News-stimulated public-attention dynamics and vaccination coverage during a measles outbreak: An observational study

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Rationale. Measles is a highly contagious disease that is responsible for about 110,000 annual deaths worldwide, even though a safe, effective, and inexpensive vaccine is available. Given that full vaccination coverage is below the desired threshold in many countries, increasing the vaccination coverage is an important public health goal, aiming to contribute to a reduction of measles deaths. *Objective.* This study investigates the dynamics between media and public attention on measles and vaccination coverage during the 2015 measles outbreak in Berlin, Germany. It was hypothesized that the epicentral distance would influence the observed effects of the outbreak on public attention due to a higher perceived threat susceptibility in more proximal states. *Method.* Using observational macro-level data from German federal states, the study taps into news-stimulated public-attention dynamics around the outbreak. We assessed public attention, media attention, and vaccination coverage among 24-month-old children. *Results.* Findings indicate that public attention increased exponentially as the epicentral distance lessened. Distance mattered more in states surrounding Berlin—a discovery we termed the "Rubicon effect." Importantly, within a small radius of the epicenter, the decay in public attention was slower, and higher rates of public attention were related to an increase in vaccination coverage among children aged 24 months. *Conclusions.* Given that full vaccination coverage for measles (after receiving the second dose) is below the desired value in Germany (and many other countries), the observed increase in vaccination coverage, in response to news-stimulated increases in public attention, can be deemed a beneficial public health outcome. The findings, including the Rubicon effect, are discussed in light of optimal resource allocation for vaccination programs.

Credit author statement

Florian Arendt: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Visualization; Sebastian Scherr: Conceptualization, Methodology, Writing - review & editing.

1. Introduction

Measles is a highly contagious disease that is responsible for about 110,000 annual deaths worldwide (World Health Organization [WHO], 2018), although a safe, effective, and inexpensive vaccine is available. Therefore, to reduce measles deaths, the WHO (2019) recommends immunization for all children for whom a measles vaccination is not contraindicated. Importantly, given that full vaccination coverage (reached only after two doses of the measles, mumps, and rubella [MMR] vaccine) is below the desired threshold in Germany and many other countries (European Centre for Disease Prevention and Control [ECDC], 2019), increasing the vaccination coverage is an important public health goal.

The media can be perceived as a "double-edged sword" in the vaccination domain. On the one hand, the media may contribute to a decline in vaccination coverage by influencing (false) beliefs related to risks through mentioning (suspected) adverse single-case stories. For example, in Denmark, the uptake dropped for the first human papillomavirus (HPV) vaccine from 90% to 54% between 2009 and 2014 following several negative single-case news reports about girls presumably showing symptoms of disability after HPV vaccines (Suppli et al., 2018; see also Callaghan et al., 2019). On the other hand, the media may elicit beneficial effects on public attention and vaccination coverage (e.g., see Arendt and Scherr, 2019).

The present paper focuses on a measles outbreak in Berlin, Germany

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in 2015, over the course of which a one-year-old child died from measles in February. Importantly, a measles outbreak can function as a "key event" (Brosius and Eps, 1995) that may elicit further public and media attention (see Waldherr, 2014). In fact, a measles outbreak may influence the media and public agenda (McCombs and Shaw, 1972), raising public awareness regarding measles as an important issue in an indirect way via an increase in media attention: the key event may increase news coverage which, in turn, may lead to higher public awareness. Furthermore, the key event in close proximity may also raise public awareness in a rather direct way (e.g., via interpersonal communication, social media). In any way, we hypothesized that the measles outbreak would stimulate both media and public attention (Hypothesis 1). However, we expected that the increase in public attention would depend on the epicentral distance, both in terms of overall volume (Hypothesis 2) and decay (Hypothesis 3).

