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How Public Health Agencies Break through COVID-19 Conversations: A Strategic Network Approach to Public Engagement

Hye Min Kim [a], Adam J. Saffer [b], Wenlin Liu [c], Jingyi Sun [a], Yiqi Li [a], Lichen Zhen [a], and Aimei Yang [a]

[a]Annenberg School for Communication and Journalism, University of Southern California; [b]Hubbard School of Journalism & Mass Communication, University of Minnesota Twin Cities; [c]Jack J. Valenti School of Communication, University of Houston

ABSTRACT

In times of public health emergencies, health agencies need to engage and communicate with the public in real-time to share updates and accurate information. This is especially the case for the COVID-19 pandemic where public engagement can potentially save lives and flatten the curve. This paper considers how the use of interactive features and strategic network positions of health agencies on social media influenced their public engagement outcomes. Specifically, we analyzed 203 U.S. public health agencies' Twitter activity and the public engagement they received by extracting data from a large-scale Twitter dataset collected from January 21st to May 31st, 2020. Results show that health agencies' network position in addition to their two-way communication strategy greatly influenced the level of public engagement with their COVID-19 related content on Twitter. Findings highlight the benefits of strategic social media communication of public health agencies resides not only in how agencies use social media but also in their formation of network position to amplify their visibility. As official sources of health and risk information, public health agencies should coordinate their social media communication efforts to strategically position themselves in advantageous network positions to augment public engagement outcomes.

As the coronavirus continues to spread in the U.S. and infect millions of Americans, public health agencies are expected to inform and engage the public with accurate information about COVID-19. Previous studies suggest that during public health crises, information-seeking and dissemination are predominantly mediated by social media (Oh et al., 2020; Sastry & Lovari, 2017; Signorini et al., 2011). This appears to be true in the context of COVID-19. One recent survey of U.S. adults found 39% have turned to social media platforms to get information about the coronavirus outbreak (Lazer et al., 2020). Moreover, a Pew survey reports that 51% of Americans identified public health agencies and officials as one of their "major sources for news about the coronavirus outbreak" (Shearer, 2020). Still, health agencies are challenged with breaking through the crowded information ecosystem to attract public attention and engage the public with accurate messages throughout the pandemic.

Social media contribute to real-time engagement, building trust, and motivating public to take actions in times of public health emergencies (Oh et al., 2020; Veil et al., 2011). Research shows that public health agencies have recognized the value of social media, like Twitter, as a way of informing, mobilizing, and coordinating actions at various stages of health crises (Chatfield et al., 2014; Chung, 2016; Park et al., 2016). Engaging the public on social media is also critical during major health epidemics because it gives health agencies a platform for combatting misinformation and disinformation that are spread by lay publics and malicious actors (Jurkowitz & Mitchell, 2020). Monitoring social media content and participating in public conversations, public health practitioners can gain a better understanding of the main issues concerning their constituents and which resources are needed during a health emergency (Avery, 2017).

Against this backdrop, health agencies' social media use and the effectiveness of their public engagement warrant a close examination. Over the past decade, health communication researchers have taken keen interest in understanding individuals' information seeking and sharing behaviors as they discuss various health topics on social media (e.g., Chung, 2016; Oh et al., 2020). Others have examined health agencies' use of social media focusing on message features or social media use patterns (Bhattacharya et al., 2014). However, relatively few studies have recognized that communication on social media is fundamentally networked (Guo & Saxton, 2018). That is, what people can see or respond to often depend on the social contacts that they maintain on social media. For health agencies to effectively engage the public, merely looking at messages or how they use social media may not fully account for the networked context of communication.

