DE GRUYTER MOUTON Communications 2016; 41(3): 339–360

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Who's right: The author or the audience? Effects of user comments and ratings on the perception of online science articles

DOI 10.1515/commun-2016-0008

Abstract: When laypersons are interested in science-related questions, they frequently visit participatory websites such as science blogs. Typically, articles on these sites are accompanied by user comments or ratings. The present research investigated the effects of different forms of user feedback on readers' interpretation of science topics. In two experiments (N = 178), participants read a one-sided blog article about the dangers of violent video games. The visible user reactions contradicted the slant of the article and were systematically varied (argumentative comments vs. subjective comments vs. ratings vs. none). Results of Study 1 showed that parents (for whom the topic is relevant) made use of comments and ratings to infer the opinion climate, while there were only limited effects on readers' attitudes. Less involved readers (student participants in Study 2), in contrast, were susceptible to the persuasive influence of user comments. Implications regarding the role of user reactions in online science communication are discussed.

Keywords: science communication, user-generated content, blogs, attitudes, comments, argument quality

1 Introduction

When laypersons aim to gather information on scientific issues, they frequently turn to the internet (Su, Akin, Brossard, Scheufele, and Xenos, 2015). Due to recent changes in the media landscape such as the development of web 2.0 and social media applications, the content that they encounter there is likely to provide a different picture than in the age of traditional mass media: readers

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are not only exposed to articles by science journalists but also to participatory websites such as science blogs (Peters, Dunwoody, Allgaier, Lo, and Brossard, 2014). On these sites, they can find numerous articles on scientific topics, presumably with considerable differences in information quality, and, most notably, also voices from the audience, for instance, comments of other users or recommendations and ratings of the article. As a result, recipients are simultaneously confronted with a central message (the blog article) and social reactions toward this message (Walther and Jang, 2012), and this juxtaposition may strongly affect readers' interpretation of the contents presented.

Comments sections on web 2.0 are places in which scientific findings are widely discussed (Len-Rios, Bahndari, and Medvedera, 2014), especially when they relate to controversial issues such as climate change or the benefits and risks of emerging technologies. Thus, it is likely that readers encounter opposing opinions, for instance, when the commenters criticize a blog article or a news story portraying positive aspects of fracking. Such cases in which the visible user statements contradict the stance of the main article raise questions of how readers decide whom to believe and under which conditions user reactions alter their attitudes toward the topics of science-related debates. In the public and scientific discourse, the merits of user comments are often called into question due to the high levels of online incivility, which may have detrimental effects on the quality of readers' reasoning (Anderson, Brossard, Scheufele, Xenos, and Ladwig, 2014). On the other hand, audience reactions might also provide valuable additional information or corrections to misrepresentations in the original messages (Bode and Vraga, 2015).

Against this background, the present research aims to empirically investigate the mechanisms of social influence in online science communication and the conditions under which user-generated statements signaling disagreement in a scientific debate affect readers' perception of the topic at hand. Based on assumptions concerning attitude formation (Petty and Cacioppo, 1986) and perceived media influence (Gunther, 1998), we aim to compare different forms of user reaction (argumentative and subjective comments as well as numerical ratings) in their effects on readers' perceptions of public opinion and their own attitudes toward the topic. Moreover, the boundary conditions of these effects are investigated by considering characteristics of the readers such as her or his need for cognition as well as the personal relevance of the topic. As exemplary setting, the experimental studies of the present research deal with violent video games and their effects on children and adolescents – a topic which is characterized by scientific uncertainty, and which is widely discussed in the social sciences (e.g., Bushman, Rothstein, and Anderson, 2010; Ferguson and Kilburn, 2010) as well as among laypersons in the general public.

2 Scientific disagreement in web 2.0

Following the logic of Karl Popper (1968), empirical findings should always be regarded as tentative and provisional as they do not represent an absolute truth and might be challenged by future research. This notion also pertains to areas in which a scientific consensus has emerged and in which specific repeated findings are accepted as given, but is all the more relevant in areas of current scientific investigations: Here, empirical studies frequently yield ambiguous results, and scientists sometimes disagree about the predominant conclusions (Bromme and Goldman, 2014). Such high levels of uncertainty may be particularly challenging for laypersons since they do not have the resources to check the validity of the claims on their own but typically have to rely on others, for instance, by attributions of credibility to specific sources (Stadtler and Bromme, 2014; Winter and Krämer, 2014). This raises the question of how laypersons cope with this complex situation.

