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Informal Learning Through Science Media Usage

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This article reviews current research on informal science learning through news media. Based on a descriptive model of media-based science communication we distinguish between (a) the professional routines by which journalists select and depict scientific information in traditional media and (b) the psychological processes that account for how media recipients select, process and integrate such information. We argue that science literacy and media literacy in laypersons can be promoted by combining insights from the research on mass media production, laypersons' reception processes and the interplay of both. Moreover, we point out potential obstacles and biases in the process of science communication and suggest strategies to prevent such problems using media-based elements of science communication. Focusing on "traditional" news media in the main parts of the article, we conclude with reflections on how online sources might change the interplay between information demand and supply.

Societies around the world evolve and develop on the basis of scientific research and empirical findings. They apply new healthcare methods, introduce new technologies and new products, and adopt new laws for goals such as environmental protection. The substantial impact of scientific innovations on individuals and society makes it desirable for the public to have adequate information about the scientific process and get engaged in public debates about science. The communication of scientific ideas and insights is therefore an essential concern of modern democratic societies and mass media, particularly news media, provide an important means of enabling such communication (Mende, Oehmichen, & Schröter, 2012; J. D. Miller, Augenbraun, Schulhof, & Kimmel, 2006; National Science Board, 2012; Nisbet & Scheufele, 2009; Nisbet et al., 2002; Pew Project for Excellence in Journalism, 2010).

Whereas formal scientific learning happens traditionally in schools and universities, media use provides an opportunity for informal scientific learning that is neither bound to educational environments nor limited to preselected or privileged segments of society. Different media formats (e.g., reports, science shows, documentations, fictional stories) in different outlets (e.g., newspaper, radio, TV, Internet) can promote informal scientific learning. Although a lot of opportunities for informal scientific learning are now provided by online content that is shared and distributed from peer to peer (e.g., Wikipedia) or directly by scientists (e.g., via social media), we focus on professional news media, that is, mass media formats that are edited by professional journalists. There are three main reasons for this focus. First, survey data provide evidence that traditional media (e.g., TV, newspaper, magazines, documentary film) are still very important sources for laypersons' information about science, even though the Internet has rapidly advanced as an information tool (e.g., Dudo et al., 2011; National Science Board, 2012; Nisbet & Scheufele, 2009; Scheufele, 2013). Second, there is still very limited empirical evidence on how the increasing relevance of online information changes the usage and understanding of science-related contents (Brossard & Scheufele, 2013). Third, literature from the political domain indicates that the traditional media have kept their influence in the online world, whereas evidence of offline effects for online content are much less common (e.g., Leskovec, Backstrom,

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& Kleinberg, 2009). In this regard, it seems likely that much of the most-read online science content is written by journalists working for organizations that maintain an offline presence. Therefore, we focus on informal science learning through established news media in this article and tackle the question how online opportunities might reshape science processes in the concluding section of the article.

Our goal in this article is to propose a descriptive model of the relationship between the media system providing journalistic formats for science communication and laypersons' learning processes based on the reception of science news content (see Figure 1). In this model of media-based communication, we outline the processes by which journalists select and depict scientific information as well as the processes that account for how individuals select, process, and integrate science information. The benefit of the proposed model for the understanding of media-based science communication is threefold. First and most important, our model aims at improving both science literacy and media literacy in laypeople by providing epistemic knowledge about the processes through which informal learning is facilitated by science news. The model describes important phases in the process of knowledge transition from the scientific representation of knowledge to laypersons' mental representation of scientific insights. From the perspective of Educational Psychology, the understanding of (a) news media production logic, (b) the laypersons' reception processes, and (c) the interplay of both can provide an important basis for the development of science literacy and media literacy in laypersons (Chinn, Buckland, & Samarapungavan, 2011). The apparent need for these literacies arises from the idea that the pace of knowledge production continues to increase, and thus laypersons will increasingly face issues involving assessments of scientific evidence and for which they may need to make a decision (e.g., when choosing between different medical treatments, consumer products, or political candidates).

A second benefit of our model results from the fact that scientific knowledge is characterized by features such as vagueness, reliance on probability assessments, and ambiguity—in short, uncertainties (e.g., Frewer et al., 2002; Friedman, Dunwoody, & Rogers, 1999; Jensen & Hurley, 2012; Johnson, 2003; Kouw, Van Den Heuvel, & Scharnhorst, 2013; Rabinovich & Morton, 2012; Smithson, 1989) that can easily produce misunderstandings and biases in the process of science communication and reception. Science communication researchers must therefore consider the impact of scientific uncertainty on how the conventions of journalism shape learning processes in laypersons. Our model points out phases in the process of media-based science communication that are sensitive to biased communication and reception and integrates theories from both psychology and communication science that can account for these biases.

Third, our model allows for the identification of research gaps in the science communication literature. We highlight these research gaps throughout the article. In the concluding section, we specifically address the question how the processes described might change as the public moves toward increased use of online sources. In the following paragraph, we first outline our model of media-based communication.

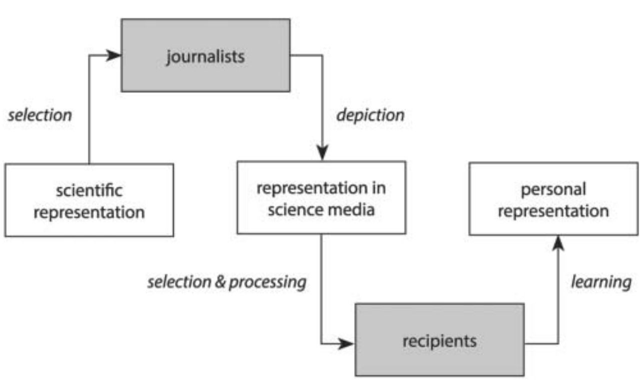

FIGURE 1 A descriptive model of media-based science communication.

A DESCRIPTIVE MODEL OF MEDIA-BASED SCIENCE COMMUNICATION

For the understanding of informal learning through science media usage, it is important to analyze the reciprocities between the scientific system, the media system, and the audience (see also Klimmt, Sowka, Rothmund, & Gollwitzer, 2012). In the present article, we focus on (a) how journalists select and feature scientific research in traditional news media; (b) how laypersons select, process, and integrate this information into existing knowledge structures; and (c) how both of these facets of science communication are mutually interdependent. Thus, to understand the process of informal learning through science media usage, we need to differentiate between two perspectives on perceiving, processing, and representing scientific research: a *journalistic perspective* and a *recipient perspective*.

The journalistic perspective focuses on the production of science media formats and is primarily reflected in the transformation of scientific representations (e.g., the current state of research in the area of media violence) into journalistic representations (e.g., the coverage of research in an article on the debate about violent video games; see Figure 1). Of importance, this communication process is based upon logical and financial constraints that are inherent to advertising-supported media systems. For example, the acceptance of the journalistic products by the audience is an essential criterion for journalistic success and thus determines science communication from the journalistic perspective (Dunwoody, 2008). On a more abstract level, the interdependencies between demand (audience) and supply (mass media product systems) reflect a crucial feature of science communication in the news. As we outline in more detail next, these constraints have a systematic impact on how scientific content is selected and transformed into news content by journalists.

