How Do Readers Explain the Occurrence of Conflicts in Science Texts? Effects of Presentation Format and Source Expertise

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Abstract

The present study set out to investigate the influence of two metatextual features-presentation format and source expertise-on lay readers' explanation of conflicts in scientific information. Secondary school students read partly conflicting information about a medical topic, which was either presented in one single document or in four different documents, and which was purportedly authored by lay or expert sources. Results show that readers deemed deficits in source expertise (source explanations) more likely to account for conflicts in information written by lay authors than for conflicts reported by experts. In addition, conflicts presented by experts and conflicts in multiple documents were explained more strongly by referring to the nature of knowledge and knowledge production (epistemic explanations). Our findings demonstrate that readers are sensitive to situational variations when considering the most likely explanations for scientific conflicts. Implications for readers' adequate understanding and subjective resolution of scientific controversies are discussed.

Keywords: multiple document comprehension; science understanding; folk philosophy/sociology of science.

Introduction

Generating explanations is key to comprehending scientific texts, be it in school or in settings of informal learning (Otero & Graesser, 2001). Explanations help readers to understand why phenomena mentioned in a text occur and how they relate to one another. Furthermore, readers may adapt their further text processing depending on whether they manage to generate satisfactory explanations and thus develop a coherent mental model of the described situation. Given the important role of explanations in lay readers' handling of scientific texts, the present study sheds light on factors that influence readers' generation of explanations, specifically, their explanations for conflict in science texts.

In generating explanations, readers draw on their folk science, that is, their own fragmentary understanding of the ontological world (Keil, 2010). Graesser and Bertus (1998), for example, demonstrated that science text readers use their prior knowledge to produce an especially high number of inferences about the causal antecedents of an event. Moreover, Costa, Caldeira, Gallástegui, and Otero (2000) report that secondary-school students reading science texts asked a high number of questions of which the vast majority pertained to causal explanations for the described phenomena.

An especially important catalyst for reader-generated explanations is the occurrence of conflicts in text (Otero & Graesser, 2001). Clashes of knowledge claims potentially stand in the way of attaining unambiguous knowledge about the world and thus call for the reader's attention. That said, developing an explanation for why two authors disagree potentially helps readers to restore coherence and eventually take a personal stance on a controversy.

However, conflicting stances on a scientific issue cannot be explained by a reader's folk science alone. Instead readers may draw on their assumptions about how knowledge in the given discipline is structured and produced. In addition, readers may draw on assumptions about how knowledge is distributed between individuals and how knowledge communication is tied to individuals' personal interests. Following Keil's notion of folk science, one might term the former assumptions as belonging to an individual's folk philosophy of science[1] whereas the latter assumptions belong to a folk sociology of science.

Bromme, Thomm, and Wolf (2013) report an interview study demonstrating how laypersons spontaneously generate a rich set of explanations drawing on these assumptions. Based on a sample controversy on the causation of a medical condition, laypersons (undergraduates from non-medical subjects) and intermediates (advanced medical students) were asked how they would generally explain the occurrence of conflicts in medical knowledge. Participants provided a rich variety of possible explanations. These fell into two major categories, of which the first one related to the nature of knowledge and knowledge production. The category reflects the structural complexity of scientific knowledge and the discursive nature of knowledge production with differences in methodology or research questions leading to incompatible research results. The highest number of explanations provided by laypersons and intermediates fell into this category. A second set of

[1] We refer to laypeople's assumptions about scientific knowledge and knowledge production as folk philosophy of science in reference to Keil's (2010) terminology. In other approaches, such assumptions are conceptualized as epistemological beliefs or nature of science beliefs. While these conceptualizations originate from different research traditions, they nevertheless overlap in terms of their reference to individual's beliefs about what scientific knowledge is and how it is justified.

explanations provided by both groups of participants focused on the source of information as the reason for conflicts. Participants explained conflicts with differences in the training and expertise of sources, or, to a lesser extent, with differences in the sources' interest or motivation. The study by Bromme et al. may be taken as tentative evidence that laypersons, at least those with a higher educational background, successfully draw on their folk philosophy and folk sociology of science to explain the occurrence of conflicts. What is currently essentially lacking, however, are empirical insights into the situational factors that determine which type of explanation readers prefer. Insights into these mechanisms could possibly inform research on public understanding of science and text comprehension.