These predictions were based on the general idea that individuals may show a higher perceived susceptibility (the extended parallel process model [EPPM]; Witte, 1992), a stronger risk perception (risk information seeking and processing [RISP]; Griffin et al., 1999), stronger affective responses to risk (the planned risk information seeking model [PRISM]; Kahlor, 2010), and less complacency (the 5C model of antecedents of vaccination; Betsch et al., 2018; Brewer et al., 2017) when living in close geographic proximity to the measles outbreak. Individuals may learn from the outbreak via interpersonal communication or through social networking sites. Furthermore, close epicentral distance (i.e., geographical proximity) may increase the newsworthiness of the key event itself (see Eilders, 2006), leading to more news coverage in close geographic proximity. Journalists themselves may perceive a higher susceptibility and stronger personal risk, and show stronger affective responses and less complacency to the risk when being in closer geographic proximity to the measles outbreak. This may contribute to a higher number and longer duration of (especially local news) media attention. Thus, a stronger increase in public attention may also be reflective of increased (local) news coverage that led to more public attention in close geographic proximity. This idea would be consistent with indirect effects of a key event on public attention via its influence on media attention. A higher perceived susceptibility or stronger risk perceptions may increase the intentional use of outbreak-related news by audience members (i.e., selective exposure) living in close geographic proximity, which may further augment public attention. Importantly, across possible conceptual avenues of media influence (from more indirect to more direct routes), the initial information is likely to have originated from a news outlet (and might have been shared through social media or interpersonal communication), which is why we use *news-stimulated public attention dynamics* to describe this phenomenon. Although the underlying mechanisms are deemed complex and intertwined, the present study tested whether the key event "measles outbreak" contributed to macro-level public-attention dynamics, rather than exploring specific underlying mechanisms.

Additionally, we investigated whether the increase in public attention was related to an increase in federal state-level vaccination coverage for young children (Research Question 1). The 2015 Berlin measles outbreak may have acted as a "nudge" (Thaler and Sunstein, 2008) by "reminding" (Auty and Lewis, 2004) parents to vaccinate their children by putting measles as a health threat as the focus of public attention. The increase in public attention may have also led to an increase in parents' more systematic rumination about the perceived susceptibility and severity of the disease, including deliberate thoughts on the perceived benefits and barriers of vaccination (see Champion and Skinner, 2008). Thus, it is certainly conceivable that the increase in public attention was related to an increase in federal state-level vaccination coverage for young children.

2. Method

2.1. Public attention

We relied on search engine volume as an indicator of public attention (Arendt and Scherr, 2017). We investigated the extent to which individuals included the term "Masern" (measles) in their online information seeking via the most popular Internet search engine, Google. The available Google Trends Data (GTD) speaks to the frequency with which the term "measles" was entered into the Google search engine on a daily basis. We collected the data for an observation period from February 1, 2015 until March 31, 2015, which represents a two-month time window around the prominently reported death of a one-year old child in Berlin, with measles being the attributed cause of death. Importantly, the GTD are normalized: that is, the day on which users most frequently used "Masern" as a search term typed into a Google search was defined as the peak day (= 100) in the dataset. The search volume for all other observation days are then expressed as the query share value relative to the peak (i.e., a value of 20 represents 20% of the search volume observed for the peak day).

2.2. Media attention

To capture media attention, we relied on a comprehensive news archive of German newspapers (Austrian Press Agency [APA], 2019). The archive includes $N = 37$ daily German newspapers including leading quality daily newspapers (e.g., *Sueddeutsche Zeitung*) as well as market-oriented tabloid newspapers (e.g., *BILD*), and local newspapers (e.g., *Berliner Morgenpost*), thereby broadly reflecting the German news media landscape (for a full list of newspapers, see APA, 2019). Consistent with the assessment of public attention, we searched the archive for articles including the term "Masern" (measles). For each day of the observation period (February 1, 2015–March 31, 2015), we assessed the number of news articles that included the term "measles" appearing each day.

