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Author Note

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Abstract

This study used eye-tracking and cued-retrospective thinking aloud to examine how laypersons, as compared to experts in the domain of nanosafety, read an online article containing conflicting scientific information and considered source information provided within the article. A sample of 21 laypersons and 20 experts was presented with a mock-up online article discussing whether nanoparticles emitted from laser printers are a potential health risk. Results showed that experts allocated more visual attention to and reflected more on source information provided in the article and attributed the scientific conflict to a greater extent to differences in sources' competence than laypersons.

Keywords: cued-retrospective thinking aloud, eye-tracking, scientific conflict, sourcing

Introduction

With the growing importance of the internet as a source for scientific information, we are often confronted with inconsistent or even conflicting scientific knowledge claims. These inconsistencies can stem from the tentative nature of scientific knowledge itself, from a lack of information curation on many websites, or from directed misinformation campaigns. Especially for individuals with a lack of prior expertise in the domain of interest (i.e., laypersons), it can be challenging to evaluate conflicting claims under these conditions. Hence, a growing body of research investigates how laypersons (compared to experts) process conflicting scientific claims and how they can be supported in their self-determined evaluation of such conflicts (e.g., Brand-Gruwel et al., 2017; von der Mühlen et al., 2016). One evaluation strategy that is considered to be of particular relevance in this context is sourcing, that is, "attending to, evaluating, and using available or accessible information about the sources of documents, such as who authored them" (Bråten et al., 2017, p. 114). Especially, the indirect validation of knowledge claims by evaluating the credibility (i.e., the competences and motivations) of the sources that provide the claims might be an adaptive strategy for laypersons who lack the domain knowledge for a direct, knowledge-based evaluation of the claims (Barzilai et al., 2015; Bromme & Goldman, 2014). Nonetheless, earlier studies on laypersons' compared to experts' (or intermediates') use of source information in the context of scientific conflicts showed that experts use source information more often than laypersons and choose more reliable sources (Brand-Gruwel et al., 2017; Wineburg, 1991). Furthermore, in a study by von der Mühlen et al. (2016), the superior performance of experts compared to laypersons in correctly evaluating the credibility of psychology texts was mediated by their consideration of source information during reading, as indicated by thinking-aloud protocols. In addition, students with expertise in the domain at hand

have been shown to mention differences in the competence or motivations of sources more often as explanations for scientific conflicts than students without expertise (Bromme et al., 2015).

The present study aimed to extend these findings by examining eye-tracking data on source information, verbal utterances about source evaluation in cued-retrospective thinking aloud protocols, and questionnaire data about individuals' subjective explanations for conflicting claims about a nanotechnology issue addressed in an online article.

Method

Participants

The sample for this eye-tracking study consisted of 20 experts (9 female, 11 male) in the domain of nanotechnology from the Leibniz-Institute for New Materials in Saarbrücken, Germany, and 21 laypersons (undergraduate students from a large German university; 15 female, 6 male) without a background in nanotechnology. On average, experts were 36.75 years old (*SD* = 8.95), and laypersons were 23.62 years old (*SD* = 3.94).

Material

The scientific conflict presented to the participants was taken from the field of nanosafety and deals with whether laser printers are a potential health risk due to their emission of nanoscale particles. To provide a natural information environment for the conflict, it was presented within a mock-up online article (see Appendix).

The article was structured in six paragraphs: (1) a short introduction to the conflict with some background information, (2) a first set of conflicting scientific information provided by embedded sources with differences in their motivations (potentially vested interest of one embedded source), (3) a second set of conflicting scientific information provided by embedded

sources with differences in their methodological approach, (4) a short description of the complexity of scientific research addressing this topic from the perspective of nanotechnology, and (5) a conclusion that stresses the importance of the topic without providing a resolution to the conflict. After the conclusion, (6) a reference list for the four embedded sources cited in the article was presented. The article's style and complexity was comparable to popular science articles.

Procedure

In the first part of the study, participants completed an online questionnaire that assessed their prior knowledge about nanotechnology (Gottschling et al., 2019). One week later, participants were invited to a laboratory setting. They were told to imagine that an acquaintance had asked for their opinion on an online article and whether he should use a laser printer in his office. Participants then read the article at their own pace, while their eye movements were recorded with an SMI RED250mobile eye-tracking system. During reading, the distance of the eyes to the 24-inch monitor was held constant at 60 cm by using a chinrest. After giving their recommendation on whether or not the acquaintance should use a laser printer, rating their confidence (on a scale from 1, "not confident at all, to 7, "very confident"), and providing a written justification for the recommendation, participants were presented with their eye-movement recordings at half speed and asked to provide cued-retrospective thinking aloud (RTA) protocols (cf. van Gog et al., 2005) of their processing of the text. These protocols and the written justifications were later coded by two independent double-blind raters according to how often they reflected on the sources within the article and on subjective explanations of the conflict. Disagreements between the raters were resolved through discussion for all protocols.