Content analyses have shown that journalists tend to neglect conflicting evidence and the uncertainty of scientific findings in their articles (Maurer, 2011; Stocking, 1999) – presumably, because they think that the audience would prefer straightforward facts. However, one could argue that such one-sided messages do not fully cover the complexity of the issues and are therefore inappropriate forms of science communication. On the other hand, references to uncertainty can be misleading if they are used to discredit widely accepted findings with a scientific consensus (Bolsen and Druckman, 2015), for example, in the area of vaccination.

In the new media landscape, conflicting viewpoints may not only be visible within one article summarizing a debate (or when reading multiple documents with opposing viewpoints) but also in the juxtaposition of an original message and opposing user reactions that are directly shown below the main article. For instance, as blogs and other forms of user-generated content foster opinionated writing, it can be seen as a common scenario that a blog article represents a clear stance toward a controversial scientific issue. Due to the interactive nature of web 2.0 and social media technologies, it is likely that the authors' views do not remain unchallenged and that other readers contradict the slant of the article.

Initial research on the effects of such user-generated comments in the domain of science mainly focused on potential negative effects of online comments. Anderson et al. (2014) argued that – although comments sections have "the potential to foster discussion and deliberation among far-reaching audiences" (p. 374) – the high levels of incivility that can be found online may rather lead to undesirable effects such as a polarization of the audience. In an online

experiment, they found that readers who saw uncivil comments below a two-sided and balanced blog post about nanotechnology expressed a more extreme risk perception (in line with their prior opinion) afterwards than readers who saw civil comments. While this points to an important concern, it is also possible that the audience can act as a 'corrective' when articles present a relatively biased view of scientific topics, and user comments add new perspectives. However, apart from the findings for incivility, the consequences of user-generated statements for readers' interpretation of science topics on web 2.0 have not yet been fully explained. In the following, we aim to add to the understanding of these phenomena by examining effects of competent (argumentative) comments and incompetent (merely subjective) comments as well as aggregate user ratings.

3 Effects of user reactions

According to models of mass media research (e.g., Gunther, 1998; Noelle-Neumann, 1974), people gauge the distribution of opinions of the general public based on their observation of media coverage (besides their impressions from interpersonal contacts). The suggested mechanism behind this approximation is that readers perceive the content of a news article as somewhat representative of the general opinion climate and also assume that this content has a wide reach: they accordingly presume that others are influenced by the slant of the article and include this potential shift in others' attitudes in their assessment of public opinion (Gunther, 1998; Gunther and Storey, 2003; Houston, Hansen, and Nisbett, 2011). This process, however, becomes unlikely if contradicting user reactions are directly visible below the original article and suggest that others have *not* been influenced as intended by the original message. Instead, readers may base their assessment of the opinion climate on the displayed user-generated statements (Lee, 2012; Lee and Jang, 2010) – even though these voices are rarely representative of the general public. For instance, a study by Zerback and Fawzi (2016) showed that the perception of the opinion climate toward a controversial political issue was affected by the valence of ostensible social media comments (as long as a considerable number of statements were presented). Thus, the following can be expected:

[H1] Readers who are exposed to contradicting user reactions perceive the public opinion on the topic as more discrepant from the science article's position than readers who are only exposed to the main article.

Beyond that, it is conceivable that readers also adapt their own attitudes toward the topic to the visible opinions of others. This may happen if they want to adhere to the predominant opinion or if they are persuaded by some of the other users' arguments. Dual-process models of attitude change such as the Elaboration Likelihood Model (ELM; Petty and Cacioppo, 1986) and the Heuristic-Systematic Model (HSM; Chaiken, 1987) correspondingly describe two main routes to persuasion: When readers are motivated and able to process information thoroughly, they check the validity of the claims (systematic processing/central route), otherwise, they rely on mental shortcuts or simple decision rules such as "the majority is probably correct" (heuristic processing/peripheral route). Additionally, the HSM posits a more subtle mechanism by which heuristic cues can influence subsequent systematic processing (Chaiken and Maheswaran, 1994): Hence, viewing negative user reactions as a cue is able to bias readers' systematic interpretation of the content. Research on user participation on web 2.0 and social media has demonstrated persuasive effects of comment valence on the evaluation of online videos (Shi, Messaris, and Cappella, 2014; Walther, DeAndrea, Kim, and Anthony, 2010) and online news articles (Lee and Jang, 2010; Winter, 2013), albeit contingent on readers' identification with the community (Walther et al., 2010), the credibility of the main news source (Winter, 2013), and readers' prior attitude (Shi et al., 2014). A recent study by Hsueh, Yogeeswaran, and Malinen (2015) showed that the tone of comments may even affect readers' stereotype levels: prejudiced (vs. anti-prejudiced) comments led to more negative attitudes toward the target groups. With regard to blog comments and science topics, research is still scarce. Yet, the study by Anderson et al. (2014) also found that readers' beliefs about scientific debates (in this case, risk perceptions about nanotechnology) were malleable based on reading different forms of user reaction. While their study focused on the tone of comments, the present investigation aims to test the effect of those user reactions which oppose the opinion of the original article:

[H2] Readers who are exposed to user reactions which contradict the original article report attitudes that are more discrepant from the science article's position than readers who are only exposed to the main article.

