Gap between science and media revisited: Scientists as public communicators

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The present article presents an up-to-date account of the current media relations of scientists, based on a comprehensive analysis of relevant surveys. The evidence suggests that most scientists consider visibility in the media important and responding to journalists a professional duty—an attitude that is reinforced by universities and other science organizations. Scientific communities continue to regulate media contacts with their members by certain norms that compete with the motivating and regulating influences of public information departments. Most scientists assume a two-arena model with a gap between the arenas of internal scientific and public communication. They want to meet the public in the public arena, not in the arena of internal scientific communication. Despite obvious changes in science and in the media system, the orientations of scientists toward the media, as well as the patterns of interaction with journalists, have their roots in the early 1980s. Although there is more influence on public communication from the science organizations and more emphasis on strategic considerations today, the available data do not indicate abrupt changes in communication practices or in the relevant beliefs and attitudes of scientists in the past 30 y. Changes in the science–media interface may be expected from the ongoing structural transformation of the public communication system. However, as yet, there is little evidence of an erosion of the dominant orientation toward the public and public communication within the younger generation of scientists.

mass media | science communication | science journalism

The relationship between science and the public—or, more specifically, that between science and the media—has been characterized by metaphors and terms such as "distance" (1), "gap" (2), "barrier" (3), "fence" (4), "oil and water" (5), and "creative tension" (6). In their well-known study on the relationship between science and journalism, based on surveys of US scientists and journalists, Hartz and Chappell claimed in 1997 that "the distance between science and journalism threatens America's future" (1), pointing to the political and economic implications of the science–media interface. Among the factors impeding communication, they noted that scientists and journalists were like strangers to each other, not able to understand each other's language, and driven by different agendas. Furthermore, they pointed to negative perceptions of the general media coverage of science and technology by scientists. Their description of the science–media relationship was probably in tune with the dominant perception at the time. Leading scientists have frequently commented on the problems of the public understanding of science, and the public communication leading to these problems (7, 8). The many activities aiming to improve the science–media relationship and to explore alternative means of communicating with the public prove the almost global perception of an unsatisfactory relationship between science and the media (9–13).

The present article looks at the science–media interface from the scientists' point of view, focusing on interactions with journalists and excluding other kinds of outreach activities such as writing for popular media or participating in science fairs (14). It focuses on "science" in the Anglo-Saxon meaning of the term, i.e., on the natural sciences, as most of the international research, concerns, and discussions have dealt with that field of the academic endeavor. However, to better understand the specificities of the science–media interface, media relations of scientists are compared with the media relations of researchers in the humanities and social sciences. While applying a cross-cultural perspective, the evidence presented is largely confined to major democratic knowledge societies.

Since the 1970s, scholars studying the science–media relationship have looked at the role of norms of scientific communities, which were thought to discourage scientists from communicating with the media by posing a risk for the academic reputation of scientists appearing in public (3, 4, 15). They studied incompatibilities between the professional cultures of scientists and journalists, as well as mutual prejudices and negative perceptions (1, 16, 17), and investigated differences in the way scientists and journalists observe and describe the world (18, 19). Empirical data from surveys even in the 1980s to 1990s would have allowed a more nuanced picture, but these data have frequently been overlooked or downplayed because of the dominant perceptions of an unsatisfactory science–media relationship. Besides evidence of a critical assessment of the media coverage on science and technology in general (1, 16), some studies show a strong motivation on the part of scientists to interact with the media (16, 20, 21) and a high degree of co-orientation of scientists and journalists (17, 22, 23). Furthermore, a large proportion of scientists were actually interacting with journalists. For example, in a survey of faculty members of Ohio State University and Ohio University in 1978, approximately two thirds of the interviewed scientists reported contacts with journalists (24). In a similar survey of all full professors at the University of Mainz, Germany, in 1983, more than 70% said that they had "occasional" or "continuous" contact with journalists (16). In addition, somewhat incongruously in view of Hartz and Chappell's alarming account of the state of the relationship between scientists and journalists, only one fourth of the scientists surveyed by them said that they had never been interviewed by a journalist or written a science news story; 30% reported that such activities took place "once a year" or more often (1).

Even in the late 1970s to 1990s, it was therefore not a rare exception for scientists to talk to journalists, but already a widespread practice. Although it is true that some scientists become particularly visible in the public eye (25), surveys show that contacts with journalists and popularization activities were not confined to a few visible scientists, but included a large proportion of

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the members of scientific communities. In her well-known book *Selling Science* published in 1987, Nelkin pointed to the strategic move away from a scientific community hesitantly responding to the information demands of society toward a community actively seeking publicity and controlling its public image (26). This is partly a response to changes in the character of science such as stronger interdependency with industry and government, the diffusion into science of legitimacy problems and controversies related to technologies, and the development of applications that raise fundamental ethical questions (27, 28). We are thus seeing an increasing strategic orientation of science toward the media today, even leading to concerns about problematic repercussions on science of the strong orientation of researchers toward the media (29). The present situation is characterized by a continuation of long-standing patterns in the interactions of science and the journalistic media (including their online variants), and a major structural change in the public communication system caused by the inception and proliferation of the Internet.