Therefore, it is particularly important to investigate health agencies' effective public health communication through social media that highlights their presence. This study addresses a pressing issue that public health agencies face in the age of COVID-19: breaking through the crowded communication ecosystem. As a pandemic affecting everyone on earth, the

CONTACT Hye Min Kim hyemink@usc.edu Annenberg School for Communication and Journalism, University of Southern California, 3630 Watt Way, Los Angeles, CA 90089, USA

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amount of COVID-related information being produced is unprecedented. With all the information, misinformation, and disinformation related to COVID-19, it is critical for practitioners at health agencies to understand how to position their accurate information as an official source of information amidst the confusion and chaos. It is particularly important to investigate health agencies' effective public health communication through social media that highlights their presence. Recognizing the importance of health agencies' social media use and gaps in previous research, the current study draws upon the social media engagement literature (Bhattacharya et al., 2014; Liu et al., 2020; Park et al., 2016) and a strategic network approach (Saffer et al., 2019; Yang & Saffer, 2020) to assess how a range of factors, including health agencies' social media use patterns and their network positions, influence agencies' public engagement outcomes during the 2020 COVID-19 pandemic.

Social media engagement in time of a public health crisis

In times of public health emergencies, health agencies need to engage public on social media to guide crisis responses. In this study, engagement is defined as "psychological and behavioral attributes of connection, interaction, participation, and involvement designed to achieve or elicit an outcome at individual, organization, or social levels" (Johnston & Taylor, 2018, p. 19). Researchers highlighted that "as public health transitions to more dialogic conversation and engagement, Twitter's potential to help form partnerships with audiences and involve them as program participants may lead to action for improved health" (Neiger et al., 2013, p. 162).

Evidence from public health emergencies like the H1N1 pandemic (Signorini et al., 2011), the Ebola epidemic (Sastry & Lovari, 2017), and the Zika outbreak (Avery, 2017) suggests that public engagement has several benefits for health agencies during COVID-19 pandemic. First, public engagement during COVID-19 may be an effective means for involving the public in co-producing information and crowdsourcing solutions. For example, Avery (2017) found that public agencies with social media monitoring teams reported higher levels of public understanding of a health threat. Additionally, increased public engagement helps health agencies' emergency preparedness and response efforts by directing public to adopt proper protective actions to mitigate risks (Lee & Basnyat, 2013). This is likely because public engagement enables health agencies to better respond to public needs during crises (Neiger et al., 2013; Liu et al., 2021). Indeed, Chatfield et al. (2014) examined government's social media use during Hurricane Sandy and revealed critical contributions of the public to share information with government agencies and (re-)distribute information.

This may be especially important when the general public show a loss of trust in health agencies. Public's trust and health agencies' credibility are crucial for reducing risk behaviors and promoting cooperation (Neiger et al., 2013). Veil et al. (2011) recommended that crisis managers use social media to partner with the public in providing timely crisis information because such partnership could give the public a sense of ownership and rebuild credibility. Given the wide spread of COVID-19 misinformation – a recent report showed that 57% of Americans who rely on social media for news have reported that they encountered misinformation about COVID-19 (Jurkowitz & Mitchell, 2020), health agencies' social media presence and public engagement with them is particularly important as it may help to identify, clarify, and correct misinformation, which in turn enhances the public's trust in and perceived credibility of health agencies.

Having established the importance of public engagement with health agencies, we review two strategic approaches for enhancing public engagement on social media in the following sections.

Health agencies' two-way communication and public engagement

Social media has become an integral part of public health communication (Yang, 2018). Health agencies have increasingly adopted social media as part of their communication channels. The key benefits of health agencies' use of social media is that social media facilitates the transmission of important health messages as well as targeting and reaching diverse audiences while listening to public feedback in real-time (for a review, see Heldman et al., 2013). For instance, a study found that health agencies' interactivity online was significantly associated with a higher level of credibility perceptions among the public during the MERS outbreak in South Korea (Yang, 2018).

Despite the potential of social media to foster two-way-communication, however, previous studies have found that health agencies tend to predominantly use social media as a one-way communication channel for the purpose of information dissemination (Chung, 2016; Heldman et al., 2013). Fortunately, more recent works suggest there is a growing trend of leveraging social media to promote public engagement. Studies have found that incorporating interactive features like hashtags, hyperlinks, mentions, and replies can promote direct engagement between public and health agencies (Bhattacharya et al., 2014; Liu et al., 2021; Park et al., 2016). For instance, Park et al. (2016) noted the primary mechanism of health agencies' Twitter communication is to provide feedback with interactive features that signifies health agencies' responsiveness and commitment to creating conversations with the public. Liu et al. (2020) focused on the presence of dialogic loop, "a linguistic feature that verbally urges the public to access information, provide feedback, as well as contribute to disaster relief efforts" (p. 5), and showed its positive effects on engagement with public risk messages on Facebook.

