value judgments are most important to discuss, how best to explain them, and how much effort to devote to discussing value judgments vs. pursuing other journalistic goals. The VJP does not provide a straitjacket that rigidly constrains journalistic practice; rather, it provides a

theoretical foundation that orients journalists toward some of their major goals.

CONCLUSION

This study has argued for a Value Judgment Principle (VJP) that clarifies an important opportunity for science journalists. According to this principle, science journalists can contribute to the open science movement by identifying and explaining major value judgments for members of the public. This is a very significant role because it helps equip non-specialists to draw on scientific information and make decisions that accord with their own values. The VJP aligns well with the skills of science journalists and the critical role to which many of them already aspire. Moreover, by drawing explicit attention to their role in highlighting value judgments, the VJP identifies recent work in philosophy of science as an important resource that can help enhance the work of science journalists. Moving forward, it would be valuable to explore whether there are individual and institutional strategies that would help facilitate journalistic work that accords with this principle.

AUTHOR CONTRIBUTIONS

KE conceptualized and wrote the paper.

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