Finally, participants completed a questionnaire about their subjective conflict explanation of the given conflict (Thomm et al., 2015).

Results

Welch's-t-tests showed that experts achieved significantly higher scores than layperson both in their subjective prior knowledge, $t(27.22) = 10.68$, $p < .001$, and in a prior knowledge test, $t(38.92) = 8.37$, $p < .001$. After reading the article, 35.00% of experts and 52.38% of laypersons recommended the use of a laser printer, $X^2(1) = 0.65$, $p = .420$, with experts being more confident in their decision than laypersons, $t(32.38) = 3.26$, $p = .002$.

Regarding visual attention to source information, mixed regression models, with experimental group as a between factor, Area of Interest (AOIs; one for each paragraph of the article) as a within factor, random intercepts for participants, and total fixation time as the dependent variable, showed a significant interaction between experimental group and AOI, $X^2(5) = 32.14$, $p < .001$. Total fixation times (in ms) on the paragraph "source references" were significantly shorter for laypersons ($M = 12082$, $SD = 11989$) than for experts ($M = 24757$, $SD = 13743$), $t(32.23) = -2.88$, $p < .007$. For the five other AOIs, in contrast, no significant differences between the two groups were present.

Furthermore, generalized linear mixed models using a quasi-Poisson distribution revealed that experts also showed more reflection on source information in their cued-retrospective verbal protocols, $t(39) = 2.35$, $p = .024$, and more often explained the conflict as being due to differences in sources' competence, $t(39) = 2.58$, $p = .014$, during the RTA protocol than laypersons (analyzed with generalized linear mixed models using a quasi-Poisson distribution).

Finally, experts also attributed the conflict more strongly to differences in researchers' competence in the final conflict-explanation questionnaire, $t(35.15) = 2.28$, $p = .029$.

Discussion

The results of this study corroborate previous findings that laypersons attend and evaluate source information to a lower extent than experts when faced with scientific conflicts (Brand-Gruwel et al., 2017; von der Mühlen et al., 2016). Specifically, as indicated by our eye-tracking data, experts showed more strategic processing of the references during the reading of the online article as well as increased verbal reflection about source information and higher attribution of the conflict to competence explanations compared to laypersons. Additionally, experts also reported higher confidence in their recommendation.

One possible application of these findings is that, since the differences in experts' and laypersons' processing of source information can be identified via eye-tracking methodology, recorded gaze paths (possibly with verbal comments), so-called eye-movement modeling examples (EMMEs), of experts could be used to train readers in the strategic use of source information (e.g., Salmerón et al., 2020). While it is unclear to which degree expert strategies regarding source use can be applied by laypersons, this could still be a promising approach since prior research has shown that increased attention to source information has positive effects on laypersons' comprehension of scientific conflicts (Bråten et al., 2009) and their memory of source information (Gottschling & Kammerer, in press).

Overall, the present findings and further investigations of the underlying processes can inform science education on how to support laypersons in their self-determined evaluation of

conflicting scientific information through interventions that stress the potential of sourcing for conflict explanation. In this context, particular focus should be put on identifying reasons for the lesser use of sourcing strategies of laypersons compared to experts and finding ways to increase source use in laypersons.

