The global spread of (mis)information on spiders

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Abstract

In the Internet era, the digital architecture that keeps us connected and informed may collaterally amplify the spread of misinformation and falsehood^{1,2}. The magnitude of this problem is gaining global relevance³, as evidence accumulates that misinformation interferes with democratic processes and undermines collective responses to environmental and health crises^{4,5}. Therefore, understanding how misinformation generates and spreads is becoming a pressing scientific, societal, and political challenge³. Advances in this area are delayed because high-resolution data on coherent information systems are difficult and time-consuming to acquire at global scales. We collated a high-resolution database of online newspaper articles on spider-human interactions. Spiders are widely feared animals⁶ that frequently appear in the spotlight of the global press^{7,8}. Our database is unique in that it covers a global scale (5,348 news articles from 81 countries and 40 languages) while providing an expert-based assessment of the content and quality of each news article⁹. Here, we first show that the quality of news on spiders is exceedingly poor—47% of articles contained different types of error and 43% were sensationalistic—and we consolidate a quantitative understanding of the relationship between article quality and different news-level features. Among other factors, the consultancy of spider experts, but not doctors and other professionals, decrease sensationalism. Next, we show that the flow of spider-related information occurs within a highly interconnected global network and provide evidence that sensationalism, along with other predictors including numbers of spider species and internet users in a country, are key factors underlying the spread of information. Our results improve understanding of the drivers of (mis)information across broad-scale networks. They also represent a starting point to formulate recommendations for improving journalism quality. In the specific case of spiders, a more accurate media framing would translate into measurable benefits, limiting resource waste and mitigating human-wildlife conflicts and the prevalence of widespread arachnophobic sentiments.

Main

In a digitized world, we have instant and unlimited access to information. Yet, the same technology that keeps us connected and informed amplifies the proliferation of dis- and misinformation^{1–3}. This became obvious at the onset of the coronavirus pandemic in 2020, when fake news and conspiracy theories were spreading online faster than the virus itself^{4,5}. As the situation worsened, the World Health Organization jointly with eight international organizations expressed concerns that *“without appropriate trust and correct information, diagnostic tests go unused, immunization campaigns [...] will not meet their targets, and the virus will continue to thrive”*¹⁰. This is not only a matter of human health. Dis- and misinformation interferes with democratic processes^{11,12} and undermines collective responses to environmental^{13,14} and climatic crises¹⁵. It follows that understanding the factors underlying the generation and spread of misinformation is central to helping us navigate an increasingly polluted information ecosystem.

For a given nugget of information (e.g., a media article, YouTube video, or social media post), it is possible to assess the quality along two dimensions. A first axis pertains to the correctness, the extent to which the content is factually right or wrong—spanning from the presence of a few errors up to the entire fabrication of facts¹⁶. A second axis pertains to sensationalism, the degree to which the content is deliberately exaggerated or presented as controversial to clickbait viewers or readers. Ultimately, the interplay between these two axes affects the reach and appeal of information^{1,17}, to the point of potentially conditioning the decision-making of receivers¹⁸. Yet, measuring these two dimensions of the quality and trustworthiness of information remains challenging. First, assessing sensationalism and errors is prone to subjectivity, especially for topics for which we lack an agreed-upon truth (e.g., politics). Second, in the internet era, information flows through global-scale networks, making it challenging to obtain high-resolution data for any given topic.

Here we overcame both impediments by focusing on the media representation of spiders as a test case⁹. We contend that media framing of wildlife is an excellent model system to explore the interplay between the correctness and sensationalism dimensions in driving the spread of information. Wildlife is a powerful emotional trigger in humans^{19,20} and nature-related stories are omnipresent in the global press. Stories about spider bites, in particular, are often overplayed by the media^{7–9}. This makes it relatively easy to quantify sensationalism, insofar as sensationalistic articles consistently use emotional words and images and tend to exaggerate morphological features triggering arachnophobia⁷—e.g., body size^{6,21,22} or hairiness²². For spider experts, it is also straightforward to identify basic errors associated with spider contents. Common errors typically pertain to anatomy and behavior (e.g., ‘spider sting’²³), unrealistic outcomes of envenomations^{24,25}, or incorrect taxonomic information (e.g., ‘spiders are insects’²⁶).