As attitude changes based on messages and user reactions are quite a strong media effect and in light of the above-mentioned moderators, more work is needed to understand the boundary conditions of this mechanism. The results related to the effects of comments and ratings obtained so far predominantly employed topics that were of low or moderate relevance to the participants (e.g., sensationalism in TV dramas [Lee and Jang, 2010] or nanotechnology

[Anderson et al., 2014]). But a scenario in which laypersons decide to retrieve science articles from the internet may be particularly common when they are highly involved in the topic or when the question at hand is relevant for their daily lives (for instance, parents who want to know under which circumstances their children's video game usage is problematic). In such cases, people might already have a relatively strong prior attitude that may not be as easily affected by a low number of user statements. In the terms of the dual-process models, the general information about a negative evaluation by the audience (without a thorough consideration of potential arguments) can be considered as a heuristic or peripheral cue. Therefore, it can be assumed that user reactions are more influential when the topic is less relevant and readers are in a lower-effort mode of processing (Petty and Cacioppo, 1986).

[H3] The effect hypothesized in H2 is more pronounced among readers for whom the topic is less personally relevant.

Besides the general comparison of readers who are only exposed to the main article and those who additionally see negative voices within the audience, it appears valuable to also distinguish between different forms of user reaction. Based on a typology by Walther and Jang (2012), textual comments as statements by individual users can be differentiated from aggregate representations of the behavior of several audience members, which are typically displayed as ratings that summarize the votes of many users (e.g., an average star rating). Theoretically, comments can be regarded as exemplars, while aggregate ratings are more abstract base-rate statistics. Exemplification theory (Zillmann and Brosius, 2000) suggests that due to their vivid nature exemplars are more influential than statistics (even though ratings may contain information about larger proportions of the audience [Lee and Jang, 2010]). For the area of product reviews, Ziegele and Weber (2015) already found that the effect of textual comments on purchase intentions exceeded the influence of a statistical rating. We assume:

[H4] Comments have a stronger influence on readers' attitudes and perceptions of public opinion than aggregate ratings.

When focusing on user comments, anecdotal as well as systematic observations indicate a wide range in the quality of these user-generated statements (see Ziegele and Quiring, 2013). Although the free exchange of users' opinions without editorial restrictions and serious discussions that would resemble democratic ideals is possible, there is growing concern about low-quality comments

and online incivility. While prior studies mainly analyzed the tone of comments (e.g., Anderson et al., 2014; Gervais, 2014), the present research focuses on the quality of the arguments that are provided within the comments: specifically, we distinguish between statements that contain relevant arguments to the debate (and would therefore live up to the ideal of deliberation and discussions of scientific findings) and those that merely express subjective opinions without further reasoning. When assuming that readers are interested in the topic, it can be expected that they detect these differences in argument quality, as has been shown for comments on societal topics on online news sites (Winter, 2013). However, since this requires effort, we also expect differences based on the readers' levels of elaboration. In this regard, the ELM posits a person's general motivational tendency to enjoy complex thinking – the need for cognition (Cacioppo and Petty, 1982) – as a moderator that strengthens the consideration of argument quality. Thus, we assume:

[H5] Argumentative comments have a stronger influence on readers' attitudes and perceptions of public opinion than subjective comments.
[H6] The effect hypothesized in H5 is more pronounced among readers with higher need for cognition.

4 Study 1

The first study aimed to investigate these hypotheses with the exemplary topic of violent video games and effects on children and adolescents. We chose a target group who would be likely to look up information on this topic as it is relevant for their daily lives: parents of minors. All participants were exposed to a science blog which showed a one-sided article that presented arguments supporting the view that video games are dangerous. In a laboratory experiment with a between-subjects design, we systematically varied the type of user reactions that were visible (negative argumentative comments vs. negative subjective comments vs. negative ratings vs. none).

4.1 Method

Sample. Eighty parents participated in the laboratory experiment. They were recruited via advertisements, posts in online forums, and flyers. Respondents received 25 Euros. Four participants were excluded because they indicated that they had not noticed the comments or the ratings in the respective conditions.