The *recipient perspective* highlights the psychological underpinnings of laypersons' reception of science news. These include the selection and processing of science media representations (e.g., scientific documentations) and the learning or integration of ideas and insights into personal knowledge structures (e.g., cognitions, beliefs, attitudes). This process of knowledge acquisition varies depending on attributes of the recipient (e.g., personal interest) and attributes of the message (e.g., complexity of an argument). Of importance, the selection, processing, and learning of scientific information can be affected and even distorted by cognitive (e.g., cognitive overload) and motivational (e.g., confirmation bias) effects. We outline some of these effects and focus on the question how characteristics of media-based science communication can amplify these effects.

The sections of the current article are structured based on our model of media-based science communication. First, we focus on science communication from a journalistic perspective. In this part of the article, we outline (a) journalists' selection routines as well as (b) the way in which they typically depict scientific information. We then focus on the recipient perspective. We differentiate between (c) the selection and processing of media content by the audience, and (d) learning effects concerning cognitions, beliefs, affects, attitudes, interest, and behavior. We point out which aspects are crucial to the development of epistemic knowledge regarding science communication through "traditional" media and provide an outlook to perspectives brought about by "new" media.

JOURNALISTIC PERSPECTIVE IN MEDIA-BASED SCIENCE COMMUNICATION

From a normative perspective, it appears desirable for science journalism to promote the general public's understanding of scientific processes and its correspondent uncertainties. However, there has been an ongoing debate, as to whether media coverage can be expected to meets the normative desires of the academic system (Goldman & Bisanz, 2002; Kua, Reder, & Grossel, 2004). A number of authors have criticized inaccuracies and simplifications in journalistic pieces about science (Cooper, Lee, Goldacre, & Sanders, 2012; Hijmans, Pleijter, & Wester, 2003; Klimmt et al., 2012; Leon, 2008; Milde, Günther, & Ruhrmann, 2013; Stocking & Holstein, 1993), whereas others have pointed to the specific logic of the media system. For example, Günther and Ruhrmann (2013) stated, "Scientists want to inform the public, while journalists want to satisfy the audience's needs" (p. 22; see also Dunwoody, 2008; Hodgetts, Chamberlain, Scammell, Karapu, & Nikora, 2008; Milde & Hölig, 2011). The question of which science-related issues journalists choose to report about and how they depict these issues is crucial to the analysis of science communication. However, students and laypersons should also be aware of the specific logic of the media system in order to reflect on the reliability of media claims (Chinn et al., 2011). As discussed next, in traditional media, journalists are "gatekeepers" for public communication about science. This means they decide not only which topics get put onto the public "agenda" but also how these topics get "framed." In doing so, they shape the information the public may learn and attitudes that the public may develop. In the next paragraph, we first turn to the selection process of scientific topics for media publications by journalists (see Figure 1).

Selection Routines in Science Journalism

Selecting topics and editing texts for publication are the core professional tasks of journalists and knowledge about these routines is central to the understanding of the origin of media content. The selection of issues is challenging because the many sources journalists have access to provide an overwhelming amount of information. At the same time, journalists face constraints on the amount of space that their publications are willing to devote to science and the amount of time they can devote to producing stories (see also Clark & Illman, 2006). Science has a number of features that attract journalists' attention but many aspects of science may also seem daunting (see next). To explain journalists' news selection processes, research on science communication relies on theories well established in journalism studies,[1] for example, "gatekeeping" theory (Lewin, 1951; White, 1950), which uses the metaphor of the gatekeeper for the journalist—including editors and producers—who decides which information get published. Gatekeeping research has shown that there exist five categories of factors that influence the selection of topics in science journalism (see, e.g., Shoemaker & Reese, 1996; Shoemaker, Vos, & Reese, 2009): (a) individual factors, (b) professional routines, (c) organizational influences, (d) influences by journalists from other media, and (e) influences by the media system and society.

[1]Journalism studies are one of the very traditional and active fields in communication research, and so is research on science journalism within science communication. There is a huge amount of relevant papers published. Due to space restrictions and the focus of this special issue, we can't provide a complete literature summary on science journalism here, and therefore decided to report only empirical data that was collected since the year 2000. The significant changes in the media market and organizations may add to the plausibility of this decision, and we apologize for this systematic limitation.

On the *individual level,* science journalists select news topics in part according to their own individual *interests* (see Günther & Ruhrmann, 2013; Stocking & Holstein, 2009, also for critical remarks), *beliefs*, and *attitudes*. Such beliefs and attitudes also manifest themselves in the *role perceptions* science journalists have. Studies across countries have shown that although objectivity, balance, and credibility are the central premises for science journalism (Clarke, 2008; Dunwoody, 2008; Hodgetts et al., 2008), many science journalists not only see themselves as neutral "disseminators" of facts but want to provide the information necessary to enable critical reflection on scientific findings (e.g., Meier & Feldmeier, 2005; Stocking & Holstein, 2009). Practically this means, that most journalists will seek to provide balanced reports about developments in science taking into account different perspectives whenever available. However, a significant number of science writers will also try to provide their audience with additional information in order to stimulate a critical reflection on the topics. For the most part, however, journalists themselves will provide subjective reflections on issues only in clearly marked commentary sections of the media. The task of critical reflection based on media information is to a great deal assigned to the citizens.

On the *level of professional routines,* selection processes are guided, for example, by whether a particular topic is newsworthy (see Galtung & Ruge, 1965; O'Neill & Harcup, 2009; Östgaard, 1965). For science journalism, the *news factors* novelty, composition (adding to the variety of issues), controversy (including uncertainty of scientific evidence and disagreement between scientists), and range (number of people affected/relevance for the audience) have been shown to be highly important in several studies (Badenschier & Wormer, 2012; Goldman & Bisanz, 2002; Günther & Ruhrmann, 2013; Hijmans et al., 2003; Hodgetts et al., 2008; Leon, 2008; Stocking & Holstein, 2009). This means that new science topics that are controversial among experts but at the same time have the potential to affect many people have a good chance to be picked up by journalists.

On the *organizational level*, Dunwoody (2008) and Milde and Hölig (2011) pointed out the relevance of editors' priorities (see also Chinn et al., 2011), meaning that most journalists will follow the selection rules the management of their organization sets. Empirical evidence for an *extra-media-level* influence on science journalism is thinner. However, an exploratory study by Günther and Ruhrmann (2013) found that 38% of the science journalists said that *colleagues from other media outlets* were important points of reference to them. The final level comprises the influences of *media and social systems* in that evidence suggests that the *national context* (e.g., perceived public opinion) influences science journalists' choices. For example, the works by Zehr (2000) and Olausson (2009) convincingly show that media coverage about global warming is determined by national public opinion: Whereas in the United States scientific evidence about global warming was described as highly uncertain in the media, Swedish journalists depicted it as taken for granted.