We capitalized on a global-in-scale, high-resolution database of online newspaper articles on human-spider encounters—consisting of 5,348 news articles from 81 countries and 40 languages⁹. We started by tackling the exploratory question: What news-level factors are associated with errors and sensationalistic content, and to what extent is there covariation between the correctness and sensationalism dimensions of article quality? Once we consolidated a quantitative understanding of the relationship between article quality and news-level attributes, we used network analyses to predict how information quality, along with different country-level predictors, affect the global flow of information. As emotions constitute a potent driver of decision making¹⁸, we hypothesized a direct relationship between the influence of a country on the global flow of information and the degree of sensationalism associated with the information it produces. Furthermore, we hypothesized that the international prominence of a country and its press should directly influence its centrality in the global network. Lastly, we hypothesized that a high diversity of spiders or medically important spiders in a country should translate into greater production of spider-related news, thereby influencing the country's importance in the global network of information exchange. Our results improve global understanding of the drivers of (mis)information across broad-scale information networks. They also provide a starting point to formulate general

recommendations for improving the quality of wildlife news. Better framing of spider-related information would translate into a measurable benefit to both spiders and humans, limiting waste of money, mitigating human-wildlife conflicts, and diminishing arachnophobic sentiments.

Article-level drivers of quality

The quality of global articles on spiders was exceedingly poor, with 47% of articles containing errors and 43% being classified as sensationalistic by spider experts. However, the proportion of sensationalistic articles varied substantially across countries (Figure 1).

To investigate the factors driving the probability of a news article being sensationalistic, we tested for relationships between sensationalism and eight predictors at the news-article level, while controlling for the species involved in the human-spider encounter and the language and country of the news as random factors. The regression model explained 52% of the variance (Conditional R^2 : 0.525), of which over 45% was attributable to the random factors. The probability of an article being sensationalistic increased in international and national newspapers compared with regional ones, it was higher when the article contained photos of spiders and bites, and it was lower when the reported event was either a bite compared to a deadly bite or a human-spider encounter. Furthermore, there was strong evidence that the probability of an article being sensationalistic decreased when a spider expert was consulted in the news article; there was no evidence of a similar effect when other experts, including doctors, were consulted. Finally, there was strong covariation between sensationalism and the presence of errors (Figure 2A, 2B; estimates in Table S1).

Next, we tested for relationships between the presence/absence of errors and six predictors, while controlling for the same random factors introduced earlier. The model explained 51% of the variance (Conditional R^2 : 0.514), of which 44% was attributable to the random factors. There was strong evidence that the probability of an article containing errors increases when the articles referred to bites and deadly bites compared to human-spider encounters. Also, the probability of an article containing errors decreased when a spider expert was consulted, although this effect was weaker compared to the model of sensationalism (Figure 2B; estimates in Table S2).

While our article-level models had high explanatory power, the most variance was explained by the country, language, and spider species involved, indicating that the story subject and cultural aspects are central in predicting article quality. The remaining missing variance explained (~50%) is likely to be related to harder-to-capture factors, such as the writing style of the journalist and cultural variation in news outlets at a finer scale (e.g., editorial policies).