The remaining 76 participants (52 female, 24 male) were on average 37.03 years old (*SD* = 7.30). Twenty-seven of them had a university degree, 22 had university entrance-level qualification, and 27 had a lower degree of education.

Design and stimulus material. The main article (551 words) summarized scientific findings and expert statements that emphasize the dangers of playing violent video games. The text was written in a relatively neutral style and neither included powerful language to present findings as overly certain nor hedges as references to scientific uncertainty – in a prior study (Winter, Krämer, Rösner, and Neubaum, 2015), this text type was shown to be most persuasive.

The type of user reaction that was shown on the blog page was systematically varied as an independent factor. User reactions were predominantly negative toward the stance of the article: Three out of four comments contradicted the author's claims by describing positive effects of media consumption or by calling the presented findings into question; similarly, the rating indicated that 76% of readers had given a negative rating (with a graphic below the headline). Argumentative comments referred to evidence (e.g., "Studies have shown that video games are not the only reason for violence. In fact, it depends on a range of factors such as personality, education, family, or the personal background of the children" or "This doesn't tell the whole story: It has been shown that video games can help to regulate one's mood. Teenagers can live out their fantasies or aggressions in virtual environments without any harm to others"), while subjective comments included opinions of the ostensible writer without further arguments (e.g., "As long as my kids like these games, it's no problem. These are only games. Therefore I can't understand the whole panic in this debate" or "Some people always want to argue against something. They only need a topic to aggrandize themselves. Video games are not as bad as everyone claims").[1] In the control group, no user reactions were shown. Participants were randomly assigned to one of the four conditions. Randomization checks showed that participants' age, perceived relevance of the topic, as well as the distribution of gender and education did not differ significantly between the conditions.

Pilot study of the comments. To ensure that the comments reflect the intended manipulation, we conducted an online pilot study with 19 participants (11 female, age: *M* = 24.37, SD = 2.59). Seventeen comments about the topic were evaluated with regard to the stance that is advocated (against or in favor of media usage) and the level of perceived competence (low vs. high) on 7-point scales. Among the selected comments for the main study, the argumentative

1 Full versions of the text material are available from the authors.

comments (M = 5.21, SE = 0.14) were regarded as more competent than the subjective comments (M = 2.54, SE = 0.13), F (1, 18) = 260.09, $p < .001$, η_p^2 = .94; furthermore, there was a clear effect of the comment's position on the perception of stance, F (1, 18) = 218.77, $p < .001$, η_p^2 = .92 (contra comments: M = 1.68, SE = 0.22 / pro comments: M = 5.84, SE = 0.11).

Reader characteristics. The questionnaire assessed users' need for cognition, that is, their tendency to enjoy effortful thinking, with 16 items such as "I really enjoy a task that involves coming up with new solutions to problems" (Bless, Wänke, Bohner, Fellhauer, and Schwarz, 1994; Cacioppo and Petty, 1982), which were rated on a Likert scale from 1 to 5. The items showed a high internal consistency (Cronbach's α = .80) and were averaged (M = 3.71; SD = 0.51). The personal relevance of the topic was assessed with five items on a 7-point scale such as "I frequently think about the topic of media usage among children and adolescents" (α = .82, M = 4.52, SD = 1.22).

Dependent measures. Five items (e.g., "First-person shooter games such as Counter-Strike should be forbidden", see Appendix) measured participants' attitude toward violent video games (Winter et al., 2015). They were rated on a 7-point Likert scale from "strongly disagree" to "strongly agree" and were averaged (α = .66, M = 5.14, SD = 1.11). Higher values indicate stronger agreement to the main article's view that video games are dangerous. As a limitation of this measure, it should be mentioned that the reliability is slightly below the threshold of .70. Additionally, six items measured the attitude on general effects of violence in the media (α = .72; M = 5.90, SD = 0.87). As a measure of perceived public opinion, participants were asked to what extent the general public would agree with the five above-mentioned statements toward violent video games (between "public would strongly disagree" and "public would strongly agree", α = .77, M = 4.82, SD = 1.12).

Manipulation check. Participants evaluated the stance of the article as well as the opinion of the ostensible commenters/raters with three items on a semantic differential (e.g., between "positive" and "negative", 5-point scale, α between .75 and .88). As intended, the user reactions were regarded as somewhat negative with regard to the position of the text (comments: M = 3.87, SD = 0.67 / rating: M = 3.50, SD = 1.20). The stance of the main article was perceived as mainly negative toward the consumption of violent media (M = 3.72, SD = 0.81).