Although there is both a theoretical reason and convincing empirical evidence to assume that factors on all these different levels contribute to the selection of scientific topics for publication (also see Nelkin, 1987), the relative impact of these factors has not yet been assessed (also see Engelmann, 2012). In the following, we therefore inspect the findings of media content analyses to provide a more detailed description of actual media coverage of science (see "representation of science topics in media" in Figure 1).

Depiction of Science in the Media

Two concepts that are central to communication studies—agenda setting and framing—focus on how news content depicts science. *Agenda setting* theory follows the idea of "the mass media presenting certain issues frequently and prominently with the result that large segments of the public come to perceive those issues as more important than others" (Coleman, McCombs, Shaw, & Weaver, 2009, p. 147). Assessing how much science information is readily available is therefore central to agenda setting processes. However, the amount of science news that is available to consumers and how this might have changed over time remains unclear. Some researchers claim that science coverage has intensified over recent decades (e.g., Elmer, Badenschier, & Wormer, 2008; Leon, 2008; Schäfer, 2009), whereas others point to a decline in science coverage due, for example, to significant budget cuts within newsrooms (e.g., Dudo, Dunwoody, & Scheufele, 2011; Nisbet & Scheufele, 2009). Finally, content analyses have revealed that the amount of coverage varies depending on topics, dynamics of events, and country-contexts (e.g. A. Anderson, Allan, Petersen, & Wilkinson, 2005; Bauer, 2009; Dudo et al., 2011; Kjærgaard, 2010; Leon, 2008; Listerman, 2010; Marks, Kalaitzandonakes, Wilkins, & Zakharova, 2007; Schäfer, 2009; Weaver, Lively, & Bimber, 2009; Weingart, Salzmann, & Woermann, 2008). In the United States, science news appears to make up only about 2% of mainstream news content in newspapers and the main evening newscasts of the major networks (National Science Board, 2012). Generally speaking, science coverage rarely appears during prime-time or on the front page (Elmer et al., 2008; Leon, 2008; Maeseele & Schuurman, 2008; Milde, 2009; Verhoeven, 2010). A range of specialty channels for science news have emerged in recent years (e.g., the Discovery Channel in the United States and countless websites and blogs), but research has not assessed yet how the emergence of such outlets may have affected agenda-setting processes. It seems likely that, at a relative to other subjects, science information receives little prominent media attention. Regarding the question of which specific science topics are covered by the media, Dunwoody (2008) found that most reports in science journalism across the world were about medicine and health, especially in newspapers, whereas there was a focus on natural history and environmental issues on TV (see also Clark & Illman, 2006; Elmer et al., 2008; Hodgetts et al., 2008; Verhoeven, 2010).

The second concept—*framing*—deals with the question of *how* journalists depict scientific information. The central notion is that journalists strategically choose an "organizing idea", so-called frames (Gamson & Modigliani, 1989; see also Entman, 1993; Entman, Matthes, & Pellicano, 2009), for the story they will produce, thereby lending greater weight to certain considerations and arguments over others, translating why an issue might be a problem (or an opportunity), who or what might be responsible, and what should be done" (Nisbet & Scheufele, 2009, p. 1770). For example, the use of nano-materials in medicine could be described from the perspective of possible benefits for patients stemming from the specific characteristics of the materials. Alternatively, it would be possible to emphasize risks, as no long-term experiences are currently available. Nisbet and Scheufele (2009, pp. 1771–1772), building on Gamson and Modigliani (1989), list eight frames that are often used in the public communication about science: (a) social progress, (b) economic development/competitiveness, (c) morality/ethics, (d) scientific/technical uncertainty, (e) Pandora's box/Frankenstein's monster/runaway science, (f) public accountability/governance, (g) middle way/alternative path, and (h) conflict/strategy. Recent empirical studies have pointed towards the importance of a "utility" frame, which stresses that aspects of science are beneficial to human life, and which may be seen as a version of the "social progress" frame (Donk, Metag, Kohring, & Marcinkowski, 2012; Listerman, 2010). This is in line with the majority of studies that seem to support Dudo, Brossard, et al. (2011), who claimed that science coverage in the media draws a primarily positive picture of science (e.g., Elmer et al., 2008; Groboljsek & Mali, 2012; Kjærgaard, 2010; Milde, 2013; Ruhrmann, Günther, Kessler, & Milde, 2013; Stephens, 2005; Ten Eyck & Williment, 2003; Vicsek, 2011). However, not all findings on the evaluative tone of science coverage are quite so clear (also see Hijmans et al., 2003). Marks et al. (2007) found very different evaluations for two sets of biotechnology in the United States and the United Kingdom: a significantly more positive coverage pointing to more benefits for medical applications of biotechnology, and a more negative coverage emphasizing the risks for agricultural applications. Their findings stress the variation of evaluations depending on topics, the attitudes journalists hold toward these, and the social context (e.g., public opinion toward this topic as aforementioned).

Regarding the presentation of scientific uncertainty (Frame 4) and controversy (Frame 8) in media coverage, there is some discrepancy in the findings. Ruhrmann et al. (2013) and Milde (2013) found quite different proportions of uncertainty and controversy in the coverage on molecular medicine and nanotechnology in German TV science magazines, and print outlets. Zehr (2000) and Olausson (2009), as mentioned already, came to contradictory results regarding the coverage of climate change research in the United States and Sweden. However, the total number of studies concluding that news coverage neglects uncertainty of scientific evidence seems to be higher than the share of studies finding that the uncertainty frame is common (see Cooper et al., 2012; Dudo, Dunwoody, et al., 2011).

Taken together, we can state that media coverage of science, in general, comes to rather positive evaluations and does not often bring scientific uncertainties and quarrels to the fore. Instead, the so-called "utility" frame, which stresses that aspects of science are beneficial to human life, seems to be very common. However, uncertainty is an inherent feature of scientific processes, and it seems desirable that laypersons develop a critical appreciation of this facet of science. The literature summary leads us to the conclusion that media will point out uncertainties only if specific news factors (e.g., controversy) are very prominent (e.g., if scientists engage in a public dispute regarding conflicting findings or interpretations) or if the social context (e.g., public opinion) seems to call for a controversial coverage. To overcome these biases, students and laypersons in general should develop the skill to critically reflect on science-related media contents. As is discussed next, the characteristics of science media coverage have the potential to influence the knowledge, beliefs, and attitudes that laypersons develop about and toward science. However, individual patterns of science media usage must be taken into account.