The present study

With our present study we set out to research whether readers' preferred conflict explanations depend on metatextual information about the sources providing the information and its presentation format. Our approach was informed by a recent study that examined how metatextual information impacts lay readers' understanding of a controversial scientific issue (Stadtler, Scharrer, Brummernhenrich, & Bromme, 2013). Stadtler et al. presented participants with partly conflicting information on a medical issue. Presentation format and source expertise were systematically varied. The information was either presented in one single document by a single author or spread across four documents presented by different authors. In addition, the information was either purportedly written by expert sources (medical doctors) or lay sources (high school students). Results revealed that readers of multiple documents exhibited better memory for conflicts and were more likely to acknowledge the controversial nature of information in a subsequent knowledge communication task. How readers reported conflicting information also depended on source expertise. The variation of presentation format only mattered for expert information, which readers deemed worthy of effortful processing. The study by Stadtler et al. thus demonstrates that readers are sensitive to metatextual information in terms of memory for and use of conflicting scientific information. However, it deserves further clarification whether variations in presentation format and source expertise also effect on readers' preferred explanations for the occurrence of scientific conflicts.

The conceptual link behind this assumption is that metatextual information may differentially activate readers' tacit assumptions about how knowledge is structured and produced (i.e. their folk philosophy of science) and how it is distributed between individuals (i.e. their folk sociology of science). Presenting science information in multiple documents, for instance, may particularly highlight its complexity and the discursive nature of knowledge production (Britt & Aglinskas, 2002; Wiley & Voss, 1999). As a result readers of multiple documents may prefer *epistemic* explanations for the occurrence of conflicts. A presentation of the same information in a single document, in contrast, may rather downplay the discursive nature of scientific knowledge production stimulating readers to a lesser degree to forward conflict explanations of an epistemic kind.

The degree to which readers prefer epistemic explanations may also depend on variations of source information. Conflicts in expert information should be regarded as particularly representative of the underlying scientific discipline, thus stimulating epistemic conflict explanations. In contrast, when scientific conflicts are presented by lay authors, this may not activate readers' folk philosophy of science to the same degree resulting in fewer epistemic explanations.

Both metatextual factors are also likely to influence readers' preference for source explanations as the reason for conflicting information. Since readers should consider laypeople more prone to mistakes than experts, information authored by lay sources should more strongly stimulate readers to explain conflicts with deficits of source expertise. Moreover, readers might interpret unresolved conflicts presented by a single author in a single text as indicative of the author's lack of understanding of the subject matter. As a result deficits in source expertise should appear more appropriate for explaining conflicts if contradictions occur within a single text rather than between multiple documents.

In spite of this reasoning, whether or not lay readers' explanation of conflicting science information is in fact determined by source expertise and presentation format is by no means a trivial question. So far, it is not clear whether readers are at all sensitive to situational factors when explaining encountered conflicts, or whether they have preconceived ideas of which conflict explanation is most relevant, irrespective of situational variations. Moreover, it is unclear whether lay readers use the provided author and document information (student vs. doctor; single vs. multiple documents) to draw conclusions about the most appropriate conflict explanations. Readers' reliance on source expertise is particularly uncertain in light of previous findings showing a notorious lack of spontaneous attention to source information (e.g., Bråten, Strømsø & Salmerón, 2011; Britt & Aglinskas, 2002; Kammerer, Gerjets, & Werner, 2011; Wineburg, 1991).

Assuming that lay readers are sensitive to metatextual information when determining the most likely explanation for encountered conflicts, we formulate the following hypotheses:

Epistemic explanations: We expected an epistemic explanations to be deemed more likely by those reading multiple documents compared to participants encountering a a single document (H1a). Similarly, we hypothesized that readers consider epistemic explanations more appropriate for conflicts encountered in expert texts compared to conflicts in lay texts (H1b).

Source explanations: Furthermore, we expected that readers deem source explanations to better account for conflicts encountered in lay texts than conflicts encountered

in expert texts (H2a). In addition, reading a conflict in a single document should be explained more strongly with a lacking ability of the author than a conflict that exists between different sources (H2b).