Procedure. The experiment was conducted in a laboratory room of a large European university. First, the questionnaire displayed multiple-choice questions to assess participants' prior knowledge of the topic. Then, the stimulus material with the blog page was shown (see Figure 1). Afterwards, participants expressed their evaluation of the text as well as their attitudes and perceptions

Figure 1: Example of the stimulus material: Blog article with subjective comments.

of public opinion. Furthermore, the questionnaire included questions about their need for cognition, their general beliefs about science, and further reader characteristics. Finally, participants were debriefed about the goals of the study and the manipulation within the text material.

4.2 Results

For hypothesis testing, we conducted planned contrast analyses: In the first contrast, the control group was compared with the three conditions with negative user reactions (H1 and H2). In the second step, the two comments conditions were contrasted with the rating condition (H4), and the third contrast included a comparison of argumentative and subjective comments (H5). For the dependent measure of perceived public opinion, results showed a significant difference for the first contrast, t (48.37) = –2.88, p = .003 (one-tailed),[2] suggesting that readers who were exposed to negative user reactions perceived the opinion climate as more discrepant from the main article's position (see mean values in Table 1). This finding supports H1. For the dependent measure of readers' attitudes toward the topic (violent video games and general media violence), however, results did not show a significant contrast. Thereby, H2 has to be rejected. The second and third contrast were not significant in either analysis for perceived public opinion and readers' own attitude. On this basis, H4 on the superiority of comments over ratings and H5 on stronger effects of argumentative comments are not supported by the data.

H3 assumed that people for whom the topic is less personally relevant would be affected more strongly by the reader reactions. To test this moderation effect, we conducted a hierarchical regression analysis with attitude toward the topic as criterion. The following predictors were entered in three blocks: (1) gender (as control variable) and a dummy variable comparing the control group with the comments and rating conditions, (2) personal relevance, and (3) the interaction of the dummy variable and personal relevance (computed as the product of the centralized variables). However, only gender (β = –.449, p < .001) and personal relevance (β = .302, p = .004) emerged as significant predictors, indicating that women as well as people for whom the topic is relevant express a more negative attitude toward violent video games, F (4, 71) = 8.76, p < .001, R^2 = .330. The interaction term was not a significant predictor, which would have been an indicator of the expected moderation effect.

2 In cases of non-equal variances (as indicated by a significant Levene test), we report the adapted values of the t-tests.

Table 1: Descriptive statistics (means and standard deviations) – Effects of user reactions on readers' perceptions of public opinion and attitudes toward the topic (Study 1, parents sample).

	Perceived public opinion	Attitude toward violent video games	Attitude toward media violence
Control group	5.32 (0.79)	5.35 (0.99)	6.15 (0.70)
Argumentative comments	4.55 (1.50)	5.09 (1.23)	5.96 (0.95)
Subjective comments	4.91 (0.78)	5.03 (0.90)	5.79 (0.88)
Rating	4.47 (1.14)	5.09 (1.34)	5.68 (0.95)

H6 posited stronger effects of argumentative comments on the perception of public opinion and readers' attitudes for those with higher need for cognition. In moderated regression analyses, (1) gender and a dummy variable representing the comparison of experimental conditions (argumentative comments vs. other conditions), (2) need for cognition, and (3) the interaction of the dummy variable and need for cognition were entered. The interaction term emerged as a significant predictor ($\beta = -.275$, $p = .018$) of perceived public opinion, F (4, 71) = 2.80, $p = .032$, $R^2 = .136$. Subsequent simple slope analyses (Aiken and West, 1991) revealed that people with higher need for cognition estimated a more moderate opinion climate when argumentative comments were shown ($b = -0.56$, $SE = 0.23$, $t = 2.44$, $p = .017$), while there was no difference between argumentative comments and the other conditions when need for cognition was low. This finding is in line with H6. In the regression analysis with readers' own attitudes as criteria, the interaction term was also significant ($\beta = .256$, $p = .013$, F (4, 71) = 8.28, $p < .001$, $R^2 = .318$). However, against expectations, simple slope analyses showed that people with lower need for cognition were persuaded more easily by argumentative comments ($b = -0.48$, $SE = 0.17$, $t = 2.81$, $p = .006$), while the attitudes of people with higher need for cognition remained unaffected.

