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The echo in flu-vaccination echo chambers: Selective attention trumps social influence

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ABSTRACT

Background: Online discussions may impact the willingness to get vaccinated. This experiment tests how groups of individuals with consistent and inconsistent attitudes towards flu vaccination attend to and convey information online, and how they alter their corresponding risk perceptions.
Methods: Out of 1859 MTurkers, we pre-selected 208 people with negative and 221 people with positive attitudes towards flu vaccinations into homogeneous or heterogeneous 3-link experimental diffusion chains. We assessed (i) which information about flu vaccinations participants conveyed to the subsequent link, (ii) how flu-vaccination related perceptions were altered by incoming messages, and (iii) how participants perceived incoming information.
Results: Participants (i) selectively conveyed attitude-consistent information, but exhibited no overall anti-vaccination bias, (ii) were reluctant to alter their flu-vaccination related perceptions in response to messages, and (iii) evaluated incoming information consistent with their prior attitudes as more convincing.
Discussion: Flu-vaccination related perceptions are resilient against contradictions and bias online communication. Contrary to expectations, there was no sign of amplification of anti-vaccine attitudes by online communication.

1. Introduction

Vaccinations are one of the most effective ways to prevent diseases, but their success relies — in absence of mandatory regulation — on public acceptance. With the increasing use of the internet for obtaining information, this acceptance is disputed [1]: As health experts lose their gate-keeping position in providing health-related advice and facts, lay peoples' preference for personal narratives and the lack of intuitiveness of both effectiveness statistics and the concept of vaccination itself may lead to a focus on misleading information [2–4]. Furthermore, potential risks of vaccinations and vaccine adverse events may be exaggerated, leaving people with more negative attitudes towards vaccination and stronger hesitancy than warranted by the scientific evidence [5,6].

Individual misconceptions about the potential benefits or risks of vaccinations may be further exacerbated by the mechanisms governing online interactions. This "social amplification of risk" is suggested to operate in the following ways [7–9]: Online information exerts social influence on people, so that they adjust their attitudes and risk perceptions towards it to conform with perceived norms (persuasion). In a second step, people selectively share information consistent with their adjusted attitudes (diffusion of information). As people with similar attitudes towards vaccinations tend to cluster in homogeneous online groups due to the search for and affiliation with like-minded people [10], the combination of social influence and selective attention in so-called echo-chambers yields a problematic distortion of vaccination facts and a polarization of attitudes [7]: attitudes shift to be more extreme, the more like-minded individuals are involved in the communication (Fig. 1).

This proposed social amplification mechanism also suggests that an approach to prevent the polarization of attitudes and vaccine message signals may be to mix people into attitude-heterogeneous groups. If individuals were confronted with opposing viewpoints, both the signal transferred to others and the individuals' attitude should polarize to a lower degree [7]. Contrary to this prediction, being exposed to counter-attitudinal information may backfire and further polarize attitudes and message signals,

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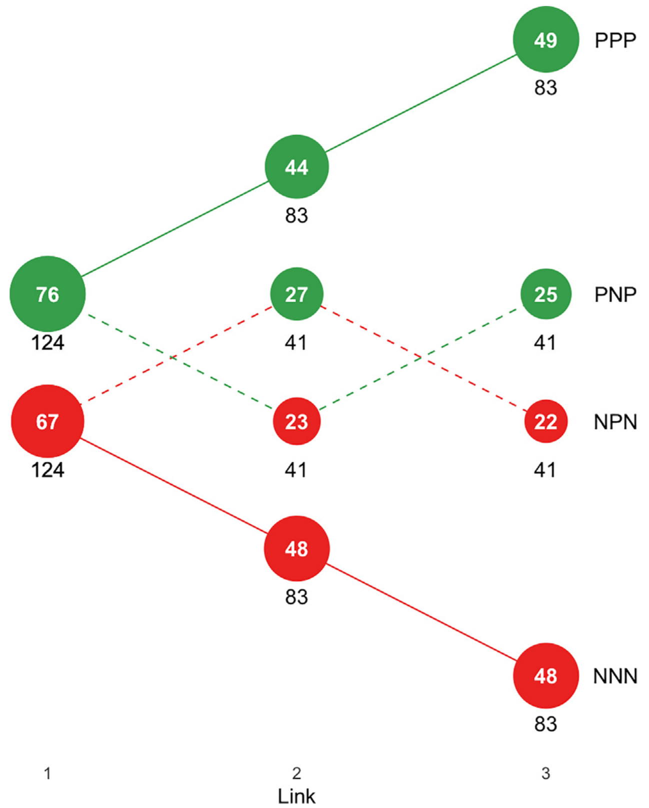