To support the arguments presented in this article, published and unpublished data from our own surveys of scientists will be used. These include a five-country postal survey of 1,354 biomedical researchers in 2005, covering the United States, Japan, Germany, the United Kingdom, and France; a cross-disciplinary online survey of 1,600 German researchers from 16 academic disciplines covering the sciences, social sciences, and humanities in 2011; and extensions of that survey (that used similar sampling strategies and questionnaires) to include samples of 216 neuroscientists in the United States (2012) and 280 life scientists in Taiwan (2011). A description of the survey methodology is provided in *SI Methods*. Additionally, published results will be quoted from the Pew survey of American Association for the Advancement of Science members in 2009 (30–33), the Royal Society survey of British scientists and engineers in 2005 (14, 32–34), and other surveys (35–39).

Scientists' Perception of a "Gap"

The notion of a gap between science and the media may not be a valid description of the science–media interface if it is taken to mean a gap separating scientists and journalists, with scientists standing on one side and journalists on the other. As shown later, scientists and journalists seem to get along together quite well. However, as a metaphor to describe a separation of "arenas" of internal scientific and public communication, it captures some important aspects of public science communication. According to this view, scientists are communicators in each of the two arenas, which are structured by different institutions and governed by different rules. Scientists in the "public arena"—an arena still ultimately structured by journalistic mass media—have to adjust to the logic of the media to attract attention.

Survey data presented later suggest that the majority of scientists do actually distinguish clearly between the arenas of internal scientific and public communication as far as journalistic mass media are concerned. This distinction has at least two aspects: the exclusion of the public from communication dealing with knowledge creation and validation, and the conceptualization of scientific knowledge as "special knowledge." Both distinctions lead to a communication pattern that is usually labeled "popularization," i.e., the use of selected, simplified, sensationalized, and pedagogically tailored messages when addressing the general public. These messages systematically differ from the content of the internal scientific discussion without being completely detached from it (40). Dissemination of "science reconstructed for public consumption" (41) is thus seen as a follow-up step after scientific results have been achieved.

Empirically, we find evidence of both aspects of demarcation of public communication from internal scientific communication in the surveys mentioned earlier. More than half of US neuroscientists and more than 60% of German neuroscientists perceive the so-called Ingelfinger rule (42) as still effective. According to that rule, "acceptance of a publication by a scientific journal [is] threatened if the research results have already been reported in the mass media" (Table 1). The data also suggest that this rule is not simply imposed on reluctant scientists by jealous journal editors attempting to protect the exclusivity of the content of their journals, but that it actually conforms to scientific norms, in particular those of the biomedical research community. In the five-country study of biomedical researchers in 2005 mentioned earlier, 71% to 83% of the respondents agreed that "scientists should communicate research findings to the general public only after they have been published in a scientific journal." In another study, leading US nanoresearchers also tended to agree with that statement (35). Approximately half of the neuroscientists and scientists at large surveyed in Germany and the United States in 2011 to 2012 disagree with the demand that scientists, if asked, should "provide information about current research or research that has not yet appeared in scientific publications" (Table 1). Perhaps most relevant as an indicator of a respective norm, 48% of German scientists, 57% of German neuroscientists, and 69% of US neuroscientists think it is an important condition that makes talking to the media about research results acceptable to their peers, namely that these results have been previously published in a scientific journal (Table 1).

The other aspect of the "gap" concerns the distance between scientific/academic knowledge and everyday knowledge. Approximately two thirds of German scientists in general and neuroscientists in particular do not consider their knowledge part of general education, i.e., they regard it as knowledge that not everybody is supposed to have. Furthermore, in approximately 60% of the most recent interactions, scientists indicated that the talks focused on "research" rather than on general expertise (Table 1). The journalistic reporting of science therefore labels this knowledge as originating from a different sphere than that of journalists and their audiences. Branding scientific knowledge as specialist knowledge relieves scientists of the need to treat the general public as a peer group; this group is rather conceived of as an external audience that has to be informed or "educated."

Interestingly, the humanities and social sciences typically show a less strict demarcation between internal scientific and public communication and between scientific and general knowledge than the sciences (43). A comparison of the aggregated results of sciences and humanities/social sciences shows statistically significant differences for all indicators in Table 1: the Ingelfinger rule and the corresponding scientific norms are much less effective in the humanities and social sciences than in the sciences, and the perception of the specialist nature of academic knowledge is less pronounced. Researchers from the humanities and social sciences more frequently address a broader audience through their own publications than researchers in the fields of technology, medical sciences, and natural sciences (39), and, according to an Argentine study, are more often involved in a range of popularization activities than researchers from the hard sciences (36). To phrase it in terms of the gap metaphor: The gap may be a steep canyon in the sciences but a smooth valley in the humanities and social sciences.