Following the previous work highlighting the two-way communication, we posit that public health agencies' use of interactive features on social media will be positively associated with the public engagement they received during the COVID-19 pandemic:

H1: Health agencies' use of interactive features for two-way communication about COVID-19 will be positively associated with the level of public engagement received.

Toward a strategic network approach of engagement

Recent scholarship on strategic engagement has shifted from an organizational-centric approach that focuses on isolated organizations to a network perspective which recognizes that individuals who form public as well as organizations are embedded in complex communication networks. These networks can enable or constrain organizations' and individuals' communication behaviors and outcomes (Yang & Saffer, 2019). Juxtaposed to traditional message-centered strategic communication approach, the strategic network perspective broadens the view to consider the structural aspects of communication environments (O'Connor & Shumate, 2018; Yang & Saffer, 2019, 2020).

The network perspective recognizes that communicative actions are networked. Network ties can form when an individual or organization mentions, follows, likes, or retweets another actor. The aggregated patterns of these ties determine where actors are positioned in relation to other relevant actors. In order to increase organizations' visibility on crowded social media, organizations need to adopt effective networking building strategies that align with their goals and external contexts (Yang & Saffer, 2020). Network management is especially important for organizations facing challenges in crises or disasters like COVID-19. For instance, organizations impacted by Hurricane Katrina strengthened their existing relationships and built dense networks that fostered bonding social capital, which made them more resilient after the disaster (Doerfel et al., 2013).

The strategic network perspective argues that communicators need to recognize their network positions in order to achieve the desired communication outcomes. Saffer et al. (2019) identified two types of advantageous network positions: star and community positions. On the one hand, some organizations may wish to be the stars in networks because central positions could afford them great influence and fast, easy access to information and resources (Borgatti, 2006). On the other hand, some organizations may be less concerned with being central. Instead, they want to socialize with others and build communities to advance shared goals (Yang & Saffer, 2020). We further discuss these two network positions in detail below.

Star network position

The star network position follows the "key-player" tradition (for review, see Borgatti, 2006) in social network research and focuses on how well individual actors, in our case, health agencies, are positioned within a network. Being a "star" in a network means an agency occupies an advantageous network position, and thus allows a health agency to have more connections with the general public, "influencers," or other diverse groups. Two types of star positions are considered advantageous.

The first type is being central in the network. Actors occupy central network positions by having more connections with others. Health agencies can strategically position themselves at central points in networks by sending a large number of connections to others or by attracting ties from other users. Actors with high levels of centrality are generally understood as having more prestige and influence. For instance, a study examined the CDC's use of Twitter and identified central individual users as well as nonprofit organizations with high centralities (Chung, 2016). The study found that the nonprofit organizations with higher centrality scores amplified the reach of health messages by exposing the message to a large audience. Similarly, in studies of nonprofits' network positions, researchers found that organizations with higher centrality garnered more engagement from others on Twitter (Saffer et al., 2019). Hence, we propose that:

H2: Health agencies with central positions in the network will receive significantly more public engagement than those that are less central.

Another type of star network position connects otherwise disconnected actors. This type of position is known as a broker, and the ties that connect disconnected actors are brokerage ties. Burt's (2009) structural hole theory (SHT hereafter) defines the benefits of social relationships in terms of information advantages deriving from linkages among otherwise disconnected individuals. According to Burt (2009), if organizations can fill structural holes in a network, they serve as "tertius gardens" (the third who benefits). As the third who benefits, health agencies in the brokerage position could efficiently reap informational benefits and excise a greater control over information flows. In other words, a broker is best positioned to receive (or send) diverse information from (or to) diverse communities.