Country-level drivers of quality

Network analysis revealed that media representation of spiders is a global phenomenon, with human-spider encounters and bites being reported by the press from every corner of the world (Figure 1). The flow of this spider-related information occurs within a highly connected network (33% of all possible connections among countries are realized; Figure S1). Yet, the influence that different countries have on the flow of information is not uniform. To test this, we identified 15 country-level factors (including news-related attributes, spider-related attributes, and socio-economic descriptors) that are potentially relevant predictors for the country's importance in the network. Because many of these variables were strongly intercorrelated (Figure S2), we consolidated variation to five main predictors (Supplementary text S1) and tested their effect on the centrality of each country in the network, while controlling for the effect of language as a random factor. The model explained 31% variance (Conditional R^2 : 0.307), of which 6% attributable to the random factor. The centrality of each country increased with the number of internet users, the number of spider species, and the proportion of sensationalistic news. There was no evidence of other factors exerting a strong effect on country centrality (Figure 2C; estimates in Table S3).

Next, we modeled the contribution of the same factors in determining the probability of forming connections between any two nodes in the network. Once again, the number of internet users, the number of spider species, and the proportion of sensationalistic news published in the country strengthened its connection with other countries (Figure 2D; estimates in Table S4). The same variables exerted a strong positive effect on the actual realized number of connections among countries (Figure S3; estimates in Table S5). Furthermore, English-speaking countries were more likely to connect in the network compared to any other language (node factor in Figure 2D). Self-evidently, there was a higher probability of connection between countries publishing news in the same language (node match in Figure 2D).

Discussion

General implications pertaining to any type of information system, as well as discipline-specific considerations, emerge from our analysis. First, through these kinds of studies, we are able to identify the potential roots of poor-quality information and ultimately target and avoid bad practices (as writers) and sources (as readers). Second, our analysis emphasizes how quality matters in determining the spread of information. This effect was mostly associated with the sensationalism axis, consistent with the idea that emotional language is a powerful driver of the spread of information^{27,28}. Importantly, our results suggest that there is an improvement on both axes of quality when journalists engage with experts. Not all experts, however, provide equal value: consulting spider experts, but not medical personnel and other professionals such as pest controllers, decreases sensationalism and the presence of factual errors. This corroborates observations by Vetter²⁹ that medical personnel and other authorities often provide incorrect identifications of spiders and information about bites. An additional benefit of consulting the “right” expert, in this specific case, is that it may provide social recognition and appreciation of zoologists³⁰.

Our network analysis also showed that even local-scale events published by regional newspapers can quickly become broadcast internationally. Furthermore, and perhaps obviously, wealthier and/or more technologically developed countries (measured as the number of internet users) emerged as more

influential in driving the spread of information. This implies that improving the quality of the information produced in these local nodes could have a positive effect reverberating across the network—a typical example of a “think globally, act locally” management strategy.

All of this is of central importance given that the spread of misinformation has direct real-world consequences. A recent estimate indicates that the online proliferation of fake news accounts for an economic loss of ~\$78 billion annually³¹. Thus, a better framing of information on a given topic would translate into measurable benefits. As far as spiders are concerned, misinformation foremost results in waste of money and resources by people and institutions. Emblematic cases include the closure of schools in the UK due to alleged “invasions” by false black widows (genus *Steatoda*) (e.g., article ID UK_328 in our database); or the story of a Californian man accidentally setting his house on fire while using a blowtorch to clear spider webs out of his backyard (e.g., article ID US_0461). Second, the content, tone, and quality of these stories shape people’s perception of risk^{7,14,32} and influence socio-political decisions around the management and conservation of wildlife^{33–35}. Besides the indirect effects on biodiversity caused by people’s attitudes and actions led by misinformation, a negative media framing of spiders amplifies arachnophobic sentiments⁷—an important mental health issue when considering that arachnophobia has an estimated prevalence between 3.5–11.4% of the world population^{36–39}.

Conclusion

A presence on the Internet of poor-quality information on any given topic², and the amplification of sensationalistic news through emotional contagion⁴⁰, is causing an unprecedented spread of misinformation on a global scale. This is emerging as a central challenge of the digital age. Our analysis of the framing of spiders on the media provides an example of how to study flows and drivers of (mis)information. We revealed strong drivers of information quality and spread (Figure 3); identification of these factors can be translated into efforts to promote higher-quality news and to decrease the prevalence of inaccurate information—for instance, by closer collaboration between journalists and experts⁷ and by exploiting new online channels to communicate accurate science⁴¹. Our approach could be easily applied to other information systems, producing tangible benefits in terms of resource management and public health and safety by limiting the costs associated with widespread misinformation.