When dealing with the mass media, scientists—more than social scientists and scholars from the humanities—are aware they are talking to an audience of "outsiders," i.e., that they are communicating in an arena clearly distinguished from that of internal scientific communication. The gap between the arenas has two aspects: First, the content of communication, marked as special knowledge and carrying the label "scientific," is not easily merged into the everyday knowledge of the audience. Second, scientific knowledge is produced and validated without the expectation that the general public should be involved.

Frequency of Scientists' Interactions with Journalists

The reported frequencies of media contacts in surveys of scientists varies. Fig. 1 summarizes the results of surveys of four

Table 1. Scientists' beliefs and preferences regarding the demarcation of arenas of communication within science and science communication in the public sphere

Statement	US neuroscientists (n = 216)	German neuroscientists (n = 241)	Diff.	German scientists (n = 863)*	German researchers in humanities/social sciences (n = 646)†	Diff.
1. Disagree that scientists, if asked, should "provide information about current research or research that has not yet appeared in scientific publications"‡	50.9%	42.9%	NS	45.8%	25.8%	§
2. Agree or partly agree that the "acceptance of a publication by a scientific journal is threatened if the research results have already been reported in the mass media"	51.8%	61.0%	¶	43.7%	17.8%	§
3. Agree that it "is an important condition" for talking about scientific topics in the media being acceptable to colleagues that "the results in question have already been published in a scientific journal"	69.3%	56.7%	§	45.4%	20.2%	§
4. Disagree that "research in my research area is part of general education"‖	Not asked	68.2%	—	67.3%	43.4%	§
5. Indicate that their most recent interaction with a journalist was focused on "actual research and findings of this research" or on the "state of research on a certain topic" (including potential practical applications) rather than on "general expertise on a certain topic, event or problem"	Not asked	60.1%	—	55.4%	38.5%	§

Methodological details of the surveys are provided in *SI Methods*. Diff., difference; NS, not significant.
*Weighted data to achieve an equal representation of the following research fields: biology, neuroscience, veterinary medicine, chemistry, mathematics, geosciences/geography, material sciences, informatics, and construction/architecture.
†Weighted data to achieve an equal representation of the following research fields: archaeology, history, philosophy, psychology, economics, law, and communication studies.
‡Proportion of values −2 and −1 of a five-point rating scale ranging from −2 ("completely disagree") to +2 ("completely agree").
§$P \leq 0.01$ and ¶$P \leq 0.05$: significant difference between proportions.
‖Proportion of values 1–3 of a six-point rating scale ranging from 1 ("completely disagree") to 6 ("completely agree").

different groups of researchers in which the same question design and the same sampling strategy was used. (Unlike the items shown in Table 1, the question about frequency of contacts was also used in the five-country study.) The majority of researchers in each sample (60–79%) had at least some media experience in the past 3 y. Frequent interactions with journalists (six or more contacts) were confined to a smaller group (16–35%), whereas a larger group (39–56%) had one to five contacts.

Compared with other surveys, the figures on frequency of scientists' media interactions presented in Fig. 1 appear quite high, although a direct comparison is not possible as a result of the different target groups, sampling strategies, and question designs. In 2009, 45% of the respondents in a survey of members of the American Association for the Advancement of Science said that they had never talked with reporters, and another 31% indicated that they did this only rarely (30, 31). In a survey of British scientists and engineers in 2005, 12% said they had been interviewed at least once by a radio journalist and 23% by a newspaper journalist in the previous 12 mo (34). The equivalent figures are lower for Argentine researchers. Of a sample of Argentine researchers, only 10% said they had been interviewed for a radio program and 9% for a newspaper article within the previous year (36). In an Italian study, only 49% of the surveyed researchers reported media contacts in the previous 3 y (37).

Besides real differences between countries and research fields, a possible methodological reason for these discrepancies is that the samples used in Fig. 1 included only scientifically productive (i.e., publishing) researchers, whereas those of other studies were based on membership in scientific associations or universities, for example. Such samples are more likely to include scientists in earlier phases of their careers and those with duties other than research—e.g., teaching, infrastructure, or research management—who are less likely to be attractive media sources (44). It should also be noted that all figures about the frequency of media interactions mentioned so far are based on scientists' self-reporting, which will not be completely accurate. An Israeli study that combined a survey of researchers with content analysis data on the number of actual references to those researchers in the media found a considerably lower figure of media appearances by researchers than of contacts reported in Fig. 1 (38). However, not every talk with a journalist leads to a story in which the researcher's name is mentioned; there is thus the possibility that the frequency of contacts is underestimated.