In summary, results support the assumption that laypersons make use of the visible user reactions to infer the public opinion regarding a science-related debate. If these comments or ratings indicate disagreement between a one-sided article and the audience, they perceive the general opinion climate as more uncertain. This was largely independent of the specific type of user reactions, as results did not show the presumed superiority of textual comments over ratings and of argumentative over merely subjective statements. Only readers with higher need for cognition were influenced more strongly by argumentative comments in their assessment of the opinion climate. However, effects on readers' own attitudes were limited, although prior studies (Hsueh et al.,

2015; Lee and Jang, 2010; Walther et al., 2010; Winter, 2013) had demonstrated numerous persuasive effects of comments or ratings. This discrepancy may be explained by the generally greater relevance of the topic violence in the media for the target group of parents so that a small number of user reactions might not have been sufficient to change parents', presumably, strong attitudes. In order to examine the question of whether the discrepancy to prior studies is due to the specific science topic or to the high level of involvement of the target group, we replicated the study with a student sample.

5 Study 2

As in Study 1, a blog article about the dangers of violent video games with mainly negative user reactions was shown as stimulus material and the same between-subjects design (user reactions: argumentative comments vs. subjective comments vs. rating vs. none) was employed. The only difference was the target group: In order to test the hypotheses with a less involved group, the study was addressed to students without children. Furthermore, the recruitment focused on disciplines that have no connection to the topic.

5.1 Method

Sample. 128 participants completed the questionnaire. Following the exclusion criteria of Study 1, data of participants who indicated that they had not noticed the user reactions and those who viewed the main stimulus for less than 20 seconds were not considered for further analysis. Additionally, three participants who were parents were excluded. The remaining 102 participants (56 female) were on average 22.88 years old (SD = 2.58). The study was conducted in the laboratory (18 participants) and online (84). Those who participated in the laboratory did not significantly differ from online participants in any of the dependent variables. Randomization checks showed no significant differences between the conditions with regard to age, personal relevance, gender, and education.

Measures. As in Study 1, we assessed readers' attitudes toward violent video games (α = .67, M = 4.05, SD = 1.09) and general media violence (α = .74, M = 5.05, SD = 0.96) as well as their perception of public opinion (α = .62, M = 5.23, SD = 0.84). It has to be noted that two of the reliabilities are slightly below the threshold of .70 and the respective measures thus have to be interpreted cautiously. Additionally, the questionnaire measured need for cognition

(α = .81, M = 3.53, SD = 0.52). Participants expressed a low to moderate personal relevance of the topic (α = .71, M = 3.42, SD = 1.06) – these values were significantly lower than in the parents sample, F (1, 176) = 40.95, p < .001, η_p^2 = .19. According to the manipulation check, the article was perceived as negative toward media consumption (M = 3.98, SD = 0.60). As intended, participants evaluated the opinions of the commenters (M = 3.96, SD = 0.51) and the raters (M = 3.60, SD = 0.91) as predominantly negative toward the main article's stance.

5.2 Results

As in Study 1, we conducted planned contrast analyses, comparing the control group with the three other conditions (contrast 1), the two comments conditions with the rating condition (contrast 2), and argumentative with subjective comments (contrast 3). For the dependent measure of perceived public opinion, no significant contrasts emerged. Therefore, H1 is not supported by the data of the student sample.

When considering readers' attitudes toward media violence, analyses showed significant comparisons for contrast 1, t (98) = –2.05, p = .022 (one-tailed), and contrast 2, t (98) = –1.90, p = .030 (one-tailed). As predicted, participants in the control group expressed a more critical attitude, while those in the experimental conditions with contradicting user reactions expressed a more moderate attitude. According to contrast 2, the comments were more persuasive in this regard than the rating (see mean values in Table 2). In the related measure of attitude toward violent video games, only the second contrast was significant, t (98) = –1.70, p = .047 (one-tailed). On this basis, H2 on persuasive effects of user reactions is supported for readers' attitudes toward media violence. The significant comparisons in contrast 2 provide support for H4 on the superiority of comments over statistical ratings. However, against expectations of H5, we did not find differences in the effects of argumentative vs. subjective comments. Moderated regression analyses did not yield significant interactions between readers' need for cognition (H6) and their consideration of argumentative comments (vs. other user reactions).

In summary, results suggest that participants with a low to moderate relevance of the topic can be persuaded by contradicting user reactions, particularly by textual comments. Unlike Study 1, results showed considerable effects on readers' own attitudes, but not on their perception of public opinion.

Table 2: Descriptive statistics (means and standard deviations) – Effects of user reactions on readers' perceptions of public opinion and attitudes toward the topic (Study 2, student sample).