RECIPIENT PERSPECTIVE ON MEDIA-BASED SCIENCE COMMUNICATION

We now address the psychological underpinnings of how recipients select, process, and integrate media-based science communication. The goal is to increase epistemic knowledge not only regarding the media production logic but also regarding the psychological processes and mechanisms underlying media reception. In line with our theoretical model of media-based science communication, we distinguish between two phases of the reception process (see Figure 1). First, recipients select and process scientific content through mass media communication (selection and processing). In this part we emphasize the motivational underpinnings of media selection and outline how motivation can promote, and even bias, the selection of scientific content. In regard to cognitive information processing, we address the fact that scientific content generally requires high resource allocations (RA) on the side of the recipient. Based on this boundary condition for the processing of scientific information, we discuss different ways of preventing cognitive overload using media-based elements of science communication.

Second, we address learning processes in media recipients and distinguish between media effects on *cognitive* variables (especially scientific knowledge), *beliefs* (e.g., about the nature of science and scientific evidence), *affective* reactions (e.g., toward emerging technologies), *attitudes* toward science or scientists, *interest* in science, and *behaviors* (such as the engagement in environmentally sustainable behavior).

Selection and Processing of Educational Content

When media recipients are asked which topics they want to learn about through news media, "scientific research" is mentioned frequently and recipients' interest in scientific content sometimes even exceeds politics or sport (for the United States, see Burns, O'Connor, & Stocklmayer, 2003; Durant, 2010; for Europe, see Eurobarometer, 2008, 2010). However, this high self-reported interest is not reflected in the consumption of science-related media content. For example, in Germany, there is not one science-related item in the 20 most-watched formats (for a similar situation in the United States, see Pew Research Center for the People and the Press, 2008; Pew Research Center's Project for Excellence in Journalism, 2013; Zubayr & Gerhard, 2012). This discrepancy between high self-reported interest and low selection rates raises the question of which motivational and cognitive processes underlie the selection and usage of science-related information in mass media and how these processes can impede the choice of and the engagement with scientific media content.

Media Selection and Motivation

Uses and gratification approaches in media psychology emphasize the idea that media recipients actively select media content in order to satisfy basic needs or receive gratifications from media consumption (e.g., Blumler & Katz, 1974; Rayburn & Palmgreen, 1984). Based on this line of thinking, the *information utility model* (Atkin, 1973) conceptualizes the selection of (scientific) information in mass media as a rational choice that depends on an individual's motivation and message attributes. In other words, recipients choose content if they expect this content to be useful based on their current motivations. For example, a woman who is diagnosed with breast cancer might be motivated to search for scientific information on breast cancer treatments because she is motivated to identify effective treatment options. This assumption is line with the idea that information seeking and selection in media is generally determined by a sufficiency principle (Griffin, Dunwoody, & Neuwirth, 1999). Information sufficiency is reached when the current knowledge somebody has on a specific science-related topic meets the amount of information that is needed by the person. When information insufficiency is high the motivation for effortful selection behavior is expected to be high (Griffin, Neuwirth, Dunwoody, & Giese, 2004; Kahlor & Rosenthal, 2009). In contrast, perceived information sufficiency can lead to information avoidance (Kahlor, Dunwoody, Griffin, & Neuwirth, 2006). The sufficiency threshold itself is influenced by personal predispositions like attitudes (Z. J. Yang, Kahlor, & Li, 2013) and emotional responses toward the presented scientific information (Z. J. Yang & Kahlor, 2012). If somebody, for example, lives next to an industrial plant, his need for information on environmental pollution may be rather high, and thus his or her selection and processing of scientific information concerning these hazards may be more effortful. As soon as his or her need for information is met, the selection and seeking behavior will become more superficial (see, e.g., Z. J. Yang et al., 2013). This information sufficiency principle has been demonstrated to predict seeking and selection behavior in different contexts of science communication like climate change communication (Griffin et al., 2008; Z. J. Yang & Kahlor, 2012), communication of industrial hazards and environmental pollution (Griffin et al., 2004; Johnson, 2005; ter Huurne, Griffin, & Gutteling, 2009), and health communication (Z. J. Yang et al., 2010). The sufficiency principle has also been validated across different cultures, including the Netherlands, the United States, and China (ter Huurne et al., 2009; Z. J. Yang et al., 2013). From an educational perspective, the sufficiency principle highlights the importance of problem-based learning in informal learning environments (e.g., Hmelo-Silver, 2004). But how can information insufficiency be understood from a motivational perspective?

In his information utility model, Atkin (1973) distinguished between four motivations for searching (scientific) information through mass media: guidance (what is happening?), performance (how should I do it?), surveillance (is there danger or risk?), and reinforcement (how can I get affirmed?). On a more general level, the first two motivations reflect accuracy motivations (i.e., the desire to form accurate appraisals of stimuli; Hart et al., 2009), whereas the latter reflects defense motivation (i.e., the desire to defend one's existing attitudes, beliefs and behaviors; Hart et al., 2009).

Of interest, there is very limited empirical research that tests the relevance of accuracy motivation for the selection of scientific media content. There are some correlational studies showing that epistemic needs promote the search of scientific information in news media (Dehm, 2008; Littek, 2012). Recently, Winter and Krämer (2012) found that individuals with a high need for cognition were more likely to prefer two-sided scientific argumentation to one-sided argumentation (in this case, scientific information about the effects of violent media). Because two-sided scientific argumentation generally involves a higher amount of uncertainty compared to one-sided argumentation. This finding could indicate that accuracy motivation increases exposures to uncertainty and ambiguity in science communication. However, the relevance of accuracy motivation for media selection in the area of science communication as well as the boundary conditions for such relationships remain largely unclear.

The relevance of defense motivation for media selection has been investigated in more detail. In line with Atkin's (1973) idea of reinforcement motivation and based on the predictions of cognitive dissonance theory (Festinger, 1957), Zillmann and Bryant (1985) introduced the concept of *selective exposure*, which describes an individual's tendency to preferably select messages that are in line with prevalent attitudes and beliefs or satisfy individual needs and goals (for an overview, see Hart et al., 2009). In line with these predictions, Rothmund, Bender, Nauroth, and Gollwitzer (2013) showed that pacifists exposed themselves to more scientific arguments for the harmfulness of violent video games compared to scientific arguments that speak against the harmfulness of violent video games. Likewise, religious beliefs influence exposure to (and the effects of) media information about genes and health (Parrott, Silk, Raup Krieger, Harris, & Condit, 2004). Both findings are in line with meta-analytic results from Hart et al. (2009), indicating that selective exposure is more pronounced when attitudes or behaviors are highly relevant to people's core values or held with strong conviction. Further research on selective exposure has identified recipient variables and message attributes that buffer or enhance defense motivation and selective exposure in the context science related messages (for an overview, see Smith, Fabrigas, & Norris, 2008). First, on the side of the recipient, attitude consistent exposure to news seems to be more relevant for people with low openness (Hart et al., 2009) and high need for cognitive closure. Recipients with high need for cognitive closure are even more motivated to reduce the complexity of media choice and thus more prone to selective exposure (Fischer, Schulz-Hardt, & Frey, 2008). Moreover, attitude consistent media selection is reduced when attitude consistent messages are perceived as low in credibility or information quality (Hart et al., 2009; Winter, Krämer, Appel, & Schielke, 2010). From the perspective of educational psychology, the existence of selective exposure to scientific content in mass media provides an explanation for how people can develop contradictory representations of the same state of evidence in a given field of research. For example, 67% of Republicans compared to 20% of Democrats in the United States believe that news of global warming is exaggerated (Gallup, 2012). This finding can be partly explained by means of defense motivation on the side of Republicans (Feygina, Jost, & Goldsmith, 2010).