As there are several ways of initiating contacts between scientists and journalists, many factors influence how often a researcher comes into contact with a journalist. Of major importance is the journalists' interest in the respective research based on assumed audience relevance, and their preference for certain types of sources. Public information activities by research organizations

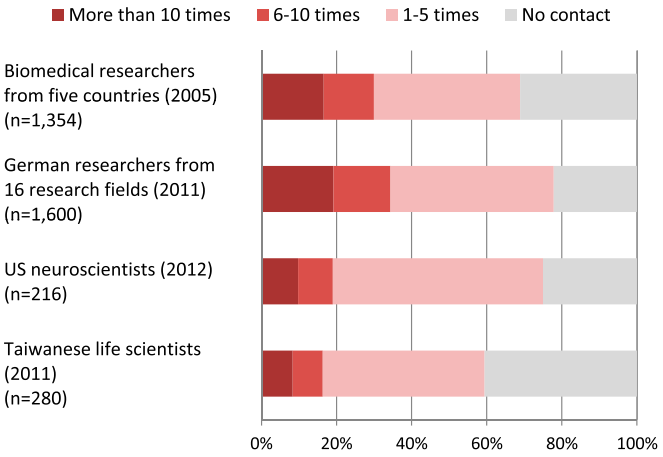

Fig. 1. Frequency of media contacts of different samples of researchers. Distribution of answers to the question "In the past 3 y, have you had professional contact with journalists from the general mass media face-to-face, by phone, or by mail/fax/e-mail?" Methodological details of the surveys are provided in *SI Methods*.

and high-ranking scientific journals will influence the likelihood of being contacted by the media. Finally, the willingness or reluctance of the researchers themselves and their visibility for journalists will play a role.

The surveys point to some general patterns. Most studies find that organizational status and scientific productivity are positively associated with the likelihood of media interactions as well as with public engagement activities in general (14, 36, 37, 39, 45–47). This is probably the combined effect of journalists' preferences for sources with a high reputation, a preference of public relations departments for advertising the leading researchers in their organizations, and the formal or implied privilege of the heads of research units or the principal investigators (PIs) of projects of representing the research of their groups in the media.

Overall, researchers from the humanities and social sciences tend to have more interactions with the media than those from the sciences (24, 36, 48). The recent German survey of researchers found that, in "informatics," "mathematics," "chemistry" and "material science," little more than 10% of researchers reported frequent media contacts; in "communication studies," "law," "history," "archaeology," and "philosophy," this proportion exceeded 50% (Fig. 2). The differences across research fields are partly caused by the selective interests of journalists and their audiences in certain types of research and expertise, and their disregard of others. However, the number of researchers in a research field and the typical size of the research teams mediate the relationship between journalistic interest and the distribution of media contacts among researchers.

One of the reasons leading to cross-national differences in the frequency of scientists' interactions with journalists is the interest in science of the respective media audience. Another factor is the size of the media system relative to the size of the research system: How many (science) journalists report about the work of how many researchers? Further factors are the working routines of science journalists in different countries: Do journalists mainly rely on press releases or scientific publications, or do they routinely talk with scientists when reporting about their work? Finally, journalists in different countries might focus more or less intensively on research in their home countries compared with foreign countries. For example, journalists in developing countries with a less competitive research system may prefer sources in countries with a strong research system (49).

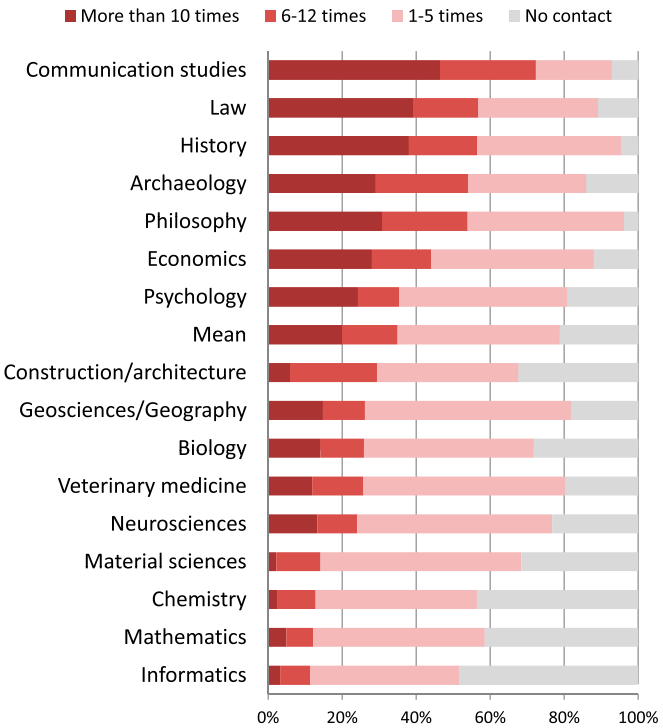

Fig. 2. Frequency of media contacts of German researchers (n = 1,600) by research field. The question wording is identical to that in Fig. 1. Methodological details of the survey are provided in *SI Methods*.