2.3. Vaccination coverage

We relied on data provided by *KV-Impfsurveillance* (Robert Koch Institut, 2019), which provides vaccination coverage data for birth cohorts. The Standing Committee on Vaccination (STIKO) in Germany recommends the first measles vaccination for children aged 11–14 months and the second vaccination at the age of 15–23 months. Thus, we looked at vaccination coverage data among 24-month-old children. Although children can still get vaccinated after two years of age, most vaccinated individuals receive their second vaccination within the recommended time interval (Schönberger, Grote, von Kries and Kalies, 2009). We used vaccination coverage data for the 2012 and 2013 birth cohorts. Importantly, the key target event of the 2015 measles outbreak in Berlin could not have influenced the number of recommendation-consistent vaccination behaviors (i.e., the second dose of the vaccine) in the 2012 birth cohort. However, the 2013 birth cohort represents the first cohort that could possibly have been affected by the 2015 measles outbreak. We therefore calculated the difference in vaccination coverage of 24-months-old children between both birth cohorts as a percentage-point difference score (i.e., vaccination coverage of the second dose for the 2013 birth cohort minus the 2012 birth cohort) for 15 of the 16 German federal states. Unfortunately, we could not use Sachsen data. In Sachsen, the recommendations differ from the rest of Germany in that the second dose is recommended considerably later (i.e., after 60 months instead of 24 months). Therefore, this analysis is based upon $N = 15$ German federal states.

2.4. Geographic distance

Above and beyond these variables, we also included the distance

from the epicenter of the 2015 Berlin measles outbreak using beelines (in kilometers) between Berlin and the capital of each federal state to investigate how much the effects were mitigated by distance.

2.5. Statistical analysis

We used a time-series analysis to investigate the day-by-day variations in media and public attention. For all other analyses, we used macro-level (i.e., federal state) data. Consistent with previous research (Watt et al., 1993), we used the *k* constant and its 95% confidence interval as a measure for the decay.[1] The *k* constant allows us to measure the rate of decay in public attention. The smaller the *k*, the slower the decline. For the curve-fitting procedure related to the decay, we restricted the observation period insofar that x = 0 represented the peak day with a Google search volume of 100.

We used GraphPad Prism (Version 8) to fit a one-phase decay model (see the Online Appendix for the statistics): Y = (Y0 − Plateau)*exp (−k*X) + Plateau.

- Y is public attention
- X is days (number of days after the peak day)
- Y0 is the peak value of public attention (at x = 0),
- k is the rate constant, expressed as a reciprocal of the X axis time units (i.e., days),
- Plateau is the Y value (public attention) at infinite times – the asymptote or residual effect.

3. Results

Hypothesis 1 predicted an increase in media and public attention in response to the key event. As can be seen in Fig. 1, there was a sharp increase in both media and public attention, temporally co-occurring a few days after the death of the one-year-old child from measles in Berlin. There was a strong correlation between media and public attention, $r(57) = 0.79$, $p < .001$.

Hypothesis 2 predicted that the overall volume of public attention would depend on the distance from the epicenter. There was a strong negative bivariate (linear) Pearson correlation between distance and public attention, $r(14) = -0.83$, $p < .001$. A visual inspection of the scatterplot (see Fig. 2) indicates that a nonlinear model may reflect the data better than a linear model. Consequently, we fitted a nonlinear, exponential decay function. The nonlinear model was better able to predict the empirical pattern ($R^2 = 0.88$) than the linear model was ($R^2 = 0.69$), $F(1, 13) = 21.55$, $p < .001$. The relationship between public attention and distance supports Hypothesis 2. The discovery of the nonlinear nature of this relationship, however, complements our theoretical assumptions: Geographic distance mattered most when federal states were closer (i.e., proximal to Berlin); in contrast, if a specific distance was exceeded, distance no longer substantially mattered. We return to this finding in the discussion section.