Concluding, exposure to scientific information in news media follows the sufficiency principle and can be driven by accuracy motivation and by defense motivation. Whereas accuracy motivation seems to promote a rather balanced search for scientific information, defense motivation can enhance selective exposure to one-sided scientific information that is in line with preexisting attitudes or beliefs. From the perspective of educational psychology, the relevance of defense motivation for the engagement with scientific content in news media nicely illustrates that informal learning is not always driven by epistemic motives. Further research is needed in order to investigate how selective exposure to scientific information is amplified by structural elements of scientific information (e.g., uncertainty), by social identification and group processes (e.g., Nauroth, Gollwitzer, Bender, & Rothmund, 2014), and by the increasing use of online communication. We follow up on the latter in the concluding section of this article.

Information Processing and Cognitive Load

To understand how media recipients learn from media-based science communication, we also need to focus on information processing during the reception of science-related information. The *limited capacity model of mediated message processing* (LCMP; Lang, 2000) highlights the fact that informal learning through mass media depends on the amount of cognitive resources individuals allocate to information processing. Lang (2000) distinguished between three sub-processes in information processing: encoding, storage, and retrieval. Learning outcomes depend on the performance of all three processes and as a function of the resources required (RR) by a message and the RA by a media recipient.

Of importance, the understanding of scientific content often requires a high amount of cognitive resources (RR). When RR is high and RA is low, cognitive overload is likely to occur as more resources are required than are allocated by the recipient (Mayer & Moreno, 2003). Research on informal learning through television (D. R. Anderson, Lorch, Field, & Sanders, 1981; Valkenburg & Vroone, 2004) indicates that cognitive overload leads to a drop in motivation and attention and to a decrease in learning. Thus, one question that needs to be addressed in regard to information processing is how cognitive overload can be avoided during the reception of scientific media content. Generally speaking, we distinguish between two ways of preventing cognitive overload have been identified: reducing RR and increasing RA (Buijzen, Van Reijmersdal, & Owen, 2010).

The amount of RR for understanding and learning largely depends on the complexity of the message. Thus, to *reduce the RR* for the processing of scientific information, the complexity of the information must likewise be reduced. This may be achieved by journalistic ways of structuring content, for example, by using advance organizers (e.g., Calvert, Huston, & Wright, 1987; Neuman, Burden, & Holden, 1990), summaries (e.g., Kelly & Spear, 1991; Mayer, Bove, Bryman, Mars, & Tapangco, 1996), repetitions (e.g., Michel & Roebers, 2008), and graphics (e.g., Johnson & Slovic, 1995). Advance organizers in journalism are "cues presented early in the program to alert viewers as to its subject matter, such as previews of upcoming material" (Fisch, 2000, p. 71). These journalistic tools can help recipients to direct attention more efficiently to the science-related media content and to more easily extract core information.

To *increase the RA* during media reception, Lang (2000) proposed two means: (a) increase of novelty, unexpectedness, or change in the media message, and (b) increase the relevance to the goals and needs of the recipient (Lang, 2000). The first class of message characteristic primarily refers to *formal features* (e.g., auditory and visual characteristics that result from production and editing techniques, such as cutting, headings, or sounds; Huston et al., 1981). Perceptually salient formal features have been shown to attract attention and are therefore likely to increase RA (Barr, 2008). On the other hand, the relevance of media messages to the goals and needs of recipients is primarily dependent on *content features*. Fisch (2000) distinguished between educational and narrative content in scientific TV formats. Educational content refers to the concepts or messages that a science program is intended to convey, which can include both declarative knowledge (e.g., scientific facts) and procedural knowledge (e.g., problem-solving strategies). Narrative content refers to the story presented in a program (e.g., the sequence of events or the goals set and achieved by its characters). This leads us to an interesting way of increasing RA in media-based science education: the integration of educational content in a narrative structure. Narrative structures increase the recipients' involvement in processing information by means of *transportation*, defined as "a convergent process, where all mental systems and capacities become focused on events occurring in the narrative" (Green & Brock, 2000, p. 701). Thus, narrative structures might also increase the amount of cognitive RA to the scientific content. A famous example for the combination of narrative structures and scientific learning in mass media is the TV series *Sesame Street*, which was first broadcasted in 1969. However, Fisch (2000) pointed out that both the comprehension of narrative structures and the comprehension of educational content require cognitive resources. If narrative structures and educational content are more or less independent and distinct, allocating resources to the processing of narrative content stands in conflict to the allocation of resources to the understanding of educational content. However, RA to educational content can benefit from *narrative integration,* if scientific information is semantically or conceptually relevant within a narration (M. Yang & Roskos-Ewoldsen, 2007). Based on the LCMP it is, thus, reasonable to argue that narrative integration can prevent cognitive overload by increasing RA. Yet there has not been sufficient research in order to investigate this assumption empirically. Moyer-Gusé and Nabi (2010) provided empirical evidence that narrative integration can support learning of scientific content by comparing the effects of a narrative versus a non-narrative program on unplanned teenage pregnancy. After exposure to the narrative program, recipients felt more vulnerable to the risks of sexual intercourse without birth control and reported stronger safe-sex intentions compared to recipients who had seen the non-narrative program. These stronger effects from the narrative format on the recipients' beliefs were mediated by increased identification with the teenage characters and decreased counter arguing against the educational message. This finding indicates that narrative integration promotes informal learning by decreasing resistance to the integration of scientific content into knowledge structures (see also Moyer-Gusé, 2008).

Taken together, cognitive overload presents an important obstacle for successful science communication. From the perspective of Educational Psychology, it is important to note that the way scientific information is provided has an important impact on how likely cognitive overload occurs. Whereas journalistic ways of structuring media content can reduce the amount of cognitive RR for the processing of scientific information, narrative integration provides a means for increasing the amount of resources that recipients allocate to a media-based message. Thus, emphasizing strategies for (a) structuring scientific information in media messages and (b) integrating narrative elements in science communication provides an important avenue for Educational Psychology and media-based science communication.

On a more general level, both motivational (e.g., selective exposure) and cognitive (e.g., cognitive load) processes can impede the choice of and the engagement with scientific media content. Thus, both kinds of processes add to the understanding of the discrepancy between high self-reported interest and low selection rates regarding scientific content in media formats. In the next section we outline the psychological underpinnings of successful learning through media-based science communication.