Fig. 1. Allocation design of diffusion chains and valid entries. *Notes.* The positive *Attitude* condition (P) is coded by green dots, the negative *Attitude* condition (N) is coded by red dots. In the circles, valid entries as defined in the method section are noted, whereas the numbers outside the circles indicate the number of allocated participants. On the right, the chain history is denoted by the respective *Attitude* conditions of involved *Links*. Dashed vs. solid lines represent heterogenous vs. homogeneous chain conditions, respectively. The vertical alignment reflects our hypotheses regarding the development of message signal and flu perceptions, with higher positions representing more positive attitudes towards vaccination. As such, we predict that both transmitted signal and final attitudes will be more extreme in chains with homogeneous (non-alternating) initial *Attitudes*. (For the interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

especially of individuals with prior negative attitudes towards vaccinations [11–14]. For instance, individuals with high concerns about the side effects of flu vaccinations were even less willing to get vaccinated after being exposed to messages challenging their concerns [12]. Furthermore, negative attitudes and contra-vaccine information might spread particularly fast within online network environments [2,15]. Accordingly, being confronted with opposing viewpoints may as well lead to a general amplification of negative attitudes towards vaccination instead of mitigating polarization.

The current study examines how online communication on vaccinations unfolds in both attitude-homogenous and attitude-heterogeneous groups. Exemplarily, we focus on the topic of flu vaccinations as these vaccination decisions are regular and not by proxy. In order to circumvent sampling problems of natural online communication [10,15], we use an adaptation of the classic diffusion chain paradigm initially employed by Bartlett [16] to study (i) which messages are transmitted from one individual to the next (diffusion of information), (ii) how attitudes and perceptions of flu vaccinations are influenced by the received messages (persuasion), and (iii) how individuals perceive messages that are inconsistent to their own view points (acceptance). As in an earlier application of this paradigm for testing the social amplification of risk framework [7], one individual is presented with a list of both pro- and contra-statements concerning flu vaccinations and then asked to write a message on this topic that is subsequently presented to the next study participant. By repeating this procedure, we establish communication sequences with each individual serving as a *Link* in a diffusion chain. Within such chains, we experimentally manipulate whether similar attitudes are shared by all *Links* or whether attitudes alternate between *Links*. Fig. 1 illustrates the expected development of attitudes by information diffusion in the chains based on previous simulations assuming the social amplification of risk [7]: Homogenous chains are expected to polarize their attitudes more strongly than heterogenous chains, while the direction of the hypothesized distortion is partly determined by the initial attitude of each *Link*.

2. Method

2.1. Participants and procedure

In order to determine participants' attitudes towards flu vaccination for the allocation in diffusion chains, we assessed these attitudes during a pre-test in April 2018 in a 3-item online questionnaire via MTurk with N = 1859 respondents finishing the pre-test (the same as in the main study; M = 9.82, SD = 4.04, *Range* 0–15, with higher values indicating more positive attitudes; Box 1.5). The pre-test was only presented to MTurkers located in the USA with a minimum of 50 completed task, a task acceptance rate of more than 90%, and not having participated in another vaccine-related project of our laboratory. The 372 participants with an attitude score below 7 on a scale from 0 to 15 and valid contact information were selected into the negative *Attitude* (N) condition (M = 3.24, SD = 2.23). To obtain a matching number of participants with pro-vaccination attitudes, we randomly sampled 372 of 1311 participants with an attitude score higher than 8 into the positive *Attitude* (P) condition (M = 11.9, SD = 1.90). Participants with rather neutral attitudes towards flu vaccinations (7–8 on the scale) were screened out to ensure that the diffusion chains only contained participants with a distinctive view on flu vaccinations.

Prior to the start of the main study, all selected participants of the pre-test were randomly allocated to one of the three *Links* (1/2/3) of an experimental diffusion chain conditioned on their pre-determined *Attitude*. Fig. 1 depicts how participants were distributed according to their *Attitude* into one of four chains to yield a homogeneous positive (PPP), a homogeneous negative (NNN), and two heterogeneous chains (PNP/NPN). Accordingly, the factor *Chain Heterogeneity* describes whether individuals at Link 2 and 3 receive messages from others that have consistent or inconsistent attitudes towards flu vaccinations.