Finally, Hypothesis 3 predicted that the decay in public attention after the public attention had peaked was slower in Berlin relative to other federal states. We used a nonlinear regression analysis to fit an exponential decay function for (a) public attention in Berlin versus (b) public attention in the rest of Germany. Consistent with the hypothesis, the decay was significantly slower in Berlin, $k = 0.22$, 95% CI [0.20, 0.24], $R^2 = 0.97$, compared to the rest of Germany, $k = 0.30$, 95% CI [0.28, 0.32], $R^2 = 0.99$, as indicated by the non-overlapping confidence intervals. Fig. 3 visualizes the two decay functions, including the half-life (i.e., the time required for the decaying public attention to fall to one half of the span, defined as the public-attention peak value minus its plateau). In order to test these findings for their robustness, we compared Berlin's *k* constant with the *k* constant of all other German federal states (see Online Appendix). This additional analysis also supports Hypothesis 3.

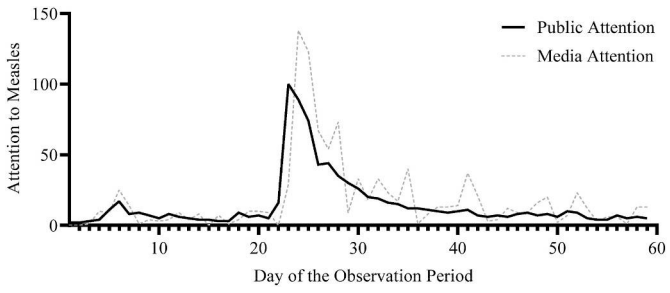

Fig. 1. Public and media attention on measles during the 2015 measles outbreak in Berlin, Germany.

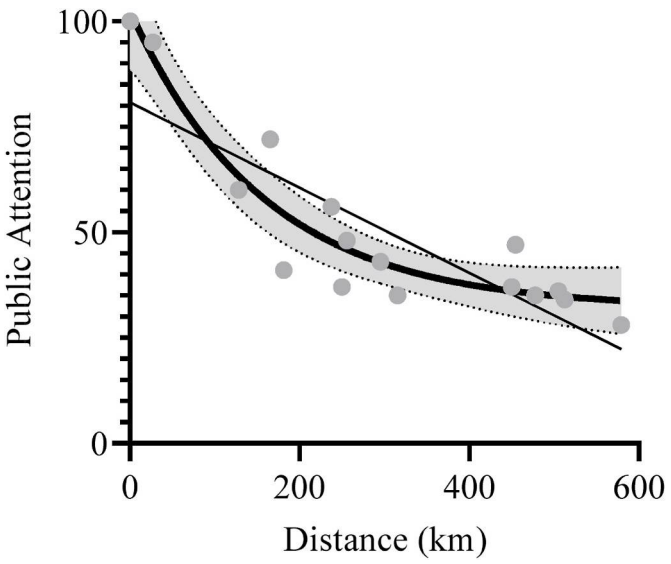

Fig. 2. Public attention as a function of epicentral distance for $N = 16$ federal states. The black curve (line) is based on a nonlinear (linear) regression analysis and represents an exponential decay (linear) function. The gray area between the dotted curves represents the confidence band (95%) of the exponential decay function. The two federal states on the left upper side of the scatterplot represent Berlin and Brandenburg. The decay constant *k* is 0.006, 95% CI [0.003, 0.011] and the plateau is 31.98, 95% CI [15.48, 40.89].

3.1. Vaccination coverage

Research Question 1 asked whether the increase in public attention was related to an increase in vaccination coverage among young children. There was a positive linear relationship between public attention toward measles during the measles outbreak and an increase in vaccination coverage, $r(13) = 0.77$, $p = .001$. As can be seen in Fig. 4 on the right-hand side of the scatterplot, two federal states (Berlin, Brandenburg) contributed the most to the strength of the statistical relationship.

As a test for robustness, we re-ran this analysis with public-attention data from 2013 to 2014 and 2016–2017 (i.e., the two years before and the two years after the Berlin measles outbreak). Analyses indicated that there were no significant relationships between the increase in vaccination coverage (the 2012 vs. 2013 birth cohorts) and public attention in those four years (2013: $r(12) = 0.06$, $p = .833$; 2014: $r(13) = 0.33$, $p = .230$; 2016: $r(12) = -0.04$, $p = .892$; 2017: $r(13) = 0.24$, $p = .393$), indicating that the relationship is unique to the 2015 data (i.e., the Berlin measles outbreak).