	Perceived public opinion	Attitude toward violent video games	Attitude toward media violence
Control group	5.03 (0.78)	4.32 (1.07)	5.38 (0.96)
Argumentative comments	5.44 (0.90)	3.83 (1.11)	4.70 (0.86)
Subjective comments	5.19 (0.86)	3.82 (1.20)	4.88 (0.94)
Rating	5.27 (0.82)	4.29 (0.88)	5.24 (0.98)

6 Discussion

The new media landscape provides a wide access to scientific information and opportunities of user participation. As a result, participatory websites such as blogs have become important sources of science information for laypersons (Su et al., 2015). On these sites, readers are likely to encounter opposing opinions, for instance, a discrepancy between a science article and the visible reactions by other users. The aim of the present research was to investigative whether and how this modern manifestation of scientific uncertainty changes readers' perceptions of the topic at hand. Two experimental studies with the exemplary topic of media violence assessed the effects of contradicting comments and negative ratings on readers' perception of the opinion climate and their own attitude toward the topic.

Among the highly involved target group in Study 1 (parents of minors), perceived public opinion was significantly affected by the user reactions. That is, people who only read the main article assumed that the general opinion climate would be in line with the stance of the text, possibly by assuming that other readers had been influenced by this article (Gunther, 1998; Gunther and Storey, 2003). But when seeing contradicting user reactions that express a negative evaluation of the text or opposing opinions, this assumption of media influence on other members of the public is precluded: Instead, readers appear to base their perception of the general opinion climate on the visible user opinions (Lee, 2012; Lee and Jang, 2010; Zerback and Fawzi, 2016). This may be a reasonable approach (as it is more likely that the opinion climate deviates from the article's position when the majority of the visible audience expresses the opposing view), but it may also be a premature approximation since the composition of the visible reactions is unlikely to be representative. However, unlike perceptions of public opinion, readers' own attitudes remained unaffected by comments and ratings in the sample of Study 1.

In the less involved target group in Study 2 (student sample), these persuasive effects occurred: Participants' own attitudes toward media violence were less in line with the slant of the text when negative user reactions were displayed. This finding is consistent with prior results on online social influence (Lee and Jang, 2010; Shi et al., 2014; Walther et al., 2010) and the assumption that peripheral/heuristic cues about majority opinions can bias readers' interpretation of the topic (Chaiken and Maheswaran, 1998). However, it has to be noted that the significant contrast only emerged for the general attitude toward media violence but not for readers' attitudes toward violent video games. One potential explanation may refer to the tendency that young people might have identified themselves with the group of gamers and thereby had more resistant prior attitudes in this specific domain (Nauroth, Gollwitzer, Bender, and Rothmund, 2014). In contrast to Study 1, analyses did not show significant differences concerning perceived public opinion, which indicates a more direct persuasive effect that may have overruled the effect of gauging the opinion climate. Perhaps the student participants were primarily motivated to weigh the given arguments on their own, since following the crowd based on social pressures might have seemed undesirable. It is also conceivable that uninvolved readers are satisfied with their effort at information processing after having adapted their own attitude, and are less interested in what the opinion climate may look like.

The different patterns of the two studies may suggest different routes by which the visible user reactions exert social influence on readers, depending on the personal relevance of the topic: A relatively small number of comments quite easily persuades uninvolved people. However, in the high-relevance target group, this strong media effect of persuasive influence did not occur: Here, few user reactions appear to be insufficient to change the preexisting attitudes. Still, the user reactions are not ignored and do exert a meaningful effect as readers use them to infer the general opinion climate (knowing the distribution of opinions in the public may be more important for people who already have a pronounced opinion themselves and expect future discussions).

It has to be noted that the non-significant contrast analyses concerning attitudes in Study 1 and perceived public opinion in Study 2 cannot be regarded as clear evidence for the absence of these effects. However, we believe that the observed patterns suggest different routes of the predominant effects depending on the relation to the topic. One explanation could be the strength of the prior attitude: People who are interested and involved in a topic are likely to have stronger attitudes, while the attitudes of readers for whom the topic is less relevant are probably less solid and more susceptible to social influence. As we did not measure participants' prior attitudes and related characteristics

(in order to reduce demand effects of the experimental situation), this interpretation needs to be tested in further studies.

Concerning the different types of user reactions, findings are mixed: while Study 1 did not show superior effects of one specific category, textual comments were more persuasive than the aggregate rating in Study 2. The latter finding is in line with exemplification theory (Zillmann and Brosius, 2000), which posits that vivid exemplars are more influential than base-rate statistics (that do not include reasons for readers' disagreement with the text). In contrast to prior studies (Winter, 2013), argumentative and subjective comments did not differ significantly in their impact. Perhaps the subjective comments that were employed in this study were still regarded as higher-quality statements than some of the uncivil comments that can be found online. Only parents with higher need for cognition based their assessment of the opinion climate more strongly on argumentative comments. This extends results by Lee and Jang (2010), who generally found a stronger consideration of comments in the perception of the opinion climate among analytic individuals. In contrast, parents with lower need for cognition in Study 1 were affected in their own opinions by argumentative comments, which contradicts the ELM assumption that people who enjoy effortful thinking (Cacioppo and Petty, 1982) consider argument quality to a stronger degree. One could argue that being affected by a limited number of comments represents a less thoughtful way of processing information, and that people with greater need for cognition therefore avoid this potentially superficial influence (regardless of the comments' quality). However, more research is needed to clarify the conditions under which high or low-quality comments affect individuals' attitudes, which may dramatically affect the conclusions that readers draw based on online discussions.