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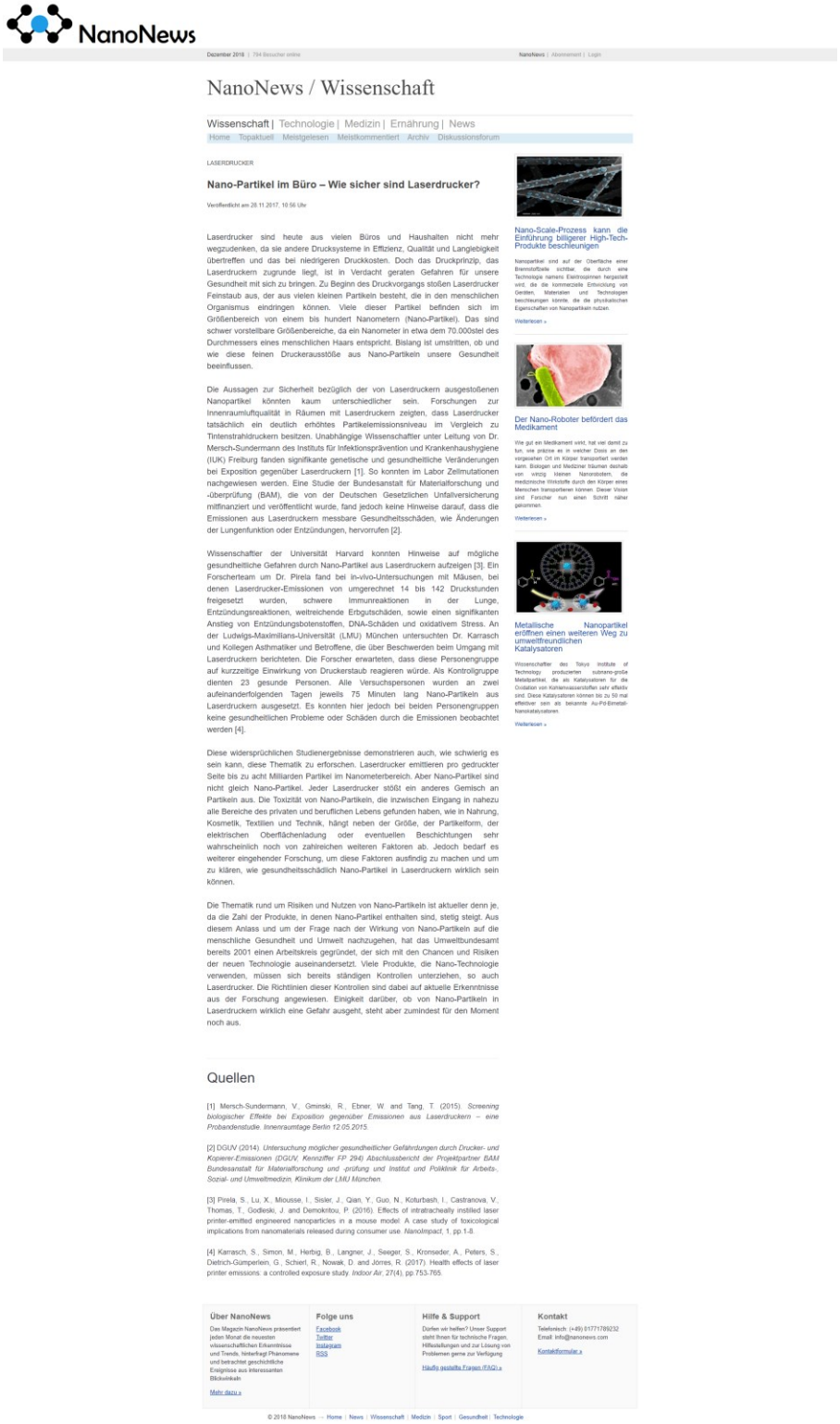
Appendix

The mock-up article on nanoparticles emitted by laser printers that was used in the study.



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LASERDRUCKER

Nano-Partikel im Büro – Wie sicher sind Laserdrucker?

Veröffentlicht am 28.11.2017, 10:56 Uhr

Laserdrucker sind heute aus vielen Büros und Haushalten nicht mehr wegzudenken, da sie andere Drucksysteme in Effizienz, Qualität und Langlebigkeit übertreffen und das bei niedrigeren Druckkosten. Doch das Druckprinzip, das Laserdruckern zugrunde liegt, ist in Verdacht geraten Gefahren für unsere Gesundheit mit sich zu bringen. Zu Beginn des Druckvorgangs stoßen Laserdrucker Feinstaub aus, der aus vielen kleinen Partikeln besteht, die in den menschlichen Organismus eindringen können. Viele dieser Partikel befinden sich im Größenbereich von einem bis hundert Nanometern (Nano-Partikel). Das sind schwer vorstellbare Größenbereiche, da ein Nanometer in etwa dem 70.000stel des Durchmessers eines menschlichen Haars entspricht. Bislang ist umstritten, ob und wie diese feinen Druckerausstöße aus Nano-Partikeln unsere Gesundheit beeinflussen.

Die Aussagen zur Sicherheit bezüglich der von Laserdruckern ausgestoßenen Nanopartikel könnten kaum unterschiedlicher sein. Forschungen zur Innenraumluftqualität in Räumen mit Laserdruckern zeigten, dass Laserdrucker tatsächlich ein deutlich erhöhtes Partikelemissionsniveau im Vergleich zu Tintenstrahldruckern besitzen. Unabhängige Wissenschaftler unter Leitung von Dr. Mersch-Sundermann des Instituts für Infektionsprävention und Krankenhaushygiene (IUK) Freiburg fanden signifikante genetische und gesundheitliche Veränderungen bei Exposition gegenüber Laserdruckern [1]. So konnten im Labor Zellmutationen nachgewiesen werden. Eine Studie der Bundesanstalt für Materialforschung und -überprüfung (BAM), die von der Deutschen Gesetzlichen Unfallversicherung mitfinanziert und veröffentlicht wurde, fand jedoch keine Hinweise darauf, dass die Emissionen aus Laserdruckern messbare Gesundheitsschäden, wie Änderungen der Lungenfunktion oder Entzündungen, hervorrufen [2].