4. Discussion

The present study found that a measles outbreak in Berlin stimulated media and public attention about measles. Moreover, public attention

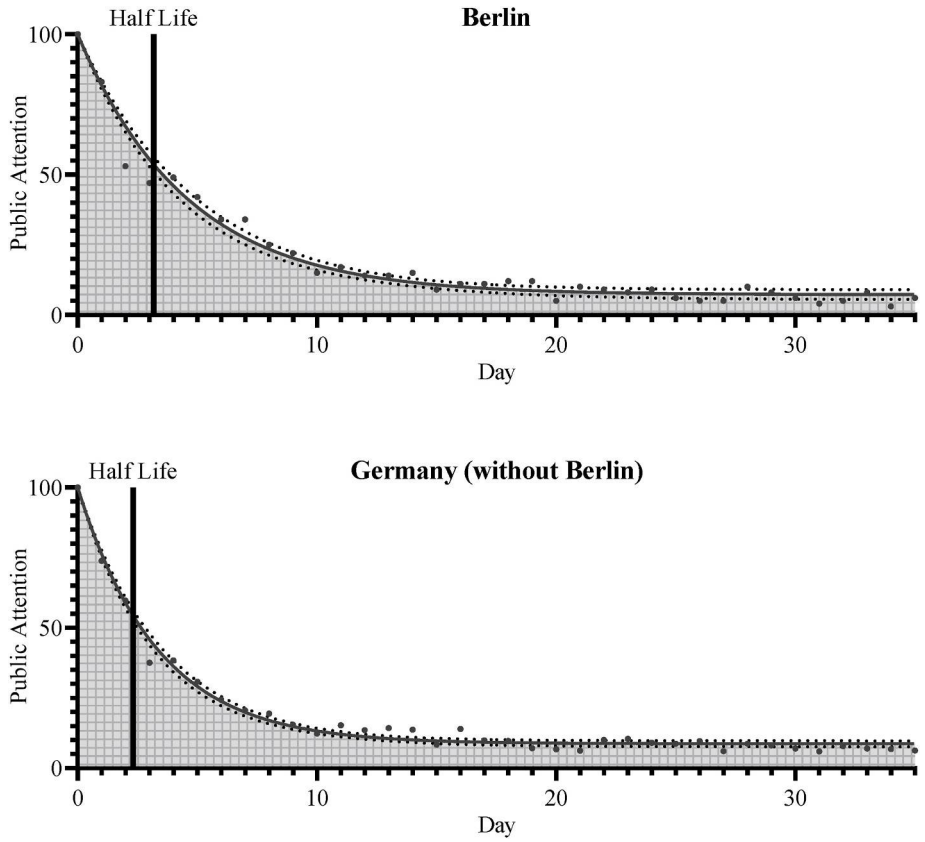

Fig. 3. Public attention as a function of time in Berlin (upper scatterplot) and the rest of Germany (bottom scatterplot). The vertical bold black lines indicate the half-life (= peak minus plateau/2), which depends on *k*. A greater half-life value is indicative of a slower decay. The dotted black curves represent the upper and lower limits of the confidence band (95%).

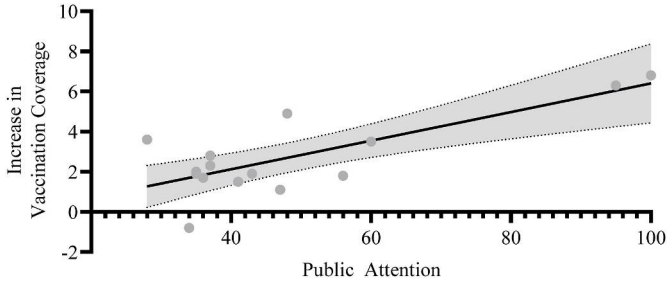

Fig. 4. Public attention on measles predicted an increase in vaccination coverage of children aged 24 months. Each gray dot represents one federal state. The black line is based on a linear regression analysis. The gray area between the dotted curves represents the confidence band (95%). The two federal states on the right-hand side of the scatterplot represent Berlin and Brandenburg.

was positively related to an increase in vaccination coverage among 24-month-old children. Given that full vaccination coverage for measles (after receiving the second dose) is below the desired value in Germany and many other countries (ECDC, 2019), the observed increase in vaccination coverage in response to news-stimulated increases in public attention can be deemed a beneficial public health outcome.