In major knowledge societies, scientists interact frequently with the media. Variations exist between countries and, in a more pronounced manner, between research fields. Only for a few scientists are contacts with journalists a routine activity, but neither are media contacts restricted to a small group of visible scientists. Researchers with high status and leadership function interact with journalists much more frequently than junior researchers.

Media Orientation as Part of Scientist's Role

Much research has focused on the possible effects of psychological factors on the frequency of interactions such as the scientists' intrinsic motivations, perception of moral duty, extroversion, presumed media influence, stereotypes of journalists, and motivations based on the perception of costs and benefits (14, 33, 36, 38, 50). Empirically, we do find moderate statistical associations between such factors and the frequency of self-reported media contacts, but, compared with the influence of status, they are relatively weak (45, 47). Furthermore, given the high overall satisfaction of researchers with their own media contacts (as detailed later), positive attitudes and motivating beliefs may be the result of scientists' media experiences rather than decisive motivators leading to media contacts.

Rather than viewing scientists' interactions with the media as the result of individual decisions based on a consideration of costs, benefits, and perceived moral duty, it is more appropriate to conceive of their readiness to interact with the media as a more general orientation, i.e., as part of the modern scientist's role, especially of the leadership role. If scientists are involved in research relevant for the media, it is now expected of them by journalists and by their own organization, and tolerated or even rewarded in terms of gain in reputation by their scientific community, for them to be prepared to interact with the media. Psychological factors may still have a mediating influence on how scientists play out this part of their role—they may do it enthusiastically or reluctantly—but "playing along" is the default, and refusing media contacts without legitimate reason has become unacceptable. Catalysts for this change of the scientist's role are research organizations (e.g., universities), which consider visibility in the media as an important way to secure public and political support (51, 52), and high-ranking journals such as *Science* and *Nature*, which aim not only at scientific resonance but also at a wider public impact (53). A large proportion of scientists believe they have profited in their careers from media visibility whereas only a very small minority experienced mostly negatively impacts (47). This suggests that media visibility of scientists, by and large, conforms to normative expectations in the social contexts relevant for scientists and is perceived as an indicator of the broader impact of their work.

Scientists nowadays perceive a duty to talk to the media about their research, not only in a moral sense, but as part of their professional role. Some like it; some do not. However, most universities and research organizations react positively to their researchers' work being covered by the mass media.

"Governance" of Scientists' Interactions with Media

Norms of scientific communities toward the public have been characterized as ambivalent—partly rewarding, partly condemning media interactions (47, 54). Using the perceived impact of media visibility on scientific reputation as an indicator of scientific norms and success criteria, Fig. 3 provides evidence that a considerable proportion of researchers in the United States and—even more so—in Germany indeed think the scientific community

is ambivalent toward media visibility. Rödder interprets this ambivalence as resulting from the conditional nature of peer acceptance of media interactions. From interviews with biomedical researchers in four countries, she concluded that the peer acceptance of media interactions depends on certain conditions, for example, that scientists have a record of research in the subject of their talk to the media, and that they avoid undue self-marketing (54). Rödder's criteria, as well as some other plausible criteria, were presented to neuroscientists in a survey in the United States and Germany. Fig. 4 shows that scientists indeed perceive that media interactions are acceptable to their peers only if certain conditions are met. These criteria concern the competence of scientists, the content of their statements, their self-presentation, the priority of scientific communication, and the reputation of the news organization. Norms of the scientific community therefore do not generally discourage media interactions, but they include explicit expectations about who should represent science in the media and how.

Besides scientific communities, universities and other science organizations are also increasingly relevant for interactions of scientists and journalists. Public information departments function as "mediators between scientists and journalists" (55), as they create opportunities for scientists to talk to journalists and for journalists to contact scientists, and as they preselect and produce stories anticipating journalistic criteria. However, their current function goes far beyond that of an information broker. Based on the belief that visibility in the media helps secure societal support and legitimacy, attracts the attention of sponsors, and increases competitiveness in "markets" for students, patients and research and development contracts, public relations on the part of scientific organizations have become part of the strategic management of these organizations (26, 56). In recent decades, the institutionalization and professionalization of media relations on the part of science have increased, as has the strategic use of media relations (51, 52, 57). Bauer and Gregory attribute this trend to the growing commercialization of science (58). Others see it as a consequence of new management styles in universities and other research organizations (59) or an increased need to establish public legitimacy (29). Finally, concerns about the rationality of social responses to risk issues such as global climate change have motivated scientific institutions