Brokerage is an important concept and it reveals aspects of key players that cannot be captured by centrality alone. For example, research showed that actors having only high centrality, but lacking brokerage capacity may suffer because they do not have access to information from the distant parts of the network, which makes them vulnerable to a rapidly changing environment. In the context of social media mediated communication, a health agency may have high centrality by connecting well with a large number of others. However, if these others are from homogenous backgrounds and are well connected with each other themselves only, it would be less effective for the agency's messages to reach diverse public. Indeed, one study showed that U.S. federal health agencies acting as an intermediary on Twitter received greater engagement (Bhattacharya et al., 2014). Based on this logic, we propose:

H3: Health agencies with brokerage positions in the network will receive significantly more public engagement than those that are less broker.

Community network position

The community network position uses community detection algorithms to inductively identify subgroups, communities, and clusters within a network. Contrary to the star position where emphasis is placed solely on individuals' positions, the community network position considers the second-degree ties of those around the focal actor (also known as community, see Saffer et al., 2019). This approach recognizes that social ties do not occur randomly. Rather, actors tend to interact with others in ways that create overlapping group connections or clusters.

Applied to this study, health agencies' interactions with others may position them to have different community network positions. One way to assess the community network structure of a focal actor is to calculate neighborhood average degree centrality. Neighborhood average degree centrality calculates the centrality of an actor's connections' connections (i.e., second-degree connections) and takes the average of those scores. Importantly, if a health agency connects with many other that are well connected, it is more likely that they have a favorable network position to receive public engagement. Following this logic and prior works, we posit that:

H4: Health agencies with higher average neighborhood degree centrality will receive significantly more public engagement on Twitter.

Health agencies must also sustain public attention during the pandemic. By belonging to a subgroup where a health agency has numerous overlapping ties with others, a community may collectively keep the public's attention on COVID-related health information. In other words, such communities may amplify the health agency's messages.

Network researchers have developed a number of algorithms for identifying subgroups within networks. Rather than determining group members *a priori*, community detection algorithms take the connections among actors to identify points of overlaps. One calculation, k-core, allows "actors to join the group if they are connected to *k* members, regardless of how many other members they might not be connected to" (Hanneman & Riddle, 2005, p. 182). This approach to identifying group members can reveal how many groups a health agency is a member of. Drawing from the strategic network perspective, we hypothesize:

H5: Health agencies with greater overlapping group connections will receive significantly more public engagement on Twitter.

Method

Sample

Using the list of health department directories through the Centers for Disease Control and Prevention as well as the U.S. Department of Health and Human Services, we identified national level and state level health agencies. Additionally, a list of local-level health agencies was obtained from the National Association of County and City Health Officials which were updated for the COVID-19 (NACCHO, 2020). In cases where an agency's Twitter account was not listed, members of the research team visited the agency's website or searched for the agency on Twitter. Accounts with no activity in 2020 were removed, yielding the final list of 203 agencies ($n_{national}$ = 22, n_{state} = 49, n_{local} = 132).

Twitter data collection

Tweets used in this study were retrieved from a large open dataset on COVID-19 published by a group of researchers (Chen et al., 2020). This dataset contained tweets collected using the keywords such as "COVID-19", "Coronavirus", "Sars-cov-2", and "Pandemic" (for a full list of keywords, see Chen et al., 2020). We used data from January 21st to May 31st, 2020. Using the list of health agencies that we identified earlier, meta data of each health agency's Twitter account and metrics for their engagement received and interactivity were included. Next, social network analysis was performed to calculate the network metrics (described below). We transformed the network by taking out all isolates. This step kept key engagement metrics of this network without disrupting its structure. After this step, a total of 29,817 engaged actors remained in the network, connected by 80,029 ties. This is the network we used for further analysis.

Measures

Engagement

Engagement metrics are based on how frequently an agency's tweets were retweeted by others in the Twitter conversation about COVID-19 (Guo & Saxton, 2018). Following previous research (Park et al., 2016; Saffer et al., 2019), we used the total number of retweets that an agency received in the study period to indicate engagement outcome. On average, health agencies received 752.94 retweets (*SD* = 5,326.41).

Interactivity

Interactivity was determined by two measures: 1) use of replies which indicated that the health agency was directly responding to a tweet made by another user (*M* = 2.84, *SD* = 7.49); 2) use of likes (*M* = 1395.17; *SD* = 1920.74) that signified the agency "liked" a tweet made by another user. Therefore, a higher score indicated that a health agency more frequently incorporated the two-way communication strategy.