Learning Effects Through Science-Related Media Use

Coming to the final part of our reference model (see Figure 1, learning), we focus on empirically observed *effects* of exposure to science communication on the *public understanding of science* (e.g., Durant, Evans, & Thomas, 1989) and the *public engagement with science* (e.g., Besley, 2010; Kurath & Gisler, 2009; Rogers-Hayden & Pidgeon, 2007; Schäfer, 2009). Potter (2012) distinguished between cognitive, belief, affective, attitudinal, behavioral, and physiological media effects. The first five categories of this classification system are directly transferable to research on informal science learning: *Cognitive* media effects refer mainly to effects on knowledge about science. Research on *belief* effects is often concerned with beliefs about the nature of science (e.g., about the process of scientific inquiry or the certainty of scientific knowledge). *Affective* reactions are mostly investigated in research on risk communication and perception. Risk communication reflects the process of communication about societal or personal risks (e.g., cigarette smoking, nuclear power; see, e.g., Visschers, Meertens, Passchier, & de Vries, 2009). *Attitudes* toward science or scientists and *interest* in science (both being constructs that combine cognitive and affective elements; e.g., Eagly & Chaiken, 1993; Renninger & Hidi, 2011) are also studied intensively. Finally, exposure to science communication could affect *behavior* such as information seeking, consumer decisions, or political engagement. We present empirical evidence on how different forms of science media affect such variables as well as interdependencies between such effects.

Cognitive Effects

Most studies find that science media consumption is associated with more science related knowledge and understanding. In a survey study, Nisbet et al. (2002) found that science TV and print magazine use were both positively related to general factual science knowledge, and science magazine use was also positively related to general procedural science knowledge. In a longitudinal study, Miller et al. (2006) found that local TV newscast viewers recalled a substantial amount of science information even 6 weeks after exposure. Similarly, Southwell and Torres (2006) presented experimental evidence that exposure to science TV news had a positive effect on the perceived ability to understand science. With respect to educational science TV programs for children, Fisch (2009) stated that most evaluation studies find positive effects of exposure to such programs on the children's comprehension of science topics.

There is also correlational data, indicating that science media use and (often self-rated) knowledge about specific scientific topics are positively related. This correlation has been found in the areas of nanotechnology (e.g., Cacciatore, Scheufele, & Corley, 2011; Lee & Scheufele, 2006), biotechnology (e.g., Brossard & Nisbet, 2007), and global warming (e.g., Stamm, Clark, & Reynolds Eblacas, 2000; Taddicken, 2013; Zhao, 2009). Support for the causal effect from science media use on scientific knowledge comes from experimental studies. For example, Kimmerle and Cress (2013) found that watching a documentary film on schizophrenia had a positive effect on knowledge about the disease. Similarly, Reid (2012) showed that participants of focus group discussions learned substantially through the reception of a dramadoc (a combination of factual and fictional content) on stem cell research. However, there are also conflicting experimental findings, showing that no increase in scientific knowledge was observed after exposure to an educational film (Sturgis, Brunton-Smith, & Fife-Schaw, 2010).

Apart from global examinations of the relationship between science media exposure and scientific knowledge and understanding, it is necessary to analyze how different presentation styles moderate these cognitive effects. For example, Yaros (2006) demonstrated that the provision of explanatory structures and explanations of scientific terms were able to boost the understanding of and the interest in scientific content. McQueen, Kreuter, Kalesan, and Alcaraz (2011) found that narrative stories about breast cancer survivors, compared to traditional information stories, were better suited to foster the long-term recall of information.

Taken together, these results suggest that the public understanding of science can be enhanced through informal learning from media-based science communication. More precisely, exposure to science media can foster scientific understanding and general as well as specific scientific knowledge, especially if enough explanations are provided and narrative presentation styles are used. However, there is still little empirical insight into the boundary conditions of these effects (e.g., influence of personality and media characteristics).

Belief Effects

Early studies on media cultivation effects found that heavy TV viewing was associated with rather negative beliefs regarding science and scientists, especially in subgroups with higher socioeconomic status and education levels (Gerbner, Gross, Morgan, & Signorielli, 1981, 1985). Similarly, Lee and Niederdeppe (2011) reported evidence from a two-wave panel survey that TV viewing causes more fatalistic beliefs about cancer prevention, even after controlling for potential confounding variables such as education or age. The authors interpreted the result in ways that the general presentation of cancer-related topics in TV influenced the cancer-related beliefs. However, it should be noted that these negative effects refer to the overall TV consumption of the recipients. Focusing on exposure to science TV programs, Hwang and Southwell (2009), on the contrary, reported positive effects: The more people watch TV news with science content, the higher are their beliefs that science is personally relevant and easy to understand.

With respect to beliefs about the nature of scientific knowledge, Rabinovich and Morton (2012) reported that short information texts were able to alter the recipients' beliefs about scientific uncertainty as an inherent feature of science. These texts were explaining science either as a search for absolute truth (and thereby emphasizing scientific knowledge as certain) or as a constant debate (thereby embracing uncertainty as an inherent feature of science). However, most science media pieces do not convey information about the nature of science in such an explicit way, but rather implicitly, by portraying research or scientific evidence as certain or uncertain. Using real science TV features as experimental stimuli, J. Retzbach, Retzbach, Maier, Otto, and Rahnke (2013) found that the presentation of scientific evidence concerning molecular medicine as either certain or uncertain had little effect on general beliefs about the uncertainty of scientific evidence. These results suggest that science communication can alter beliefs about the nature of science, at least if the respective concepts of science are explicitly explained (cf. Rabinovich & Morton, 2012). In contrast, the learning effects seem to be very small if the nature of science, as being a constant struggle with uncertainties, is only implicitly mentioned in science media reports (cf. J. Retzbach et al., 2013).

Affective Effects

Affective reactions to science communication are particularly relevant in the area of risk perception (for an overview on risk communication, see McComas, 2006). For example, Finucane, Alhakami, Slovic, and Johnson (2000) argued that risk perception and evaluation (i.e., the judgment of benefits and risks in emerging technologies) are often driven by affective evaluations. In line with their assumption that people use affect heuristics for judgments, Finucane and colleagues demonstrated that negative emotions influence both, perceived risks and benefits of various activities and technologies (e.g., cigarette smoking, solar power) especially if cognitive elaboration was restrained. This finding is supported by several studies (Finucane et al., 2000; Keller, Siegrist, & Gutscher, 2006; see also Visschers & Siegrist, 2008). On a more general level, the subjectivity of risk perception is emphasized in the psychometric paradigm (e.g., Dohle, Keller, & Siegrist, 2010).

Attitudinal and Interest Effects

Favorable attitudes toward science are positively related to scientific knowledge and understanding (Allum, Sturgis, Tabourazi, & Brunton-Smith, 2008; Koballa & Glynn, 2007) and the empirical evidence suggests that science media use can foster such positive attitudes. Dudo, Brossard, et al. (2011) reported a small positive relation between newspaper and Internet use and more specific positive attitudes toward science after controlling for possible confounding variables such as education or scientific knowledge. Nisbet et al. (2002) stated that exposure to science TV and print magazines leads to fewer reservations about science and technology. Many other studies focus on the effects of media use on attitudes toward specific scientific topics such as biotechnology (e.g., Besley & Shanahan, 2005), or stem cell research (e.g., Ho, Brossard, & Scheufele, 2008; Liu & Priest, 2009). Most of these studies find small but positive associations between the recipients' general attention to scientific content in newspapers and television and their support of such topics.