It should be noted that readers might also explain perceived contradictions with their own lacking competence to correctly understand the provided information. In this case, they would blame themselves for the inability to form a coherent mental representation rather than interpreting the perceived inconsistency as an objective conflict. Our focus was on situations in which readers can be rather certain of the objective existence of conflicts, and we therefore did not expect any impact of metatextual factors on such *self-related explanations*. However, it is important to account for the possibility of self-related explanations when investigating readers' conflict explanations, particularly when focusing on laypeople confronted with expert information.

Method

Participants, design, and task

A total of 244 German secondary school students were recruited randomly during an open day at a German university. Students participated voluntarily and without payment. Participants were randomly assigned to one of four experimental groups following a 2 (text presentation format: single document vs. multiple documents) × 2 (source expertise: high vs. low) factorial design. Participants worked on a scenario developed in previous research (Stadtler & Bromme, 2008) in which a fictitious friend, who has been diagnosed as having a high cholesterol level, is having to decide whether to take action to lower it. Participants were asked to support an informed decision by reading conflicting texts about the topic cholesterol. After reading participants provided explanations for the conflict they read. Forty-two students (18%) were not analyzed further because they failed to identify the conflict in the reading task. The data of another four students were dropped from analyses because they judged their medical knowledge to be good or very good on a five-point Likert scale ranging from very poor to very good. All other students provided lower self-assessments of their medical knowledge and therefore can be regarded as laypersons with regards to medicine. Hence, our final sample contained 194 participants (85% female, mean age = 17.76; *SD* = .92).

Materials

The materials used in this study consisted of two controversial medical issues on the topic of cholesterol that were described in four text passages. Each controversial issue consisted of two opposing standpoints. Each standpoint was mentioned in only one text passage. Claims were not marked as conflicting; hence conflicts had to be inferred by the reader. For instance, one text passage stated that a diet with low-cholesterol products is an effective means to lower one's level of cholesterol whereas another text passage contained contradictory information. The second conflict addressed the threshold level of blood cholesterol beyond which there is a high risk of arteriosclerosis. Whereas one text passage argued for a universal threshold value of 200 mg/dl, another text passage claimed that the threshold value for cholesterol varies individually. The amount of filler information was minimalized to ensure that readers succeeded in recognizing the textual conflicts. The whole text information comprised 202 words in the case of the nutrition conflict and 227 words in the case of the threshold value conflict, respectively. Note that participants read only one conflict, i.e., either the text passages presenting the nutrition conflict or the text passages presenting threshold value conflict. This was done to unambiguously link readers' conflict explanations to a specific conflict. Text passages were displayed on a computer screen and depending on the experimental condition were presented either as two separate web sites by two different authors (in the multiple documents condition) or as one web site by a single author (in the single document condition). In addition, source information was varied by introducing the information as stemming from one or two medical doctors (in the expert source condition) or from one or two high school students (in the lay source condition). To control for contingency effects (Mayer, 2005), participants reading a single document worked with a similar navigation structure to those reading multiple documents. Participants could access the four text nodes via a table of contents linking to the nodes within the web site.

Dependent variables

Explanation of textual conflicts Participants who had indicated that they noticed the conflict in the text materials were then asked to rate "to what degree do the following statements explain the occurrence of the conflict you have just found?" on 6-point Likert scales. Statements were constructed to measure preference of epistemic explanations (5 items relating to the nature of knowledge and knowledge production), source explanations (5 items relating to the expertise and motivation of sources), and self-related explanations (5 items relating to one's own ability to comprehend the conflicting information). For example, the statement "There are no clear answers to many medical questions," was intended to measure epistemic explanations; the statement "The author made a mistake," to measure source explanations; and "I don't have enough topic knowledge to solve the conflict, but an expert could" self-related explanations. Psychometric properties of the inventory are reported in the results section along with the empirical examination of the factorial structure.

Procedure After first providing information on demographic variables and assessing their own medical knowledge, participants were instructed to read the text materials and take notes of any conflict they encounter. The instructions for this reading task gave participants a definition and example of contradictory information. Only

Table 1: Mean ratings of explanations (standard deviations in parentheses) as a function of presentation format and source expertise.