Star network position

Health agencies' star network positions were assessed by two network metrics, authority centrality and brokerage (Bhattacharya et al., 2014; Saffer et al., 2019; Yang & Saffer, 2020). Authority centrality focuses on how well an account is connected. Authority centrality measures the extent to which a node's incoming ties are from others with many outgoing ties (min = 0, max = 0.03). The second metric, brokerage, focuses on the likelihood for an account to be brokers in relationships based on the Burt (2009)'s structural hole theory. Brokerage metric measures the degree to which a node's connections were disconnected among themselves, that is, how often a node connected to others on Twitter that were otherwise disconnected. Higher score indicated that a node acted as a broker between its connections (*M*= 0.96, *SD* = 0.06).

Community network position

Two network metrics were used to capture the health agencies' community network positions, average neighbor in-degree and

k-core (Saffer et al., 2019; Yang & Saffer, 2020). Average neighbor in-degree metric focuses on the neighborhood in which accounts are embedded in, and thus the greater score indicated a node's neighbors (i.e., accounts that a health agency is connected to) has a greater number of connections (M = 3.06, SD = 19.24). A k-core means a subset of network in which a node is connected to at least k other nodes (Seidman, 1983). K-core metric focuses on nodes' cluster affiliations, which has been used to identify densely connected clusters. Therefore, nodes with higher k-core values means that they belong to many sub-group clusters (M= 4.97, SD = 3.27).

Control variables

The first set of variables was controlled for the institutional status of health agencies. Each health agency was identified as one of the three categories (i.e., national, state, and local) and two dummy variables were made with the local level as the reference group. The second set of variables was controlled for health agencies' Twitter account characteristics such as the total number of tweets (i.e., how frequently an account tweeted during the study period) and total number of followers (i.e., total number of Twitter accounts that follow each health agency's Twitter account) which may influence the engagement (Saffer et al., 2019).

Analysis procedures

This study conducted hierarchical multiple regressions to test the hypotheses. Model 1 was a baseline model with all control variables including the institutional status of health agencies and Twitter account characteristics. Model 2 examined the influence of health agencies' use of interactive features on public engagement. Subsequently, star network position variables (Model 3) and community network position variables (Model 4) were entered into separate blocks to examine the additional effects of network characteristics. All the network position variables and the outcome variable, engagement, were log-transformed to account for the skewed distribution of the measures, which was a standard practice to help to normalize the distribution of social media data (e.g., Bhattacharya et al., 2014; Guo & Saxton, 2018; Saffer et al., 2019).

Results

In this section, we first report some descriptive statistics, followed by hypothesis testing results. The top five health agencies that received the most engagement with COVID-19 messages were: Centers for Disease Control and Prevention (58,171 retweets), Surgeon General (48,635 retweets), Department of Health & Human Services (6,549 retweets), Ohio Department of Health (3,353 retweets), and Los Angeles County Department of Public Health (2,732 retweets). Additionally, out of the top 15 health agencies with the highest engagement levels, nine were state-level health agencies while five were national and one was local level. Table 1 provides descriptive statistics on how health agencies differ based on their institutional status.

Hypotheses testing

To ensure the data met the assumption for multiple regression, the predictors were assessed to see if they were independent of each other. An examination of the bivariate correlation matrix (Table 2) revealed no substantial correlations among the predictors and the variance inflation factor scores for all the variables were within the range of 1.26 to 3.53, which were below the rule of thumb of 10, even below the more conservative value of 5 (Hair et al., 2006), indicating no multicollinearity issue for the study.

Table 3 presents the results of hierarchical regression analyses. Institutional status of health agencies and their Twitter account characteristics (i.e., the total number of tweets, followers) were entered first to control for the confounding effects. As expected, total number of tweets (β = .228, p< .001) and total number of followers (β = .401, p <

Table 1. Descriptive statistics by level of health agency (N = 203).