Inviting all these sampled and randomly allocated participants via MTurk, the main study was conducted in 3 waves: participants of Link 1 responded April 16th–20th, Link 2 April 25th–28th, and Link 3 May 2nd–6th 2018. In total, 484 of the invited participants completed the questionnaire. To ensure that the messages about flu vaccination reported to the participant were attended, the message included an attention check which instructed participants to confirm in an open text that they read the presented message. 54 (Link 1: 24, Link 2: 15, Link 3: 5) people did not pass the attention check. 430 people passed the attention check, of which one indicated that data should not be used. Drop-out analyses revealed no systematic differences in the number of dropped-out and valid participants between *Links* $\chi^2(5) = 1.64$, $p = 0.897$. Likewise, participants not passing the attention check differed neither regarding their attitudes ($t(483) = 0.038$, $p = 0.969$), nor by condition ($\chi^2(3) = 2.61$, $p = 0.455$). In total, Table 1 provides descriptive statistics on all N = 429 valid returns, sorted by *Attitude* condition and *Link*. As there are some demographic differences and the attention check may have biased results, control analyses with

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Box 1 Assessment of perceptions of flu vaccinations both prior (t_1) and post (t_2) message exposure.

(1) **Vaccination Intention (α ≥ 0.99)**
2 items (from 0: *not at all* to 4: *yes, definitely*)
Example: "Do you intend to receive the flu vaccine for the seasonal flu in the upcoming flu season (fall 2018 to spring 2019)?"
(2) **Vaccination Recommendation (α ≥ 0.98)**
2 items (from 0: *not at all* to 4: *yes, definitely*)
Example: "Do you recommend receiving the flu vaccine for the seasonal flu in the upcoming flu season (fall 2018 to spring 2019) to your friends?"
(3) **Vaccination Norms (α ≥ 0.86)**
(a) Injunctive Norms
2 items (from 0: *completely disagree* to 6: *completely agree*)
Example: "*Most people important to me want me to receive a flu vaccination in the upcoming season.*"
(b) Descriptive Norms
2 items (from 0: *completely disagree* to 6: *completely agree*)
Example: "*Most people important to me will receive a flu vaccination in the upcoming season.*"
(4) **Perceived Behavioral Control (α ≥ 0.57)**
2 items (from 0: *completely disagree to 6: completely agree*)
Example: "*I feel in complete control of whether I receive a flu vaccination in the upcoming season.*"
(5) **Attitudes towards Flu Vaccinations (α = 0.91)**
3 Items (0–5)
Example: "bad" – "good"
(6) **Risk Perceptions Flu (α ≥ 0.86)**
(a) Severity
"How severe are the following events to your personal health?" (from 0: *not at all severe (can be neglected)* to 6: *very severe (life-threatening)*)
(b) Likelihood
"How likely is it that you get infected with the seasonal flu?" (from 0: *very unlikely* to 6: *very likely*)
(c) Comparative Likelihood
"Compared to other people of my age and gender my chances of getting the flu are:" (from 0: *much below average* to 6: *much above average*)
(d) Affective Risk Perception
2 items (from 0: *completely disagree to 6: completely agree)*
Example: "*I am worried about the seasonal flu.*"
(7) **Risk Perceptions Side Effects Vaccine (α ≥ 0.87)**
(a) Severity
"How severe are the following events to your personal health?" (from 0: *not at all severe (can be neglected)* to 6: *very severe (life-threatening)*)
(b) Likelihood
"How likely is it that you experience vaccine adverse events, if you get the flu vaccination?" (from 0: *very unlikely* to 6: *very likely*)
(c) Comparative Likelihood
"Compared to other people of my age and gender my chances of vaccine adverse events after receiving the flu vaccination are:" (from 0: *much below average* to 6: *much above average*)
(d) Affective Risk Perception
2 items (from 0: *completely disagree* to 6: *completely agree*)
Example: "I am worried about adverse events of flu vaccinations.
(8) **Knowledge about Flu Vaccination**
"How much do you know about flu vaccinations?" (from 0: *very little* to 5: *very much*)
(9) **Perceived Effectiveness of the Flu Vaccine**
"A flu vaccination will prevent me from contracting the flu." (from 0: *completely disagree* to 6: *completely agree*)

demographic covariates and including screened out participants were conducted, but lead to the same interpretation of results (see Supplement S1).

In the experiment, participants provided informed consent and were asked to indicate their perception of flu vaccination including their attitude towards the vaccination (t_1). Subsequently, they received a message regarding flu vaccination consisting of a list of statements from either the experimenter at Link 1 (Supplement S2), or from a participant from the preceding *Link*. After reading the message, participants rated it, and were then instructed to transmit their own message for the next *Link*: "*While you now have read different statements about the seasonal flu and about the flu vaccination, we would like to provide other study participants your personal account of the matter. Considering all information regarding flu vaccinations that you are familiar with, what would you like to communicate to another study participant? Please briefly describe the information that you would like to share.*" The received message was always present during the time participants were prompted to transmit their own message. After entering what they would like to convey to another person, participants were asked to indicate their perception of flu vaccinations for a second time (t_2) and provided demographical information.