	Single Document		Multiple Documents	
Type of explanation	Lay source	Expert source	Lay source	Expert source
	n = 43	n = 50	n = 48	n = 53
Epistemic explanation	2.68 (.96)	2.81 (1.14)	3.01 (1.20)	3.64 (1.16)
Source explanation	3.89 (.93)	2.97 (.83)	3.81 (.97)	3.37 (.92)
Self-related explanation	1.95 (.80)	2.21 (.86)	2.10 (1.03)	2.11 (.82)

when participants noticed textual conflicts had they to report their explanations regarding these contradictions on the rating scale. Finally, participants were debriefed. The whole session lasted an average of 20 min.

Results

Because similar patterns of results were obtained for the two conflict topics (nutrition conflict and threshold value conflict), all analyses reported hereafter were conducted on data that were aggregated across conflict topics.

Explanation dimensions

To validate the factorial structure of the explanation inventory on empirical grounds, we subjected the 15 items to an exploratory factor analysis (ML-extraction, oblimin rotation). Three different analyses were run, in which we requested a forced two-, three, and four factor solution, respectively. An inspection of the screeplot confirmed that the best solution was the expected three-factor structure (KMO = .78; Bartlett's test $\chi^2(105) = 900.97$, $p < .001$; share of explained variance = 42.20%). This solution also revealed the lowest number of double loadings and hence offered a maximum of conceptual clarity. All items had their highest loading on the factor they were intended to contribute to; hence, the theoretically motivated factor labels (epistemic, source, and self-related explanation) were retained. Internal consistencies for the explanation dimension ranged from good (epistemic explanations: Cronbach's alpha = .87) to acceptable (self-related explanations: Cronbach's alpha = .74; source explanations: Cronbach's alpha = .62).

Influence of conflict type and source expertise on attribution

Table 1 reports mean ratings of conflict explanations and standard deviations as a function of presentation format and source expertise. To test the assumption that presentation format and source expertise influenced conflict explanation, we computed a mixed ANOVA with type of explanation as within-subject factor and presentation format and source expertise as between-subject factors. Results showed a strong effect of type of explanation, $F(1.84, 349.5) = 103.18$, $p < .001$, part. $\eta^2 = .352$. An inspection of means indicates that this effect was due to readers deeming source explanations to best account for conflicts (M = 3.40; SD = .99), followed by epistemic explanations (M = 3.06; SD = 1.18) and finally by self-related explanations (M = 2.10; SD = .88). However, this effect was qualified by the two possible two-way interactions (the three-way interaction, in contrast, did not reach significance). Firstly, there was an interaction between presentation format and type of explanation, $F(1.84, 349.5) = 4.15$, $p = .019$, part. $\eta^2 = .021$. Moreover, the interaction between source expertise and type of explanation was significant, $F(1.84, 349.5) = 15.27$, $p < .001$, part. $\eta^2 = .074$. To further examine the nature of these interactions, separate univariate follow-up analyses for each type of explanation were conducted.

Epistemic explanations: In line with our first hypothesis (H1a), we obtained a main effect of presentation format on epistemic explanations. Those who read multiple documents explained the occurrence of conflict to a greater degree with the nature of knowledge and knowledge production compared to participants who encountered a conflict in a single document, $F(1, 190) = 12.72$, $p < .001$, part. $\eta^2 = .063$. In addition, and in line with H1b, epistemic explanations were considered more appropriate for conflicts encountered in expert texts compared to conflicts in lay texts, $F(1, 190) = 5.42$, $p = .021$, part. $\eta^2 = .028$. The interaction between presentation format and source expertise was not significant, $F(1, 190) = 2.44$, $p = .120$, *ns.*

Source explanations: In addition, participants considered source explanations to better account for conflicts in lay texts than for conflicts encountered in expert texts, lending support to H2a, $F(1, 190) = 26.96$, $p < .001$, part. $\eta^2 = .124$. Moreover, the interaction between presentation format and source expertise reached marginal significance, $F(1, 190) = 3.25$, $p = .073$, part. $\eta^2 = .017$. This interaction was due to readers of a single expert source deeming source explanations less appropriate than readers in any other condition. Different from what has been expected in H2b, reading a conflict in a single document was not explained more strongly with reference to the author than were conflicts between different sources, $F(1, 190) = 1.42$, $p = .235$, *ns.*

Self-related explanations: Finally and as expected, no effects of our manipulation were observed with regards to self-attributions (all Fs$(1, 190) < 1.11$, *ns*).