	National (n = 22)			State (n = 49)			Local (n = 132)		
	M (SD)	Min	Max	M (SD)	Min	Max	M (SD)	Min	Max
Engagement	3.9 (3.82)	−2.3	10.970	5.41 (1.69)	−2.3	8.12	2.4 (1.91)	−2.3	7.91
Total tweets	13,972.36 (7562.83)	1,238	27,614	8243.18 (5223.66)	644	23,016	4034.79 (4486.44)	133	35,189
Total followers	429,219.5 (758,209.3)	907	2,856,862	20,342.94 (18,140.41)	683	84,124	3449.37 (8462.22)	86	68,838
Use of replies	4.84 (10.38)	0	43	5.38 (10.95)	0	61	1.57 (4.55)	0	30
Use of likes	2098.45 (1972.86)	66	6,979	1891.55 (2094.59)	8	10,282	1093.69 (1786.17)	1	10,214
Authority centrality	−11.49 (3.77)	−15.94	−3.51	−11.65 (1.89)	−15.94	−8.49	−15.2 (1.61)	−15.94	−8.54
Brokerage	−0.04 (0.05)	−0.15	0	−0.01 (0.02)	−0.08	0	−0.06 (0.08)	−0.37	0
Neighbor in degree	0.13 (2.79)	−2.83	5.29	−2.08 (1)	−4.02	0.98	−1.85 (1.17)	−3.91	2.91
K-core	2.28 (0.21)	1.61	2.4	1.79 (0.52)	0	2.4	0.92 (1.03)	−2.3	2.4

Note. The following variables were log-transformed: engagement, authority centrality, brokerage, neighbor in degree, k-core.

Table 2. Bivariate correlations among variables.

Variables	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. National	–										
2. State	−0.20**	–									
3. Total tweets	0.46***	0.20**	–								
4. Total followers	0.47***	−0.07	0.35***	–							
5. Use of replies	0.09	0.19**	0.26***	0.37***	–						
6. Use of likes	0.13	0.15*	0.56***	0.12	0.30***	–					
7. Authority centrality	0.32***	0.49***	0.49***	0.49***	0.54***	0.32***	–				
8. Brokerage	0.01	0.27***	0.21**	0.11	0.18*	0.12	0.28***	–			
9. Neighbor in degree	0.41***	−0.14*	0.23***	0.27***	0.17*	0.21**	0.30***	−0.04	–		
10. K-core	0.35***	0.29***	0.46***	0.20**	0.28***	0.35***	0.55***	−0.05	0.20**	–	
11. Engagement	0.08	0.48***	0.40***	0.39***	0.50***	0.38***	0.77***	0.39***	0.23**	0.45***	–

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 3. Hierarchical regression models with standardized coefficients.

	Model 1	Model 2	Model 3	Model 4
Block 1 (Control)				
1. National	−0.122	−0.066	−0.179**	−0.240***
2. State	0.439***	0.400***	0.091	0.101
3. Total tweets	0.228***	0.084	0.003	−.015
4. Total followers	0.401***	0.311***	0.136**	0.167***
Block 2 (Interactivity)				
1. Use of replies		0.245***	0.064	0.059
2. Use of likes		0.170**	0.141**	0.110*
Block 3 (Star position)				
1. Authority centrality			0.588***	0.483***
2. Brokerage			0.157***	0.202***
Block 4 (Community position)				
1. Average neighbor in degree				0.101**
2. K-core				0.150***
R^2	0.451	0.531	0.681	0.700
Adjusted R^2	0.439	0.517	0.668	0.684
ΔAdjusted R^2		0.078	0.151	0.016
Δ*F*		16.804***	45.601***	5.908**

Note. Standardized coefficients *β*s are reported. Local level was used as a reference group for the level of health agency. *$p < .05$. **$p < .01$. ***$p < .001$.

.001) of an individual health agency were positively associated with the level of retweet engagement received. Interestingly, state-level health agencies were better at receiving greater engagement than local level ($\beta = .439$, $p < .001$), but there were no significant effects for national-level agencies. These variables explained about 45.1% of the variance in the amount of engagement received.