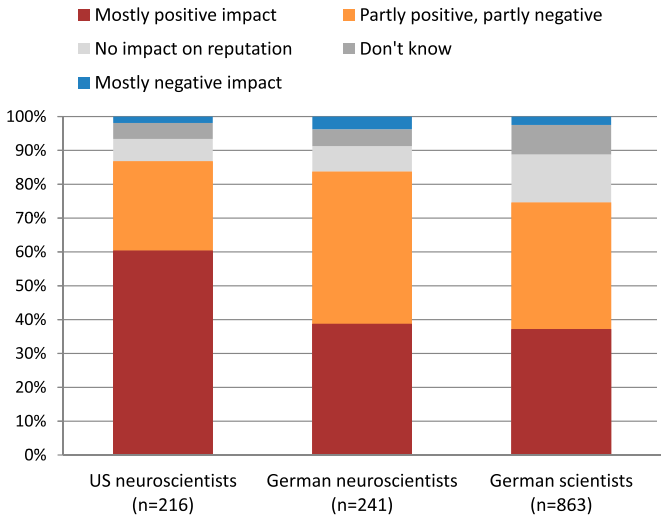

Fig. 3. Perceived impact of media visibility of scientists on their scientific reputation. The question was: "If the media report on scientists and their research, does this have a positive or negative impact on the scientific reputation among colleagues in your area of research?" Methodological details of the surveys are provided in *SI Methods*.

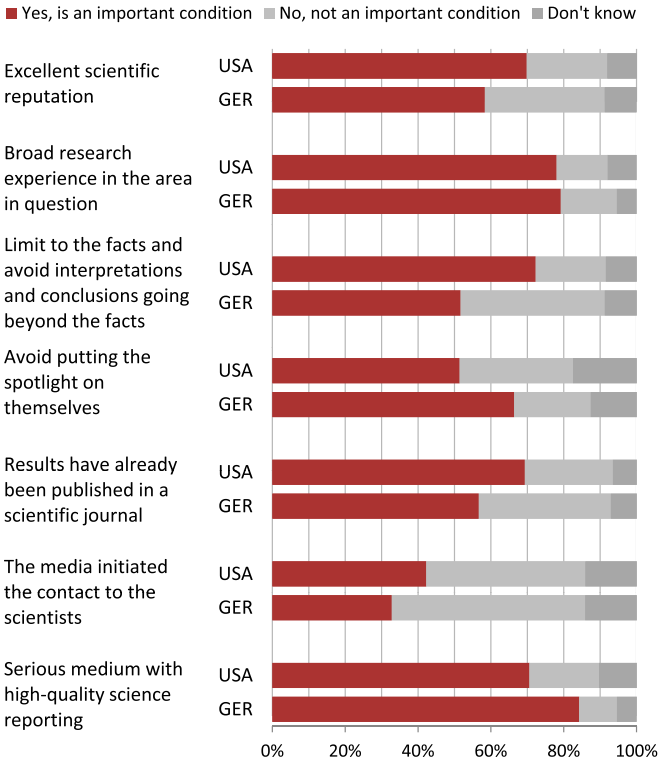

Fig. 4. Norms of the scientific community regarding interactions with the media. Answers of US neuroscientists (n = 216) and German neuroscientists (n = 241) to the question: "Under what conditions do colleagues in your research area consider it to be acceptable for scientists to talk about scientific topics in the media?" Methodological details of the surveys are provided in *SI Methods*.

and individual scientists to engage strategically in public communication (60, 61).

Public information departments of research organizations generally try to encourage and support scientists in communicating their research in the media. Approximately 70% of US and German neuroscientists perceived the policy of their research organization to be "mostly positive" toward reporting on their research in the media; only a few percent perceived it as "mostly critical." However, because of the importance research organizations attach to their public image, the organizations try to monitor and influence the scientists' activities regarding the media—mostly by subtle means—to make sure that they conform to the media strategy of the respective organization (51). Organizations exert influence on scientists' media interactions by the formal hierarchy or through their public relations department. A postdoctoral researcher may need to consult the PI of the project he/she is working on before talking to a journalist; the PI may have to consult his/her institute director; and so on. This hierarchical control seems to be effective in the United States and Germany, but is stronger in Germany. A total of 44% of the surveyed German neuroscientists say that consulting their superior is "always required" before talking to a journalist; in the United States, only 23% perceive this requirement (Fig. 5). On the contrary, in the United States, there is more need to consult the "unit responsible for press relations" before talking to a journalist than in Germany. A similar result was reported in another study (51). This may be an indicator of a higher professionalization of media interactions in the Anglo-Saxon countries.

Scientists are members of scientific communities and of research organizations. In both contexts, they are exposed to normative expectations regarding media interactions. Scientific communities nowadays tolerate media interactions or even reward them if

certain conditions are met. Research organizations usually encourage media visibility but also keep an eye on researchers' media interactions to make sure that these are in line with the organization's interests.