Epicentral distance was a strong influencing factor, eliciting a nonlinear effect pattern: Federal states in close proximity to the key event were affected more strongly by geographic distance. Distance from the epicenter mattered in those states more than it did in distal states. We term this unexpected discovery the "Rubicon effect," inspired by Julius Caesar's crossing of the North Italian Rubicon River with his troops, thereby getting too close to and becoming too much of a risk for the Roman Empire. Similarly, in the present study, when the measles outbreak was within a radius of a few hundred kilometers from the epicenter, geographic distance did matter, and public attention declined rapidly with distance. Given that the Rubicon effect seems to be a nonlinear phenomenon (see Fig. 2), we could not report one single value of epicentral distance representing it. It seems to be a rather fluent transition. However, outside this zone (i.e., "across the Rubicon"), public attention approaches an asymptote, with geographic distance no longer mattering. Thus, until the "Rubicon" had been crossed, the public in epicentral closeness to the key event may have felt increased personal susceptibility to the threat of the outbreak (see Witte, 1992), triggering its focus and action, as evidenced by increased levels of vaccination.

A more thorough understanding of the role of geographic distance may have practical implications for effective resource allocation for vaccination programs. A severe outbreak requires substantial resources, for which efficient allocation is key to any vaccination program (e.g., ordering more vaccines or increasing the number of physicians). If public attention is stimulated by a key event, online search volumes may be a useful and cost-effective (supplementary) real-time assessment tool to estimate *where* (and, of course, when) additional resources are needed (Arendt and Scherr, 2017). Search volume data can help in "identifying the Rubicon" and therefore may aid in prioritizing federal states in more immediate need of resources.

Although the present study tested the impact of the death of a one-year old child in Berlin as the key event, other events may stimulate public attention dynamics as well. Apparently, the death of a one-year old child may stimulate public attention dynamics in an especially substantial way. However, other events may also stimulate it, albeit possibly to a different extent. For example, during the course of a measles outbreak in Austria in January 2019 (see Arendt and Scherr, 2019), an older individual, an infected fifteen-year old boy, was

identified at a regional hospital. It was speculated that he infected a number of other children. However, there was a high degree of uncertainty due to the fact that nobody could know whether more cases would appear. This may have elicited uncertainty and possibly fear, stimulating an increase in media and public attention. Although it is difficult to predict whether a specific event will elicit a strong increase in public attention, search volume data may help to identify important key events from the perspective of the public. In fact, this may aid resource allocation in a cost-effective way (see Arendt and Scherr, 2019).

4.1. Limitations

The study has several limitations. First, macro-level, federal state data can only result in limited conclusions at the individual level. Second, and related to this, causal interpretations should only be made with caution. We cannot provide proof for causal effects using macro-level data. Third, GTD have known limitations (Lazer et al., 2014). For example, search volumes are not representative for the general population in Germany. As a supplement to search volume data, for example, social media monitoring data could be added in order to better grasp such news-stimulated public-attention dynamics (Mollema et al., 2015).

5. Conclusions

Despite the limitations, the present study shows that a measles outbreak that receives intensive news coverage not only influences public attention toward measles but is also likely to transform public attention into an increase in vaccination coverage—but only 'on one side of the Rubicon'. Given that full vaccination coverage (reached only after two doses of the vaccine) is below the desired threshold in many countries, including Germany, the observed increase in vaccination coverage in response to news-stimulated increases in public attention can be deemed a beneficial public health outcome.

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