Next, interactivity indicators were added in the second step to examine if the use of two-way communication positively predicted the health agencies' public engagement outcome after controlling for variables in Model 1. As expected, frequent use of interactive features including the use of replies ($\beta = 0.245$, $p < .001$) and likes ($\beta = 0.170$, $p = .006$) positively predicted the public engagement. The addition of the interactivity variables significantly increased the variance explained, F (2, 196) = 16.804, $p < .001$, ΔAdjusted $R^2 = .078$, supporting H1.

To test H2 and H3, star position metrics were added in the third model. Results showed that a health agency's authority centrality ($\beta = .588$, $p < .001$) and brokerage score ($\beta = .157$, $p < .001$) improved the amount of variance explained by 15.1%. Authority centrality score and brokerage score positively predicted the public engagement outcome that a health agency received. That is, health agencies acting as a center with many connections to highly active others or as a broker between connections were more likely to attract greater public engagement. Notably, the effects of star network position overrode the effects of interactivity measure, reply use which became non-significant after star positions were added to the models. Therefore, H2 and H3 were supported.

Lastly, H4 and H5 predicted that community network characteristics within which a health agency was embedded was significantly associated with the level of public engagement. Adding these variables slightly improved the amount of variance explained by 2%, with significant effects of average neighbor in degree ($\beta = .101$, $p = .016$) and k-core ($\beta = .150$, $p < .001$). In other words, when health agencies embedded themselves among contacts that were well connected, they significantly benefited from such a community with well-connected contacts, supporting H4. Additionally, health agencies benefitted from participating in many tightly-knit groups, supporting H5. Notably, the effects of health agencies' use of interactive features either disappeared or abated as the network characteristics were added (i.e., Model 3, Model 4).[1]

Discussion

In times of public health emergencies such as the COVID-19 pandemic, health agencies need to engage and communicate with the public to share time-sensitive updates, scientific information, and debunk misinformation that potentially cause confusion and harm public health (Avery, 2017). This paper combines the two-way communication approach and the strategic network approach to examine health agencies' public engagement in a networked digital communication environment. A number of findings were observed that could benefit health agencies' current and future public engagement efforts on social media during a health crisis.

Implications for health and strategic communication

This study draws from previous strategic network communication research (Saffer et al., 2019; Yang & Saffer, 2020) to explore how health agencies' network positions may affect their public engagement outcomes. Examining network positions are important because communication on social media are based on user networks (Guo & Saxton, 2018). Moreover, social media are crowded with competing voices and information

sources, which means health agencies cannot simply assume any tweets sent would draw public attention to or engagement with them (Yang & Saffer, 2019).

In this study, we examined the effects of two types of strategic network positions: star position and community position. Star position refers to the degree to which health agencies occupy central network positions in their social network. In this study, our network consists of health agencies and the public that have engaged with them over the first five months of the COVID-19 pandemic outbreak. In terms of the star position, our analysis showed that for health agencies that perform the role of information authority (high authority centralities) and relationship brokers (high brokerage scores), they tend to receive significantly higher levels of public engagement than their counterparts. This salient effect persisted even after controlling for health agencies' institutional status, the accounts' followership, number of tweets sent, and the interactive communication strategies.

This finding offers practical insights for health agencies. In addition to carefully planning their messages and adopting communication strategies that encourage public engagement, health agencies need to strategically position themselves in advantageous network positions through relationship building on social media (cf. O'Connor & Shumate, 2018). They can build ties through strategically mentioning, retweeting, or quoting influential actors (Yang & Saffer, 2019, 2020). Especially during health emergencies with high surges of public attention, it is important for health agencies to increase their ties with actors that are actively sending out information and building ties across different levels of health agencies and other relevant institutions (for example, actors that actively initiate relationships with others). They could also build ties with actors who are well connected with users that are otherwise unconnected with these agencies to stand out in the crowded social media environment.

Our analysis also suggests that community network position matters considerably. Community positions refer to how well health agencies are embedded in clusters and communities. Our analysis shows that for health agencies that connect with a group of well-connected actors (high average neighbor in-degree) and connect with many small clusters (high k-core values), they tend to achieve significantly better engagement outcome than their counterparts. Furthermore, health agencies' network positions had overriding effects on their use of interactive features. This suggests that the value of two-way communication strategies may largely depend on where these health agencies are located in their networks.