Science Journalism and Response of Scientific Sources

First and foremost, science journalism is expected to disseminate scientific knowledge and knowledge about science, making this knowledge widely accessible for audiences outside the scientific community. More than 90% of the biomedical researchers surveyed in the five-country study indeed considered "a better educated general public" a very important motivation in agreeing to contacts with the media (47). The societal function of the media is, however, not limited to the provision of information. Based on the necessity of selecting their topics from an extensive list of alternatives, journalistic media label issues, events, and actors as relevant to society (62). The default assumption is that, if something passes the journalistic filter, it has to be relevant. Coverage by the media is widely perceived as an indicator of relevance and success, as in policy fields related to science (63). The assumption that media visibility helps to secure social support and public legitimacy—not only for science in general but also with respect to specific organizations or projects—is widely held by the management and public relations staff of science organizations as well as by scientists (51, 52). Finally, the media contribute to a transformation of scientific knowledge by relating it to phenomena, events, issues, knowledge, and concerns outside science, for example. This transformation goes beyond simple "translation"—a misleading metaphor in this context—as the principal goal of journalism is not to maximize congruence between scientific and popularized accounts but to increase relevance and comprehensibility for an audience of nonscientists (19, 40, 62). Scientists generally embrace the two first-mentioned functions of journalism—dissemination and marking something as relevant to society—because they perceive these as being mostly beneficial to themselves and to the audience. However, they have greater difficulties with the journalistic transformation of scientific knowledge and often associate it with distortions and inaccuracies (64–66).

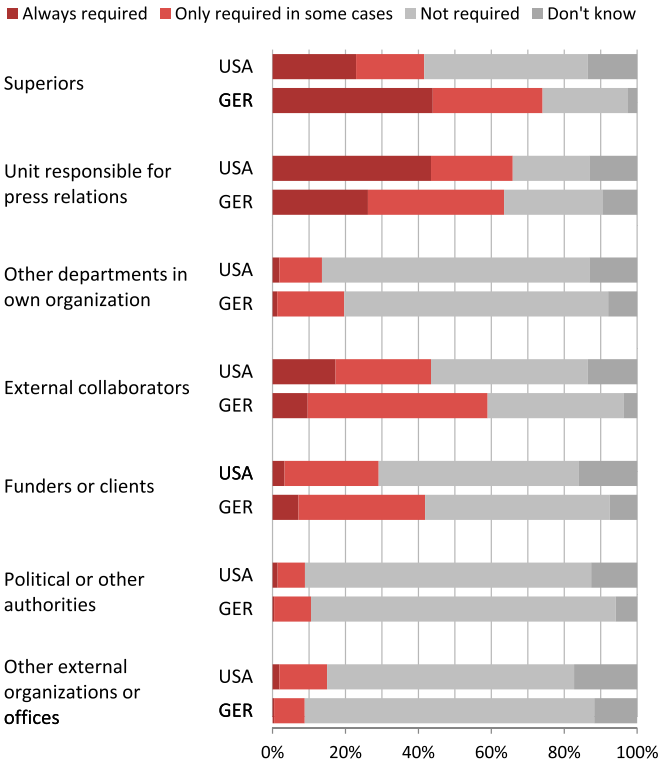

Fig. 5. Consultation requirements of scientists before media interactions. Answers of US neuroscientists ($n = 216$) and German neuroscientists ($n = 241$) to the question: "If you want to talk to a journalist about your research, whom do you have to consult in advance?" Methodological details of the surveys are provided in *SI Methods*.

Although scientists, on average, rate the quality of media coverage of science in general as neither clearly positive nor negative (32, 35, 57), they are mostly positive about their own encounters with the media (47). More than 50% of the biomedical researchers from the five countries surveyed in 2005, and approximately 70% of the US and German neuroscientists surveyed in 2011 to 2012, were "mostly satisfied" with their media encounters. Only a "few" percent were mostly dissatisfied. German surveys conducted between 1983 and 2011, in which a similar question about satisfaction with their own media encounters was repeatedly asked, suggest that researchers' satisfaction with journalism increased somewhat in this period (67). A plausible reason for increased satisfaction is a change in the evaluation criteria. In keeping with the "strategic move" in science communication mentioned earlier, researchers today may base their judgment of success less on whether their message has reached the media audience undistorted and more on whether it has alerted funders and other key actors, including the management of their own organization, to the relevance of their work. Different criteria may also explain the discrepancy in their assessment of coverage of their research field in general and of their own experiences with the media. In rating their own experiences, researchers might tend to apply criteria of perceived benefit; when assessing the coverage of colleagues' research, they might base their judgment on content quality (57). The generally positive picture of scientists' media interactions suggested by surveys should not mask the fact that there are "hot spots" in the relationship between science and the public where the relations between scientists and journalists are tenser.

One of the main problems in dealing with journalism from the scientists' point of view is a lack of control over the communication process. In the five-country study of biomedical researchers, "risk of incorrect quotation" and "unpredictability of journalists" were the two items from a list of possible concerns that found the strongest agreement (47). Both items point to a perceived lack of control over the interactions with journalists and their outcome. Surveys show that scientists try to maintain control over the knowledge they provide to journalists; they expect to be consulted before a journalistic story is actually published, for example. In the five-country study, there was almost unanimous agreement with the item that "journalists should permit scientists to check stories in which they are quoted prior to publication" (68). Interestingly, in two surveys in which scientists and journalists were asked to respond to the same set of items, that item was the one on which the two groups disagreed most (17, 21).