It is also clear that the relationship between science media consumption (and the associated informal learning) and scientific interest is likely reciprocal with interest in science, presumably leading to reception of scientific media, which might in turn foster additional scientific interest (cf. Renninger & Hidi, 2011). For example, McPherson, Houseman, and Goodman (2008) showed in an experiment that a science documentary about low-temperature physics was able to increase adults' interest in related scientific issues and their wish to learn more about these topics. However, in an experimental panel study by Sturgis et al. (2010), no lasting effects on interest in genetic science were observed after the reception of an educational film about genomics. With regard to children's interest in science, Fisch (2009) states that the effects of educational science TV shows on children's scientific interest are less consistent than the effects on children's knowledge, but nevertheless mostly positive.

Journalists (Stocking & Holstein, 2009) and scientists (Frewer et al., 2003) sometimes fear adverse effects of the presentation of scientific uncertainties on the public understanding of science, for example, on the trust in scientists or interest in science. With regard to interest in science, there is no evidence for negative effects of uncertainty presentation: J. Retzbach et al. (2013) found that TV reports on molecular medicine presenting scientific evidence as certain increased the viewers' interest in science, whereas the presentation of scientific uncertainty had no effect on this variable. In a similar experiment, A. Retzbach and Maier (in press) could show that media reports stressing the uncertainty of scientific evidence concerning nanotechnology even fostered interest in science in recipients with a low need for cognitive closure.

However, the empirical evidence with respect to trust is mixed. Some studies observed negative effects of presenting conflicting scientific results or positions on the credibility rating of scientists (Jensen & Hurley, 2012; Johnson & Slovic, 1998). Other studies found that there were more positive effects of addressing uncertainties, for example, about risk estimates, on the credibility of scientists or responsible agents (Jensen, 2008; Johnson & Slovic, 1995). These studies indicate that the trustworthiness of scientists might be fostered if the scientific uncertainties are attributed to the honesty and thoroughness of the responsible researchers but hampered if conflicting positions are attributed to the self-interest or the incompetence of the scientists.

Taken together, we can state that the evidence concerning media effects on attitudes toward science is often correlational, but the results suggest that most coverage leads to positive views about science. With respect to interest in science, survey and experimental studies suggest a positive effect of science communication. Whether information about scientific uncertainties has positive or detrimental effects on the trust in scientists seems to depend on the way in which controversies are framed in the media reports.

Behavioral Effects

The effects of science communication on behavior (such as conversations about science) and behavioral change (such as concerning environmentally sustainable behavior) are often mediated by the intervening variables discussed in the preceding paragraphs (e.g., knowledge, beliefs, or attitudes). For example, Southwell and Torres (2006) found that a better understanding of science fostered conversation about science. However, the effect of knowledge on subsequent behaviors is usually rather weak compared to the influence of moral norms, attitudes, or perceived control (e.g., Bamberg & Möser, 2007; Steg & Vlek, 2009; Weber & Stern, 2011).

Beliefs about the nature of science appear may also moderate the effect of information about scientific uncertainty in predicting behavior. For example, Rabinovich and Morton (2012) found that people with a "sophisticated" understanding of science as constant debate (rather than search for absolute truth) were more willing to engage in environmentally sustainable behavior, even if they received information about climate change research that pointed to uncertainties. This is an important result, in light of the fact that other research has shown that the communication of uncertainty can raise skepticism about climate change and undermine the willingness of laypeople to support environmental policies (Corner, Whitmarsh, & Xenias, 2012; Ding, Maibach, Zhao, Roser-Renouf, & Leiserowitz, 2011).

In the context of risk perception, many researchers agree that exposure to risk communication in the media, among other factors such as personal experience or interpersonal communication, can change risk perceptions (McComas, 2006). The evidence as to whether changes in risk perception lead to behavior change is mixed, but researchers have observed moderate positive impacts for health protection behavior (Brewer et al., 2007; Floyd, Prentice-Dunn, & Rogers, 2000). For example, Yanovitzky and Blitz (2000) conducted a longitudinal study to assess the effects of physician advice and media coverage of mammography-related content on women's decisions to obtain a mammogram. They found that, overall, physician advice was the most important predictor of behavior but that news coverage also affected on decision making.

Other specific attitude changes can also influence behavior (Ajzen, 2012). Stryker (2003) reported that adolescents' disapproval of marijuana mediated the effect of exposure to news coverage about the drug on marijuana use. Finally, interest in science or specific scientific topics is an important prerequisite for scientific engagement, for example, an individual's participation in public forums (see, e.g., Powell, Colin, Lee Kleinman, Delborne, & Anderson, 2011).

Summarizing these results, we can state that exposure to science communication can cause learning effects on different dimensions. Overall, science news seems to have small or moderate positive effects on science-related knowledge, beliefs, attitudes, interest, and behavior. However, from the perspective of Educational Psychology, it is important to note that the presented empirical results also show that science media effects are highly dependent on the way that science and research get portrayed. In addition, it should be kept in mind that science-related variables from different areas (e.g. attitudes and behavior) are highly interdependent.

In the following we summarize our findings regarding media productions processes as well as in media reception, which shape informal learning through science media, as well as our conclusions on how to develop media and science literacy. We point to the phases in public communication about science that are especially sensitive to biased communication as well as to biased selection and information processing and identify significant research gaps. In addition, we provide an outlook regarding changes that "new media" might bring about and then highlight limitation of the current discussion.

CONCLUSION: WHAT CAN BE LEARNED FOR EDUCATIONAL PSYCHOLOGY?

In this article we described the current state of research on informal science learning through the news media. We focused on science media content that was edited by professional journalists and proposed a descriptive model of the relationship between the news production system and laypersons' learning processes in the area of science communication. Whereas Educational Psychology traditionally focuses on learning in formal learning environments (e.g., school, university), Chinn et al. (2011, p. 162) argued that "given the preeminent role of media in the creation and dissemination of information," for epistemic cognition researchers, instructors and students in the field it is also important to know about the relevant processes in media communication. Based on our descriptive model of media-based science communication, we distinguished between (a) the professional routines by which journalists select and depict scientific information and (b) the psychological processes that account for how individuals select, process, and integrate science information. We had three goals in presenting and contrasting these two perspectives. First, we aimed to advance both, science literacy and media literacy of laypersons, by providing epistemic knowledge about the processes by which informal learning through mass media is facilitated. Second, we focused on biases in the process of science communication and how these can result from the logic of news production processes and motivational and cognitive processes in media recipients. We also described how the uncertainty inherent within scientific process might accentuate biases and noted tools that journalists can use to limit biased processing. Third, we pointed out research gaps in the area of media-based science communication.