The list of nine statements of the message received at Link 1 (Supplement S2) were designed to meet two criteria: balanced message *Valence* (1 neutral piece of information, 4 pro-vaccination, 4 contra-vaccination statements) and highest likelihood of being mentioned in the open text fields, as assessed by a pre-study including 63 statements from various online sources. In order to establish diffusion chains at Link 2, we divided all valid, non-empty Link 1 messages into a positive (P) and negative (N)

Table 1
Descriptive Statistics.

Condition	Link	Valid Entries	Female	Mean Age (SD)	Median Education	Mean Attitude t_1 (SD)	Vaccinated against FLU	Participation Rate
Negative attitude	1	67	61.2%	39.82 (12.23)	2-years post high school	5.10 (3.29)	7.5%	54%
	2	71	60.6%	37.97 (10.85)	2-years post high school	3.72 (2.56)	5.6%	57%
	3	70	78.6%	40.87 (11.09)	2-years post high school	4.19 (2.87)	4.3%	56%
Positive attitude	1	76	63.2%	36.59 (11.83)	Bachelor degree	11.96 (2.42)	52.6%	61%
	2	71	46.5%	36.46 (12.02)	Bachelor degree	11.63 (2.50)	49.3%	57%
	3	74	54.1%	39.84 (13.52)	Bachelor degree	11.13 (2.59)	52.7%	60%

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subset by the *Attitude* condition of Link 1. The *Chain Heterogeneity* condition of each Link 2 participant determined whether we then drew from the (P) or the (N) subset of Link 1 messages (see Fig. 1). To ensure that all messages were used, messages were dynamically and randomly drawn without replacement for each participant starting the survey and the set was only replenished once empty. (By accident, one out of 94 messages of Link 1 was replaced by another message of the same *Attitude* condition and thus, one message was not sampled and another one oversampled.) Analogously to Link 2, participants of Link 3 received randomly selected messages of valid Link 2 participants sharing same *Chain Heterogeneity* condition (see Fig. 1). At Link 2 and Link 3, participants were informed that the message they received was provided by a former participant of the study, while in Link 1 they were informed about the internet source from which the statement was adopted.

2.2. Measures

2.2.1. Coding of the transmitted message

Two blinded coders independently identified the total number of statements in a message, counted the number of statements with different *Valence* (pro, neutral, contra, $rs \geq 0.72$) and decided whether the statements were adopted from the previous *Link* ($\phi = 0.62$). Both ratings of the number of statements were averaged per statement type. Criterium for adoption was that one of the coders rated a statement to be adopted.

2.2.2. Perceptions of flu vaccination

Participants indicated whether they received a flu vaccination in the current season (*yes/no*) and answered a range of items designed to measure their attitude towards flu vaccination and risk perceptions. Box 1 summarizes the different constructs used to assess perceptions of flu vaccination (adapted from [17,18]). For instance, the sum of 3 semantic differentials was used to build an attitude toward vaccination score ($\alpha = 0.91$) ranging from 0 (*contra-vaccination*) to 15 (*pro-vaccination*) as one variable of focal interest.

2.2.3. Ratings of the received message

Participants rated the displayed message on four differential semantic rating scales asking how much the message argued against/for flu vaccination, and how trustworthy, persuasive, and informative the message was (each on a 0–4 Likert scale). The ratings of trustworthiness, persuasiveness and informativeness were averaged to build a perceived message validity score ($\alpha = 0.84$).

2.3. Statistical analysis

To scrutinize how transmitted messages are affected by different attitudes throughout the diffusion chains, effects on the number of transmitted statements across links were tested in a 3 *Link* (1/2/3) × 2 *Attitude* (P/N) × 3 *Valence* of the statement (pro/neutral/contra) mixed ANOVA (Greenhouse-Geisser corrected, where applicable). Furthermore, the polarizing effects of *Chain Heterogeneity* on the transmitted message signal (number of positive – number of negative statements) were tested in a 2 *Link* (2/3) × 4 *Chain Heterogeneity* (PPP/PNP/NPN/NNN) ANOVA. The same two factors were used in a MANOVA for evaluating social influence effects in different chains on the final perceptions of flu vaccination (t_2), and in an ANOVA to test for reactance in the perceived validity ratings of the received message. Significant results were followed up by Bonferroni-corrected post-hoc tests, the MANOVA by ANOVAs of the single constructs.

Furthermore, these tests were complemented by direct tests on the effects of the received message signal on the transmitted signal of the message, on changes ($t_2 - t_1$) in all constructs related to flu vaccination perceptions, and on the perceived message validity each in a stepwise hierarchical regression. In a first step, the correlations between the received signal and each measure were tested. In a second step, effects of initial attitudes and the interaction between initial attitude and received message signal were added. Significant interactions were followed up by simple slope analyses with effects ± 1 *SD* around the scale mean [19]. In order to obtain standardized results, initial attitudes were centered around the scale mean and all included variables were divided by their standard deviation. Perceived validity was Z-standardized.