Methods

News article data

We analyzed a global database of news articles on human-spider encounters published by online newspapers and magazines in 2010–2020⁹. The database is unique in that it covers a global scale while providing an in-depth expert-based assessment of each news article’s content and its quality. All news articles across countries and languages were retrieved using the same data mining strategy; furthermore,

to increase the accuracy and internal consistency, each news article in the most frequent languages was validated by independent assessment by different experts. The database covers news articles in 40 languages and 81 countries—note that for Botswana and Iceland no spider news items were detected. The total sample size is 5,348 unique news articles, reporting 6,204 human-spider encounters. However, many of these human-spider encounters were reported by multiple news sources, leaving a total of 2,644 unique encounters—of which 1,121 are classified as bites and 147 as deadly bites. For each news article, the database includes a number of news-level variables. We considered the following ones in analyses (see ref. ⁹ for a full description of the dataset and data collection methods):

- 1) date of publication (“Year” and “Month”);
- 2) language (“Language”);
- 3) newspaper circulation (“Circulation”; categorical variable with three levels: “Regional”, “National”, and “International”);
- 4) country in which the news was published (“Country”)
- 5) type of human-spider encounter (“Type_event”; categorical variable with three levels: “Encounter”, “Bite”, and “Deadly bite”);
- 6) genus of the species involved in the event (“Genus”);
- 7) longitude and latitude coordinates of the human-spider encounter (“x” and “y”);
- 8) presence/absence of photos of the species and the bite (variables “Photo_”);
- 9) presence/absence of errors (“Errors”; including errors in taxonomy, morphology, venom, and in the spider photo);
- 10) assessment of the news as sensationalistic vs. neutral (“Sensationalism”); and
- 11) consultancy of spider experts, doctors, or other professionals (variables “Expert_”).

Statistical analyses

We performed all analyses and calculations in R version 4.1.0⁴². We used the package “ggplot2” version 3.3.4⁴³ for visualizations. In all regression-type analyses, we followed Zuur & Ieno⁴⁴ for model construction and validation. In discussing model results, we adopted an evidence-based language⁴⁵, referring to effect sizes, directions of effects, and variance explained rather than significance⁴⁶. Exact estimates and p-values can be found in Tables S1–S5.

Relationships between sensationalism, errors, and news-level attributes

First, we explored the role of different news-level attributes in explaining the probability of a given piece of news being sensationalistic or including errors. We fitted generalized linear mixed models with the R package *lme4* version 1.1-27.1⁴⁷. Given that the response variables are incidence data (presence/absence of errors; sensationalist or not), we chose a Bernoulli family distribution (0–1, discrete). The structure of the two models, in R notation, was:

(eq. 1) Sensationalism ~ Year + Type_of_newspaper + Circulation + Type_event + Photo_species + Photo_bite + Expert_doctor + Expert_arachnologist + Expert_others + Errors + (1 | Genus) + (1 | Language) + (1 | Country_search) + (1 | ID_Event)

(eq. 2) Presence/absence of Errors ~ Year + Type_of_newspaper + Circulation + Type_event + Expert_doctor + Expert_arachnologist + Expert_others + Sensationalism + (1 | ID_Event) + (1 | Genus) + (1 | Language) + (1 | Country_search)

To check whether there was covariation between sensationalism and errors in the articles, in the model for sensationalism we included the assessment of errors as a response variable (eq. 1) and *vice versa* for the model of errors (eq. 2). Also note that, in eq. 2, we did not include variables referring to photos, because only articles with photos may contain such an error. The random part of the models allowed us to control for publication language, the country of the search, and the taxonomic identity of the species involved in the human-spider encounter. In other words, by the design of the study, we assumed that articles from the same countries and language, and dealing with congeneric species, should be more similar to one another in their news-level attributes than expected from random. Treating these variables as fixed factors would have consumed too many degrees of freedom given the high number of levels for each of these factors. Furthermore, we include a fourth random factor (“ID_event”) to account for pseudo-replication, due to multiple articles referring to the same human-spider encounters. We introduced all random effects as random-intercept factors because we did not expect them to influence the direction of effects.