Nevertheless, the present findings may already hold new implications for the debate on the usefulness of audience reactions for the public's understanding of, and engagement with, science. While prior research mainly emphasized negative effects such as a polarization due to uncivil comments (Anderson et al., 2014), the setting of this study was interested in the juxtaposition of science articles and user reactions. When assuming that many main articles are one-sided and tend to neglect the complexity of conflicting evidence (as shown for journalistic articles; Maurer, 2011), contradicting statements from the audience can be seen as a means of conveying scientific uncertainty. Particularly in current debates in which there are indeed conflicting findings or ambiguous results, the audience may act as a 'corrective' to one-sided articles and broaden other readers' horizons. This, of course, greatly depends on the quality of the comments provided. In this regard, our findings provide a mixed picture in that parts of the audience were affected by argumentative comments (which can be

regarded as desirable) but also by merely subjective statements. It will be an important endeavor for future research to further explain the differential effects of user reactions and how to moderate and foster constructive online discussions. While our studies employed a purely user-generated setting with a blog article, one may ask whether the observed effects of comments and ratings also occur in the interpretation of articles that are published by reputable news websites.

Clearly, a manuscript that deals with the concept of scientific uncertainty has to highlight the uncertainty of its own findings. In this regard, we acknowledge that the experiments are limited by a forced-exposure setting and by small sample sizes that, as mentioned above, restrict the interpretation. Furthermore, the patterns were only tested with one topic (which may have particularities that do not apply to other science topics) and a specific pattern of manipulation: the static screenshot with only four comments or a rating does not fully represent the diverse nature of user reactions in social media applications. Further information about the expertise of the commenters, which might also be influential, was not considered. Although the graphical representation of comments and ratings was based on features of existing sites, the differences in size and position on the page may restrict the direct comparison of these forms of user representation. The target groups of Study 1 and Study 2 were meant to represent different groups of personal connection to the topic, but also differ in other respects (e.g., education). Given these limitations, the above-mentioned restrictions of the measurements, and some findings that are not in line with results of prior studies, more research is needed to corroborate the interpretations that are suggested by the present findings.

With these facets of uncertainty in mind, we believe that the present studies extend prior results on the effects of user reactions on science blogs and add to our knowledge on the mechanisms of social influence in the setting of online science communication. Results suggest that audience reactions may change readers' interpretations of one-sided science articles – but this effect takes different routes for target groups with high or low involvement: people for whom a topic is less relevant are likely to follow the opinion of the ostensible crowd. In cases of higher relevance, readers' presumably strong attitudes remain unaffected, but they make use of the visible user reactions to infer the opinion climate. As laypersons increasingly rely on social media formats as news sources, we believe that analyzing the effects of user-generated statements is necessary to understand the potential and pitfalls of web 2.0 for readers' engagement with science.

Acknowledgment: This research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) in the Special Priority Program "Science and the General Public" (Kr 2240/2-2). The authors would like to thank Carolin Straßmann, Tatjana Lang, and Vera-Juliane Sauer for their assistance in data collection.

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Appendix: Items for attitude measurement

Attitudes toward violent video games:
First-person shooter games such as Counter-Strike should be forbidden.
Computer games have negative effects on children and teenagers.
Violent computer games train children and teenagers for violence.
Violent computer games are not a problem for the development of teenagers (reverse-coded).
Spending too much time on the computer has negative effects on children's school performance.

Attitudes toward media violence:
All in all, I think that violent media content has a negative influence on children and teenagers.
Violent media content increases the likelihood of aggressive behavior in children and teenagers.
To my mind, the consumption of violent media content is harmless (reverse-coded).
The consumption of media contents can have negative effects on the development of children and teenagers.

Children and teenagers should not consume violent media content.
The consumption of depictions of violence in the media can be reasonable for children and teenagers to relieve aggression (reverse-coded).
[Items were rated on a 7-point scale between “strongly disagree” and “strongly agree”.]

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DOI: 10.1515/commun-2016-0008
URN: urn:nbn:de:hbz:464-20200831-174318-3

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