3. Results

3.1. Amount and valence of transmitted information

Overall, the average amount of transmitted information yielded about 1.34 statements per individual (*SD* = 1.30). The adoption rate of statements from previous *Links* was 6.5% at Link 1 (*M* = 0.58 statements, *SD* = 0.95), 12.1% at Link 2 (*M* = 0.30, *SD* = 0.62), and 15.3% at Link 3 (*M* = 0.29, *SD* = 0.50). Given the dramatic drop in transmitted statements at Link 1, there was no further decay in

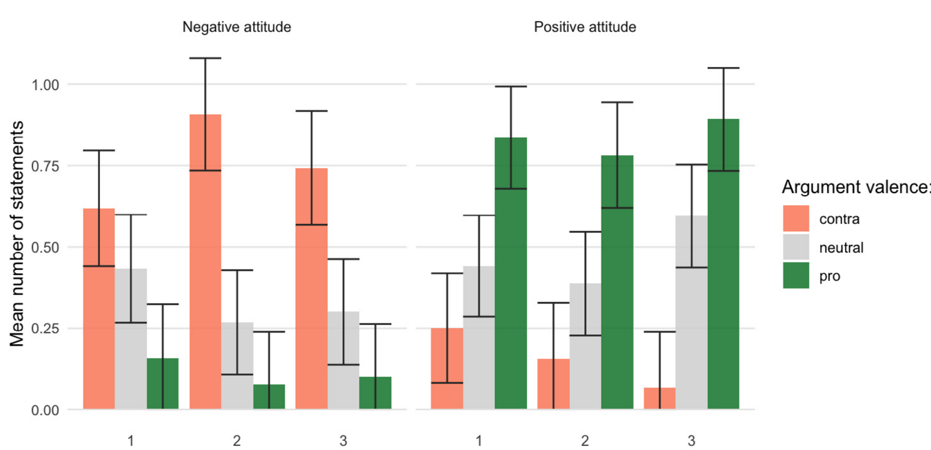

Fig. 2. Signal of messages across all *Links* for both *Attitude* conditions separated by statement *Valence* (with 95% CI). *Notes.* This figure shows the number of transmitted statements of different *Valence* in each *Link* of a chain for individuals with negative and positive prior *Attitudes*. It illustrates that individuals transmit few statements at all *Link* positions and mainly statements of the *Valence* that are consistent with their prior *Attitudes*.

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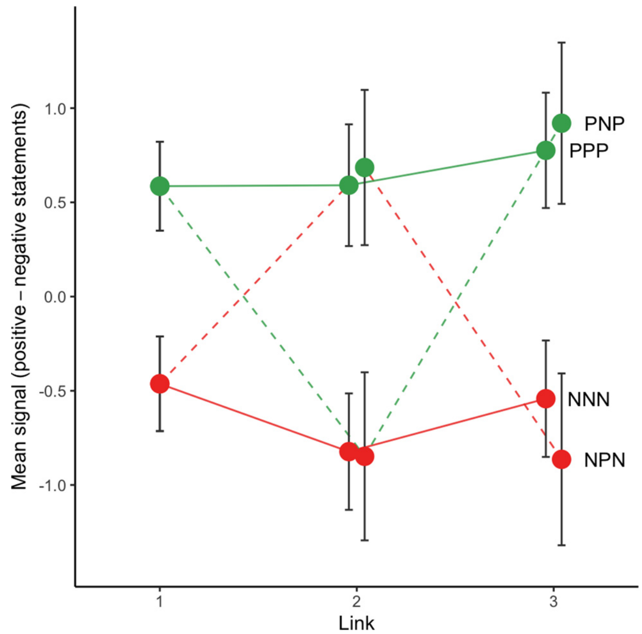

Fig. 3. Signal of messages across *Links* by *Chain Heterogeneity* condition (with 95% CI). *Notes.* Analogous to Fig. 1, P and N denote the *Attitude* condition of each chain *Link* with positive (green dots) or negative attitudes towards flu vaccinations (red dots). Dashed lines represent heterogenous and solid lines homogeneous chain conditions, respectively. This figure illustrates that the transmitted message signal was not affected by the type of chain, but rather by individuals' initial *Attitude*. (For the interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