In both models, the final sample size was 5,816 observations—after removing missing data. We validated models by constructing standard validation plots with the R package *performance* version 0.7.2⁴⁸. We also checked for spatial and temporal dependency by plotting model residuals against the year and month of publication and the longitude and latitude of the centroid of the country in which the news was published. We detected no obvious spatial and temporal patterns.

Global flow of spider-related information

We used network analyses to visualize and model the flow of spider-related information among countries. We constructed and manipulated networks with the R packages 'igraph' version 1.2.6⁴⁹ and 'tidygraph' version 1.2.0⁵⁰. First, we constructed a bipartite directed network to link each country with each spider-related event reported by the online press. In the network, the first node type represented individual countries, and the second node type represented the identifier for each human-spider encounter reported in the press (ID_event) (Figure 1). Once we constructed the bipartite network, we projected it as a one-mode network (or unipartite network) with the 'igraph' function *bipartite.projection*. This allowed us to visualize the relationships amongst the nodes of type 1 (countries). In the one-mode network, all nodes are treated as the same type, and directionality is lost (Figure S1).

For each country node, we calculated the degree of centrality within the network with the 'igraph' function *degree*. Degree centrality assigns an importance score based on the number of links (edges) held by each node. Thus, degree centrality represents a simple measure of node importance, whereby nodes with higher centrality are expected to quickly connect with the wider network. We used a generalized linear mixed model to explore the influences of different country-level attributes to the degree centrality of each country. We extracted country-level attributes deemed potentially important in influencing the system under study (full list of predictors is described in Supplementary text S1, including decisions taken after data exploration). Since degree centrality is a positive integer, we fitted an initial model with a Poisson error and a log link function. The Poisson distribution is suited for count data (degree centrality are positive integers) and the log link function ensures positive fitted values. Because many of the predictor variables were strongly correlated (Supplementary text S1; Figure S2), we selected six non-collinear variables for the model. Note that we did not include the variable N° of news, or any variable correlated with it (Figure S2), because the measure of degree centrality is directly proportional to the sample size of each node—the inclusion of sample size or any correlated variable would capture all explained variation in the regression model. The structure of the model was:

(eq. 3) Degree centrality ~ Sensationalism + Errors + Internet users + Press freedom + N° of spiders + (1 | Language)

The Poisson model was over-dispersed (dispersion ratio = 10.73). Thus, we switched to a negative binomial distribution—i.e., a generalization of Poisson distribution which loosens the assumption that the variance should be equal to the mean. The model sample size was 81 observations, including two countries with no news for which we assigned a degree centrality of zero. As before, we validated the model with appropriate functions of the package *performance*.

Next, we modeled connections among countries within the network using exponential random graph models. These are a family of regression-like models that can infer how network relationships are formed, using the network itself as a response variable. To model the probability of each node to form connections, we introduced the one-mode network with binary edge weights as a response variable in an exponential random graph model fitted within the R package ‘*ergm*’ version 4.1.2^{51,52}. We selected as covariates all variables tested in *eq. 3*. In contrast to previous analyses, however, we included Language as a fixed term because random effects are not implemented in exponential random graph models yet. Also, we excluded press freedom from the model, as the variable was not identifiable in the model—note that there was no evidence that this variable exerted an effect on degree centrality (Figure 2C). The structure of the model had the formula (in *R* notation):