In the first part of the article, we summarized the literature on *how journalists select* science topics and on how they *depict* the scientific process in their publications. Knowledge about how news media produce claims about scientific processes and findings contributes to an increase of a critical kind of epistemic knowledge in students and laypersons. We expect a broader understanding of these processes leading to a more appropriate use of science media. Specifically, our goal was to support media users' media literacy by increasing their competence to judge whether scientific evidence described in the news media is likely to be valid and reliable. For instructors, the information provided in this review might help to select aspects regarding the specific logic of the media system that are most valuable for the development of students' media literacy.

Regarding biases in science communication, the current literature on science journalists' selection routines showed that objective and balanced reporting remains a goal for most professional journalists. As a second priority, journalists also want to provide their audience with information necessary for a critical reflection. However, it is seldom that journalists want to provide citizens with their personal evaluation of current developments in science and research. Journalists see it as the citizens' responsibility to deal with the information provided by the media in a critical way. In line with this conclusion, we noted that media cover scientific topics generally with a rather positive tone and do not seem to be focused on scientific uncertainties. The so-called "utility" frame, which stresses that aspects of science are beneficial to human life, seems to be prevalent and media will only point to the uncertainties typical in science if specific news factors are prominent or if the social context seems to call for a controversial coverage. To overcome these biases, students and laypersons in general should develop the skill to critically reflect on science related media contents.

A striking gap in the literature is a lack of comprehensive information about how various news organizations present scientific information. The lack of multiyear, multiissue, multiregion content analysis makes it hard to estimate the new media's power in agenda setting. Also, the relevance of specialty (offline) media (e.g., Discovery Channel) has not been given sufficient attention in research. The relative impact of offline science media will become an even more important question as the number of online sources increases (see next).

In the second part of the article we reviewed empirical research on how individuals select, process and integrate science information. First we focused on the *selection* and on the *processing* of science educational contents and discussed two ways how psychological processes within recipients can bias and impede informal scientific learning through news media: selective exposure and cognitive overload. *Selective exposure* to scientific evidence expresses the tendency of people to search for scientific information that is in line with preexisting attitudes and beliefs. From the perspective of Educational Psychology, empirical evidence for selective exposure to scientific content in news media (a) illustrates that informal learning is not always driven by epistemic motives and (b) provides an explanation for how people can develop contradictory representations of the same state of evidence in a given field of research. It is important that there is still limited research on how scientific uncertainty buffers or enhances the influence of defense motivation on selective exposure.

Cognitive overload is likely to occur in situation in which more cognitive resources are required for the processing of scientific media content than are allocated by the recipient. From the perspective of Educational Psychology, it is important to note that the way scientific information is provided has an important impact on how likely cognitive overload is to occur. Whereas journalistic ways of structuring media content can reduce the amount of cognitive RR for the processing of scientific information, narrative integration provides a means for increasing the amount of resources that recipients allocate to a media-based message.

Finally, we reviewed *learning* effects through media-based science communication. The summary of literature made clear that exposure to science news can foster scientific literacy (i.e., scientific understanding and general as well as specific scientific knowledge). In addition, science news use seems to have small or moderate but positive effects on science-related beliefs, attitudes, interest, and subsequent behaviors of the recipients. What can be learned from these findings for science education is that media-based communication provides an effective means for informal science learning in regard to different psychological outcomes. However, more research is needed to assess the boundary conditions of media effects, especially on the acquisition of declarative scientific knowledge and the change of beliefs about the nature of science and scientific evidence (e.g., the influence of personality characteristics of media recipients, or the way of presenting research processes and uncertain scientific evidence).

On a more general level, science communicators and educators, as well as media recipients, should acknowledge that systematic biases in science communication can occur because of the way journalists select and depict scientific content, and the way that audiences select and process media content. Whereas the journalistic editing sets boundary conditions for the availability of science information and the understandability of complex scientific information, recipients' cognitive and motivational predispositions determine whether and how this information translates into knowledge structures.

LIMITATIONS

Our article has to leave some crucial questions open. First, it focuses on traditional news media as a source of informal science learning. However, in recent years the Internet has gained significant relevance as a source for science information, and online-only sources may eventually surpass traditional TV and established print media outlets in the future. Already the Internet is the first place Americans say they would go to get information about science (National Science Board, 2012; also see Brossard & Scheufele, 2013). How science learning occurs through Internet use must therefore become an even more important area of research, which is covered elsewhere in this special issue. At this point, we want to provide some thoughts on how online science communication might influence the processes described in this paper. Even though Internet usage for matters of science information may not yet be as common in other countries as in the United States, it is important to consider which influence online sources will have on informal science learning. Brossard and Scheufele (2013) pointed out that both perspectives on which we've elaborated in this article will potentially change significantly in the near future. They argued that the science-related content available online will differ from the content of traditional media as journalists' standards and routines will be less likely to the shape content. Instead, it appears that content creator's desire to appeal to search engines, and thus obtain advertising revenue, will drive content. However, content availability and media use will remain closely interlinked as people's online search behavior ultimately creates an incentive for content creation (see Brossard & Scheufele, 2013). In this regard, it is clear that media content is significantly shaped by audience demand. This also is a strong argument for why most of the processes covered in this review will remain relevant in the online world. First, the fact that the Internet allows for individuals to choose their media diet at an increasingly granular level makes the idea of selective exposure more relevant than ever. Second, the public's shift toward seeking out individualized content will increasingly push content providers to meet these demands, tightening the link between media demand and supply (for both trends, see Bennett & Iyengar, 2008).

Besides online science communication, the communication of science-related topics in *(fictional) narratives* also seems a promising expansion of the field. Recently, special attention has been given to the so-called CSI effect. Exposure to forensic crime shows (such as CSI) seems to alter beliefs about the reliability of DNA evidence and the perceived personal understanding of forensic science (Ley, Jankowski, & Brewer, 2012; see also Levine, Serota, & Shulman, 2010, and Nolan, 2010, for other examples of media effect studies with narrative science content). Ethical considerations of using narratives to communicate science have recently been discussed by Dahlstrom and Ho (2012).

Finally, also regarding offline science communication, the state of research reported here could be advanced *theoretically* as well as and *methodologically*. With regard to theory building, recent developments in psychological research on information processing and media effects research (e.g., the application of dual process models to differentiate between automatic and deliberate processes, or work connecting cognitive processing to cultivation; e.g., Shrum, Lee, Burroughs, & Rindfleisch, 2011) should be considered more often in science communication studies. We propose a stronger connection between current research in science communication and psychological theories of information processing in order to promote theoretical developments, as well as the systematic analysis of important moderator variables. Methodologically, a stronger comparative approach does not only seem to be necessary across time but also across countries and across topics. In the same vein, there is still an urgent need for more standardized procedures (also see Bauer, Allum, & Miller, 2007) and meta-analyses in science communication.

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