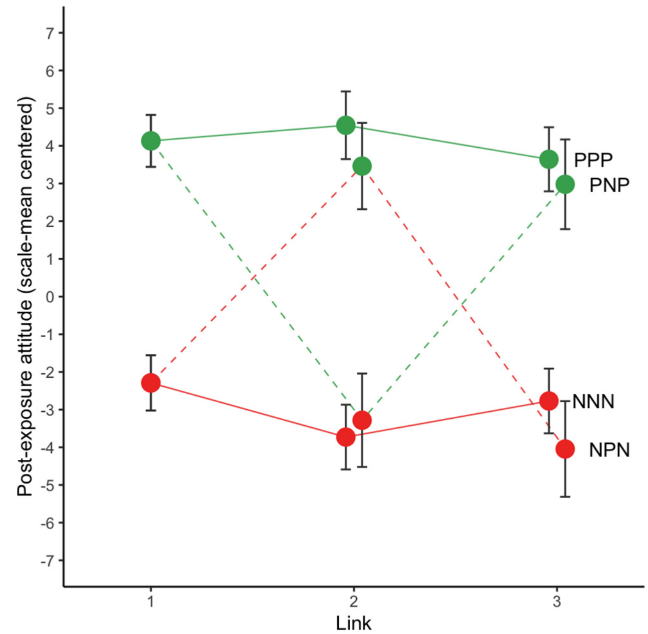

Fig. 4. Attitude after reading the message across *Links* by *Chain Heterogeneity* condition (with 95% CI). *Notes.* Analogous to Fig. 1, P and N denote the *Attitude* condition of each chain *Link* with positive (green dots) or negative (red dots) attitudes towards flu vaccinations. Dashed lines represent heterogenous and solid lines homogeneous chain conditions, respectively. This figure illustrates that the attitude after being exposed to the message was not affected by the type of chain, but rather by individuals' initial *Attitude*. (For the interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the number of transmitted statements from Link 1 to 3 (*Link* effect: $F(2, 423) = 0.14$, $p = .868$, $\eta_p^2 = .001$) and overall no difference in the number of transmitted pro-vaccine, contra-vaccine, and neutral statements (*Valence* effect: $F(1.937, 819.277) = 1.22$, $p = .296$, $\eta_p^2 = .003$).

Concerning the effect of individual's *Attitude* on the number of statements with different *Valence*, individuals in the positive *Attitude* condition transmitted more statements compared to the negative *Attitude* condition (*Attitude* effect: $F(1, 423) = 4.47$, $p = .035$, $\eta_p^2 = .010$), but this was qualified by an *Valence* × *Attitude* interaction ($F(1.937, 819.277) = 100.207$, $p < .001$, $\eta_p^2 = .192$): As displayed in Fig. 2, individuals with positive attitudes transmitted more pro-vaccine ($F(1, 423) = 117.31$, $p < .001$, $\eta_p^2 = .217$) and neutral statements ($F(1, 423) = 4.47$, $p = .035$, $\eta_p^2 = .010$), but fewer contra-vaccine statements ($F(1, 423) = 69.61$, $p < .001$, $\eta_p^2 = .141$) than individuals in the negative *Attitude* condition. These effects were stable across *Links* with no other effect reaching significance (all $p \geq 0.082$, $\eta_p^2 \leq 0.010$; see Fig. 2).

3.2. Polarization of the transmitted message signal in homogenous and heterogenous chains

When considering from whom individuals received their message by testing for the effects of chain type, *Chain Heterogeneity* had some impact on the signal of the transmitted message ($F(3, 278) = 24.92$, $p \leq 0.001$, $\eta_p^2 = .212$) with a diverging pattern for Link 2 and Link 3 (*Chain Heterogeneity* × *Link:* $F(3, 278) = 18.81$, $p \leq 0.001$, $\eta_p^2 = .169$, see Fig. 3). While the signal in both homogeneous chains did not change between Link 2 and 3 (both $p \geq 0.206$, $\eta_p^2 \leq 0.006$), the signal reversed for heterogeneous chains (both $p < .001$, $\eta_p^2 \geq 0.081$). In both Link 2 and 3, the signal of individuals in consistent *Attitude* conditions were highly similar (all $p = 1.000$), whereas it differed for individuals with inconsistent *Attitude* conditions (all $p < .001$, Fig. 3). This implies that we did not observe further polarization in the message signal of homogeneous compared to heterogeneous chains. Instead, what was transmitted was rather in line with the current *Link*'s attitude — irrespective of the attitude or message of the previous *Link*. This is also reflected in the absence of an association between the received signal and the transmitted signal ($r = 0.04$, $p = .380$), and in a high association of the transmitted signal with the initial attitude (received *signal*: $\beta = -0.01$, $p = .822$; *attitude*: $\beta = 0.57$, $p < .001$; *attitude* × *signal*: $\beta = -0.03$, $p = .418$).