(*eq. 4*) $\text{Network} \sim \text{edge} + \text{nodeCov}(\text{"Sensationalism"}) + \text{nodeCov}(\text{"Errors"}) + \text{nodeCov}(\text{"Internet users"}) + \text{nodeCov}(\text{"N° of spiders"}) + \text{nodeMatch}(\text{"Language"}) + \text{nodeFactor}(\text{"Language"})$

Where *edge* is the intercept-like term; *nodeCovariate* and *nodeFactor* test the overall probability of the node types forming connections with any other nodes based on the continuous and categorical covariates, respectively; and *nodeMatch* tests whether node types have a greater probability of forming connections within the levels of a given grouping factor. The model sample size was 79 observations, namely the number of nodes (countries) in the network. To the best of our knowledge, validation of exponential random graph models is not a fully resolved topic. As a means of model validation, we generated an empty network with the same dimensionality as our response network and used the final model to simulate, over 1,000 runs, whether the model was able to converge to the edge probability of the real network.

Besides the probability of forming connections, we tested the effects of the factors modeled in *eq. 4* on the number of connections (shared news) among countries using a generalized exponential random graph model⁵³. In the network, we weighted each edge connecting two nodes by the number of shared articles between two countries (see weights in Figure S1), and fitted a Poisson generalized exponential random graph model with ‘*ergm.count*’ version 4.0.2⁵⁴. We estimated model parameters via Monte Carlo Maximum Likelihood. We validated this model by inspecting the mixing of chains and other diagnostics via the function *mcmc.diagnostics*. As the direction and strength of effects were qualitatively the same (*cfr.* Figure 2D and Figure S3), we only showed the previous model in the main text.

Data availability

The database used in the analyses is available in FigShare (doi: 10.6084/m9.figshare.14822301). Metadata and data collection methodology are fully described in ref. ⁹. Country-level attribute repositories

and sources are described in Supplementary Text S1.

Code Availability

The R code to generate analyses and figures is available in GitHub (https://github.com/StefanoMammola/StefanoMammola-Analysis_Spider-News-Network).

Declarations

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Author contribution

Conceptualization: SM, JM-O, CS, AC; Data collection & validation: all authors; Data analysis & visualization: SM; Writing (first draft): SM; Writing, contributions: JM-O, CS, AC; All authors read the text, provided comments, suggestions, and corrections, and approved the final version.

Competing interests

None declared.

Supplementary materials

Supplementary Text S1

Table S1–S5

Figure S1–S2

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Figures

Figure 1

Global distribution of news articles on human-spider encounters. Bipartite directed network linking each country (pies; $n = 79$) with each spider-related event reported by the press (dots, $n = 2,644$). Note that two countries (Botswana and Iceland) for which we did not find any news are not displayed on the map. The size of each pie chart refers to the number of news articles published in the country between 2010–2020;

the color of each pie represents the proportion of sensationalistic news. Direct connections among countries are shown in Figure S1.

Figure 2

Drivers of sensationalism and errors in media articles on spiders, and flow of information on spiders in the online press. **A)** Estimated parameters for the model of sensationalism according to a Bernoulli generalized linear mixed model (*eq. 1*); **B)** Estimated parameters for the model of errors according to a Bernoulli generalized linear mixed model (*eq. 2*); **C)** Estimated parameters for the degree centrality of each country according to a negative binomial generalized linear mixed model (*eq. 3*); **D)** Estimated parameters for the probability of each country to form connections according to an exponential random graph model (*eq. 4*). Error bars indicate standard errors. Estimated regression parameters and p-values are in Tables S1–S4.

Figure 3

Sensationalism and the lack of expert consultation spread scientific misinformation. Two main conclusions emerged from our analysis: i) Global spread of misinformation is driven by a limited number of key factors, among which the level of sensationalism of a news article is particularly important; and ii) Sensationalism and misinformation decrease when the “right” expert is consulted, namely an expert on spiders. The latter effect does not occur when non-specialized professionals, including doctors, are consulted. Original illustration by Jagoba Malumbres-Olarte.

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