Discussion

Previous research on text comprehension has shown that readers have a strong tendency to formulate explanations when reading conflicting scientific materials (e.g., Graesser & Bertus, 1998; Millis & Graesser, 1994; Otero & Graesser, 2001). The aim of this study was to add to the literature by examining which explanations lay readers deem acceptable for the occurrence of conflicts. Readers' preferences were examined as a function of presentation format (multiple vs. single document) and source expertise (expert vs. layperson). It was argued that lay readers possess naïve theories relating to the nature of knowledge and knowledge production (folk philosophy of science) and to the distribution of knowledge between individuals and their motives in communicating scientific knowledge (folk sociology of science). Metatextual information on presentation format and source expertise should differentially activate these theories and result in corresponding explanations that either focus on the epistemic nature of knowledge or on the source of information. The results widely support our expectations.

The strongest effect we obtained was the one of varying source expertise on source explanations. Source explanations were considered more appropriate for conflicts in information that was purportedly written by high-school students than the same conflict being purportedly produced by experts. A marginally significant interaction between presentation format and source expertise revealed that this effect was slightly more pronounced for conflicts that were included in a single document. Readers of a single expert document were obviously particularly hesitant to blame the expert for the occurrence of discrepant information and in turn chose other explanations to a similar degree. In contrast to our expectations, we did not observe that readers of a single document explained the occurrence of a conflict more strongly with a mistake of the author compared to those reading multiple documents. Note that in line with our expectations, conflicts in single documents were indeed predominantly explained with reference to the source. However, this was also true for those reading multiple documents, which we had not expected. Although unexpected, this result is in line with the results of Bromme, Thomm and Wolf (2013). In their study, laypersons regarded the source as a central cause of conflicts in science. This heuristic may be so salient in laypersons that it is applied regardless of presentation format when explaining conflicts.

Our results regarding epistemic explanations provide full support for our hypotheses. Conflicts presented by experts and conflicts between documents were explained more strongly by referring to the nature of knowledge and knowledge production. As for the expert-lay author variation, it may be argued that knowledge claims presented by experts are conceived as more indicative of the underlying scientific discipline in terms of the certainty it provides. Moreover, conflicts between different sources may be seen as directly pointing to the discursive nature of scientific knowledge production. As suggested by the results of the interviews conducted by Bromme et al. (2013), young adults show awareness that conflicts among both medical scientists and medical practitioners are commonplace. This insight reflects some epistemic sophistication and it may help readers to find adequate explanations when they encounter conflicts in science texts.

It is notable that we found sensitivity for metatextual information among high-school students. This result extends previous research (Stadtler et al., 2013) which has demonstrated sensitivity for metatextual information in terms of memory for and use of conflicting information among university undergraduates. Our results suggest that at least advanced high-school students seem to possess cognitive resources that enable them to assess the appropriateness of different conflict explanations without a great amount of elaboration.

Finally, it may be seen as a limitation of our study that our results are based on presenting high-school students with predefined explanations. Thus, future research will have to show whether a similar pattern of explanation preferences will be obtained when laypersons have to generate conflict explanations from scratch. With this goal in mind, interview studies, such as the one by Bromme et al. (2013), could be conducted with younger and less educated populations.

Another important topic for future research will be to assess the implications of different conflict explanations for the processing of science texts. A triangulation of data gained with think-aloud or eye-tracking procedures might be especially helpful to examine whether readers translate their subjective conflict explanations into actual reading behaviors. This could include an intensified elaboration of source information if conflicts are primarily explained with deficits in source competence, or corroborating information between sources (Wineburg, 1991). Readers' conflict explanations may also influence their inclination to engage in further information search. For example, explaining a conflict with lacking competence of the author(s) may prompt readers to obtain additional topic information from more reliable sources. In contrast, readers who explain a conflict with the nature of knowledge may refrain from looking up any further information, because they do not consider the encountered conflict as indicative of lacking information quality. It will also be an important task to examine whether readers use their preferred conflict explanation to develop a personal stance towards the conflict. Especially when readers explain a conflict with a lack of author competence, they might also use this explanation to decide which of the opposing stances they should include in their referential representation of the world. This way, conflict explanations might serve lay readers to harness scientific information for their goals of making informed decisions on everyday problems.

Acknowledgments

This research was supported with a grant from the Deutsche Forschungsgemeinschaft (DFG).

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