3.3. Influence of the received message on vaccination-related perceptions

Flu vaccination-related perceptions after reading the message differed overall by *Chain Heterogeneity* (Pillai's trace $V = 0.66$, $F(27, 816) = 8.51$, $p \leq 0.001$, $\eta_p^2 = .220$) diverging for Link 2 and 3 (*Chain Heterogeneity* × *Link:* $V = 0.487$, $F(27, 816) = 5.85$, $p < .001$, $\eta_p^2 = .162$). While these perceptions did not change between Link 2 and 3 in both homogeneous chains (both $V \leq 0.03$, $p \geq 0.632$, $\eta_p^2 \leq 0.025$), patterns reversed for heterogeneous chains (both $V \geq 0.283$, $p < .001$, $\eta_p^2 \geq 0.283$). Running a separate ANOVA for each construct, there was no evidence for effects on perceived behavior control and knowledge on flu vaccination (all $p \geq 0.505$; $\eta_p^2 \leq 0.008$), while for the rest of the perceptions on flu vaccination both *Chain Heterogeneity* and *Chain Heterogeneity* × *Link* effects could be found (all $p \leq 0.001$; $\eta_p^2 \leq 0.102$): In both *Links* and similar to the results on transmitted message signal, these specific perceptions only differed by *Attitude* condition (different *Attitude*: all $p \leq 0.034$; same *Attitude*: all $p \geq 0.155$; Supplement S3). For example, the attitudes after receiving the message were not affected by the chain history, but just by participants' predetermined *Attitude* (Fig. 4). As a single exception, norm perceptions of NNN chains did not differ from PNP chains at Link 3 ($p = .279$).

Corresponding to the attitude-dependent perceptions of flu-vaccination, the influence of the received message on changes in flu vaccination perceptions was also rather limited in direct tests.

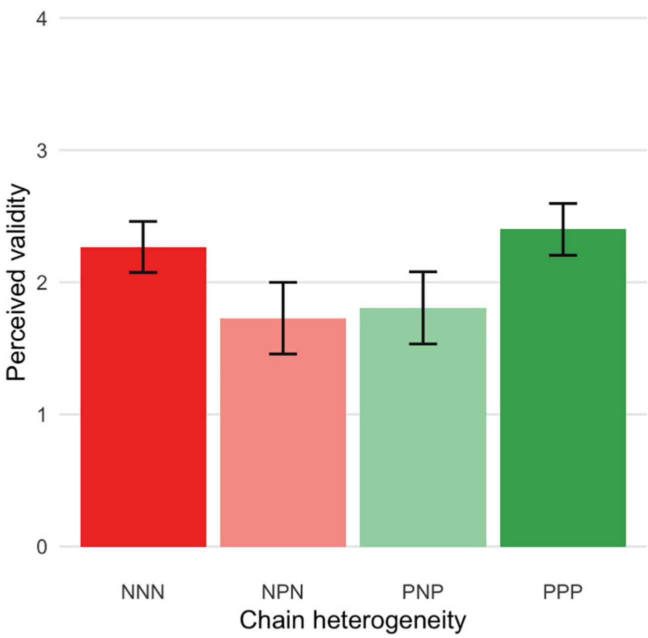

Fig. 5. Perceived validity of the message by *Chain Heterogeneity* condition (with 95% CI). *Notes. N* and *P* denote a Link in the chain history with negative or positive attitudes towards flu vaccinations. This information is aggregated across *Links* 2 and 3.

The correlation between attitude change and the signal of the received message was not differentiable from zero (r = 0.04, p = .380). Similar results were obtained for all other perceptions related to flu vaccines (all $|r| \leq 0.08$, all $p \geq 0.121$). Furthermore, effects of the signal on changes in flu-vaccine related perceptions were not moderated by the initial attitude of that individual (all $|\beta| \leq 0.09$, all $p \geq 0.062$), while there were small negative effects of the initial attitude on changes in attitude and positive effects on changes in norm and flu risk perception (all $|\beta| \leq 0.17$; Supplement S4).

3.4. Perceived validity of the received message and attitude consistency

At both Link 2 and Link 3, participants in homogeneous conditions perceived the received messages as more valid compared to both heterogeneous conditions (F(3, 278) = 7.77, p < .001, η^2_p = .077, see Fig. 5), while no clear *Link* main effect (F(1, 278) = 3.49, p = .063, $\eta^2{}_p$ = .012), and no interactions with *Link* emerged (F(3, 278) = 0.56, p = .664, η^2_p = .006). In direct tests of the effect of message signal, positive received message signal was associated with higher perceived validity ratings (r = 0.10, p = .040), but this was qualified by the recipient's initial attitude (*signal*: β = 0.07, p = .102; *attitude*: β = 0.15, p = .001; *attitude x signal*: β = 0.35, $p \leq 0.001$): For individuals with positive initial attitudes, perceived validity increased with positive message signal (β = 0.42, $p \leq 0.001$), while the opposite was true for individuals with negative attitudes (β = −0.28, $p \leq 0.001$).