Although many scientists have mixed feelings about the quality of coverage of their research field, most tend to be rather satisfied with their own media interactions. The generally positive experience does not preclude occasional conflicts between scientists and journalists caused by inaccurate or critical coverage or disagreement about the rules of interaction.

Challenges of the Present and Future

This article began with a retrospective of the science–media relationship; its final section will raise some issues regarding the future of that relationship. Two developments are challenging the once quasi-monopoly of science journalism in public science communication: the "Public Engagement with Science and Technology" movement originating in the United Kingdom and favoring direct, face-to-face and dialogic communication between scientists and members of the public in preference to

mediated communication (14, 69), and—more far-reaching and consequential in the long run—the structural transformation of the public communication system caused by the proliferation of online communication. Media studies show a clear trend on the part of audiences toward online media (70–72).

As technical and financial restrictions on addressing the public directly online have largely disappeared, nearly all science organizations and many individual scientists have turned to the new communication sphere: they create Web sites and blogs, participate in social networks, and upload videos that compete with the content provided by professional science journalism. The new communication system allows a more symmetrical communication and the formation of online communities focusing on certain topics via social networks such as Twitter and Facebook. Many scholars welcome these opportunities, as they expect them to enable a more dialogic form of science communication, increased participation of laypeople in scientific debates and debates on science policy, and discourses about the ethical, legal, and social implications of research (73–77).

Although this alternative system of public communication is already forming, it is unclear whether it will finally supplant or merely supplement science journalism (70, 78, 79). Some expect that science journalism will successfully transfer to the Internet, leading to online versions of well-known news media, adapted to the characteristics of the Internet (e.g., interactivity, hypertext structure, and multimedia). Others point to the current economic crisis of many of the "old" journalistic media, and expect that direct participation of scientists in social media, science bloggers, or "citizen journalists" can successfully replace classical journalism.

Science communicators may have different motives in looking for alternatives to science journalism. Many are probably attracted by increased control over the process and content of communication if they can avoid the interference of mediating journalists. Others may see dialogic communication with the public as more effective in terms of instructing or persuading the audience compared with the one-way dissemination typical of traditional science journalism (69). Finally, some may welcome the participation of laypeople in the governance of science or their inclusion in knowledge production—either on normative grounds to improve democracy, or instrumentally as a means to increase public support of science (80, 81). It is unclear so far how the majority of scientists will respond to the new options. If only a small proportion of researchers become active in the new media, the critical discussion about biased selection of scientific sources by journalism (66, 82) would then be followed by a similar discussion about the patterns of self-selection of scientists participating in the new media. Recent research has indicated that scientists tend to be skeptical of the abilities and attitudes of the "public" with respect to science (32). Such beliefs may hinder the full development of the democratic potential of the new media.

One might expect that a new generation of scientists, having grown up with interactive online communication, will prefer dialogic forms of science communication, seeing less of a boundary between internal scientific and public communication, and will welcome public involvement in science governance and knowledge production. Results of the five-country survey as well as of the cross-disciplinary German survey provide some insight into the beliefs of scientists about the public, and how these beliefs differ between age groups (Tables S1 and S2). The data suggest that scientists in different countries are not very convinced about the public's ability to understand scientific findings (Table S2, item 3) and are clearly critical of public participation in decision-making on research policy (Table S1, item 5; Table S2, items 4). Scientists strongly believe that increasing the knowledge of the public has persuasive effects on public attitudes toward science (Table S1, item 2, and Table S2, item 1). Despite these beliefs, scientists agree that it is "essential to establish communication as a dialogue between two equal partners" (Table S2, item 7) and mildly reject a paternalistic attitude (Table S1, item 3). At the same time, they want to exclude the public from internal scientific communication (Table S1, item 1). Scientists are thus ambivalent: they respond affirmatively to the normative expectation of conducting a dialogue with the public; on the contrary, they feel restricted by their perception of the public's limited competence in dealing with science as well as by the scientific norm of separating internal scientific and public communication. Remarkably, only few differences between the age groups are statistically significant; overall, the data do not show that younger scientists are more inclined toward dialogue and inclusion of the public in science than older scientists. Nor is there a significant age effect in the preferred forms of communication with the public (Table S2, items 5 and 6).

The future of science journalism, and, consequently, the future of the relationship between science and the media, is uncertain. The new media such as blogs and social networks open up new opportunities for science communication. If the expectations of social media protagonists were to come true, the "gap" between internal scientific communication and public science communication would be narrowed. Will this happen, and what would be the consequences? Investigating these questions is certainly a priority for science communication research.

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