Wissenschaftler der Universität Harvard konnten Hinweise auf mögliche gesundheitliche Gefahren durch Nano-Partikel aus Laserdruckern aufzeigen [3]. Ein Forscherteam um Dr. Pirela fand bei in-vivo-Untersuchungen mit Mäusen, bei denen Laserdrucker-Emissionen von umgerechnet 14 bis 142 Druckstunden freigesetzt wurden, schwere Immunreaktionen in der Lunge, Entzündungsreaktionen, weitreichende Erbgutschäden, sowie einen signifikanten Anstieg von Entzündungsbotenstoffen, DNA-Schäden und oxidativem Stress. An der Ludwigs-Maximilians-Universität (LMU) München untersuchten Dr. Karrasch und Kollegen Asthmatiker und Betroffene, die über Beschwerden beim Umgang mit Laserdruckern berichteten. Die Forscher erwarteten, dass diese Personengruppe auf kurzzeitige Einwirkung von Druckerstaub reagieren würde. Als Kontrollgruppe dienten 23 gesunde Personen. Alle Versuchspersonen wurden an zwei aufeinanderfolgenden Tagen jeweils 75 Minuten lang Nano-Partikeln aus Laserdruckern ausgesetzt. Es konnten hier jedoch bei beiden Personengruppen keine gesundheitlichen Probleme oder Schäden durch die Emissionen beobachtet werden [4].

Diese widersprüchlichen Studienergebnisse demonstrieren auch, wie schwierig es sein kann, diese Thematik zu erforschen. Laserdrucker emittieren pro gedruckter Seite bis zu acht Milliarden Partikel im Nanometerbereich. Aber Nano-Partikel sind nicht gleich Nano-Partikel. Jeder Laserdrucker stößt ein anderes Gemisch an Partikeln aus. Die Toxizität von Nano-Partikeln, die inzwischen Eingang in nahezu alle Bereiche des privaten und beruflichen Lebens gefunden haben, wie in Nahrung, Kosmetik, Textilien und Technik, hängt neben der Größe, der Partikelform, der elektrischen Oberflächenladung oder eventuellen Beschichtungen sehr wahrscheinlich noch von zahlreichen weiteren Faktoren ab. Jedoch bedarf es weiterer eingehender Forschung, um diese Faktoren ausfindig zu machen und um zu klären, wie gesundheitsschädlich Nano-Partikel in Laserdruckern wirklich sein können.

Die Thematik rund um Risiken und Nutzen von Nano-Partikeln ist aktueller denn je, da die Zahl der Produkte, in denen Nano-Partikel enthalten sind, stetig steigt. Aus diesem Anlass und um der Frage nach der Wirkung von Nano-Partikeln auf die menschliche Gesundheit und Umwelt nachzugehen, hat das Umweltbundesamt bereits 2001 einen Arbeitskreis gegründet, der sich mit den Chancen und Risiken der neuen Technologie auseinandersetzt. Viele Produkte, die Nano-Technologie verwenden, müssen sich bereits ständigen Kontrollen unterziehen, so auch Laserdrucker. Die Richtlinien dieser Kontrollen sind dabei auf aktuelle Erkenntnisse aus der Forschung angewiesen. Einigkeit darüber, ob von Nano-Partikeln in Laserdruckern wirklich eine Gefahr ausgeht, steht aber zumindest für den Moment noch aus.

Nano-Scale-Prozess kann die Einführung billigerer High-Tech-Produkte beschleunigen

Nanopartikel sind auf der Oberfläche einer Brennstoffzelle sichtbar, die durch eine Technologie namens Elektrosprinen hergestellt wird, die die kommerzielle Entwicklung von Geräten, Materialien und Technologien beschleunigen könnte, die die physikalischen Eigenschaften von Nanopartikeln nutzen.

Weiterlesen »

Der Nano-Roboter befördert das Medikament

Wie gut ein Medikament wirkt, hat viel damit zu tun, wie präzise es in welcher Dosis an den vorgesehen Ort im Körper transportiert werden kann. Biologen und Mediziner träumen deshalb von winzig kleinen Nanorobotern, die medizinische Wirkstoffe durch den Körper eines Menschen transportieren können. Dieser Vision sind Forscher nun einen Schritt näher gekommen.

Weiterlesen »

Metallische Nanopartikel eröffnen einen weiteren Weg zu umweltfreundlichen Katalysatoren

Wissenschaftler des Tokyo Institute of Technology produzierten subnano-große Metallpartikel, die als Katalysatoren für die Oxidation von Kohlenwasserstoffen sehr effektiv sind. Diese Katalysatoren können bis zu 50 mal effektiver sein als bekannte Au-Pd-Bimetall-Nanokatalysatoren.

Weiterlesen »

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