4. Discussion

This study was designed to model and measure polarization in the social transmission of flu vaccination risk information in different online communication chains. While the received message had no clear influence on altering the perceptions of flu vaccination and perceived risks, individuals adjusted the message signal transmitted to others to their initial attitude. Additionally, received messages were perceived to be more convincing, if consistent with prior attitudes. Thus, initial attitudes biased both reception as well as transmission of information, but there was no social influence or persuasion. As a consequence, the information about and perceptions of flu vaccination were no more extreme in attitude-homogeneous groups than in attitude-heterogeneous groups.

Concerning the hypotheses of the social amplification of risk [7], we thus found evidence for selective attention and the selection of attitude-consistent information that is also in line with predictions from cognitive dissonance and selective exposure theory [20,21]. However, we did not find that the message signal socially influenced the attitude of the beholder. As a result, there was no amplification of attitudes as predicted by the model and no further polarization of the signal in homogeneous diffusion chains. This indicates that strong polarization of both signal and attitudes found in vaccination online echo chambers [10] may be less a result of social influence or persuasion by an encountered message, but rather due to an active selection process, where particularly individuals with already existing, strong opinions engage in discussions on vaccination. This may hold true particularly for online fora with relatively unacquainted individuals. Yet, both social influence and polarization still may be observed, when well-trusted sources, or family and friends are involved in the discussion [2,22].

On the positive side, our results illustrate that online communication about vaccines may not be as negative and alarming as anticipated in previous research [1,2,4]. There was no sign of an overall bias in transmitted messages towards contra vaccination as some research may have suggested [2,6]. Importantly, it was not the case that positive attitudes were becoming less positive as a result of receiving negative information from social transmission. Likewise, we did not find signs of reactance of participants with negative attitudes: their attitudes did not become even more negative in response to receiving positive information. Findings pointing towards such a reactance [12] may only apply to the correction of the individual misconceptions on the vaccination and not the general gist of a message [13].

Overall, the perceptions of flu vaccines appeared to be resilient: received messages on vaccination were neither sufficient to persuade people and change individual perceptions of the matter nor strong enough to diffuse to the next chain link. Additionally, information inconsistent with the individual's attitude was derogated. Accordingly, messages stated by participants in our study did not alter attitudes, whereas other researched vaccine-promoting messages were more successful [12,23,24]. In light of these results and the very low adoption rate of statements in our study, further research on designing messages for vaccination that are both convincing and effectively spreading online is still warranted [2,4].

Moreover, while we managed to assess the role of homogeneous and heterogeneous diffusion chains by (a) particularly sampling individuals with rather extreme attitudes and (b) choosing a topic with strong prior attitudes, the effects of the message on neutral beholders cannot be evaluated. Hence, future research should also incorporate people that do not already have destinctive positive or negative opinions on vaccination, especially because these people may be more vulnerable to misinformation and still prone to attitude change [25–27]. As prior attitudes are typically not experimentally manipulated, further research may be devoted on describing and evaluating the role of demographics or other factors in vaccine-related attitudes and message acceptance.

5. Conclusion

This study was designed to assess polarization and proliferation of flu-vaccination attitudes in online communication of lay people.

Instead, we found that attitudes and risk perceptions remained unaffected by the communication and no overall shift to negative attitudes towards vaccination. Initial attitudes and beliefs trumped social influence and biased both the reception as well as the transmission of information. While this remarkable inertia of attitudes against inconsistent information can be alarming, it also implies that individuals with a positive attitude towards flu vaccination are probably not much affected by the online display of anti-vaccination information.

Author contributions

Helge Giese, Wolfgang Gaissmaier and Hansjörg Neth conceptualized and designed the study. Helge Giese conducted the study and analyzed the data. Helge Giese, Wolfgang Gaissmaier, Hansjörg Neth, Mehdi Moussaïd, and Cornelia Betsch interpreted the data. Helge Giese drafted the article and Wolfgang Gaissmaier, Hansjörg Neth, Mehdi Moussaïd, and Cornelia Betsch revised it critically with substantial input. All authors approved of the submitted version of the article.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: "Wolfgang Gaissmaier has received honoraria for lecturing/consultation from Amgen, Bayer, Biogen, Celgene, Genzyme, Merck Serono, MSD, Mundipharma, Novartis Pharma, Sanofi Pasteur, Takeda, and Teva, as well as research support from Biogen for other research projects. There are no other potential conflicts of interest. The other authors declare no potential conflict of interest."

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2019.11.038.

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