The practical insights of this finding suggest that as an official source of health and risk information, public health agencies should coordinate their communication efforts by frequently interacting with each other (e.g., Doerfel et al., 2013; Liu, Xu, St John et al., 2021). Even when they are sharing similar information, retweeting or mentioning each other still boost this community of organizations' network positions within the clusters and communities. The benefit resides not just in the message itself but in the formation of a health agency community on social media that could collectively amplify their network strength and visibility.

It is also necessary to point out that the analysis suggests that for health agencies, star positions may matter more than community positions. According to Yang and Saffer (2020), in actor-motivated communication contexts – that is, contexts where who the actors are matters more than what messages they send out – star positions are the most important types of network positions for strategic communication purposes. This finding is consistent with previous research (Yang & Saffer, 2020), which suggests that for agencies with limited resources, they may focus primarily on strengthening their status as influential or becoming closely associated with central actors.

Methodological implications

Although a line of recent research has recognized the importance of social media mediated health communication, research attention has been primarily placed on the message aspect or engagement patterns. As a result, previous research has relied on content analysis to understand the engagement efforts or outcomes. The current study offers insights from a strategic social network approach, which is a methodological and theoretical tradition best reflecting the networked context of social media. Our analysis examines health agencies' network positions in their public engagement network and further evaluates how such network positions affect their communication outcomes. We also compare side-by-side the effect of two-way communication strategies and network positions. Our results confirm that for social media mediated health communication, communicators cannot overlook the importance of their network positions. This method expands the methodological toolbox for strategic planning and evaluation in health communication campaigns.

Limitations and recommendations for future research

Like any study, this study has limitations that future researchers should note. First, we only analyzed Twitter data. While Twitter is a widely adopted platform, health agencies may utilize other platforms such as Facebook and Instagram to disseminate public health information. Future studies may collect data from several platforms to see if similar engagement patterns and network structures persist across platforms. Studies can also look at how health agencies' communication strategies on one platform may affect outcomes on other platforms or set the agenda of mass media (Lee & Basnyat, 2013).

Second, we examined the structural features of public engagement in the form of retweets, but we did not examine how message content may interact with agencies' network positions. We recognize that messages could have different impact on shaping networks as messages may lead to different public responses. For example, some messages may be designed to communicate factual, scientific information whereas others are about fostering a sense of community or calling for collective actions to advance public goods. Some messages are designed to be disseminated while others are designed to foster conversations among the public. As messages differ, different networks may form around these health agencies. Future studies may utilize computer-assisted content analysis to classify message types and examine if and how message features shape health agencies' network positions

among publics. With continued research, we could form a more comprehensive understanding of how health agencies' messages, network positions, and communication strategies all influence their engagement outcomes on social media.

Health agencies need to utilize a range of communication strategies to better engage the public and make sure their messages stand out in times of public health emergencies. As demonstrated in the current study, the network approach asserts strategic positions that could amplify health agencies' communication outcome in a networked communication context. With additional research, health agencies may design social media campaigns that capitalize on the network structure of social media and better inform the public to take the advised actions.

Note

1. To ensure that it was not determined by the order of entering star network and community network position, we tried the other way around by adding community network variables first and then star network variables: Significant change in variance from Model 2 (interactivity) to community position by 4%, $F(2, 194) = 10.634$, $p < .001$ with significant predictive power of average neighbor in degree, $b = 0.159$, $p < .001$ and k-core, $b = 0.193$, $p < .001$. Subsequently, adding star position variables improved the model by 12%, $F(2, 192) = 39.014$, $p < .001$. Results were consistent such that greater model change was observed in the star network position than community network position with the predictors remained significant.

ORCID

Hye Min Kim http://orcid.org/0000-0002-7903-9009
Adam J. Saffer http://orcid.org/0000-0001-8032-4256
Wenlin Liu http://orcid.org/0000-0003-3146-8645
Jingyi Sun http://orcid.org/0000-0001-5335-0985
Yiqi Li http://orcid.org/0000-0002-3730-5743
Lichen Zhen http://orcid.org/0000-0002-5495-6302
Aimei Yang http://orcid.org/0000-0003-3756-7812

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