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DOI
10.1177/14614448231153959

Publication date
2024

Document Version
Final published version

Published in
New Media & Society

Article

new media & society
2024, Vol. 26(12) 6838–6860

DOI: 10.1177/14614448231153959
journals.sagepub.com/home/nms
SAGE

The emotional effects of multimodal disinformation: How multimodality, issue relevance, and anxiety affect misperceptions about the flu vaccine

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Abstract

Disinformation presented in multiple modalities (textual, visual, and auditory modes; *multimodal disinformation*) has become a serious concern. This study examines how disinformation, portrayed using an image or video format, may be more powerful than text-only disinformation. In particular, we examined the impact on affective mechanisms, as well as the moderating role of perceived issue relevance. Through an online experiment with modality conditions and a control group (text-only disinformation vs image-plus-text disinformation vs video-plus-text disinformation vs control; $N=413$), results indicate that while anxiety is a critical mechanism that explains the overall effects of disinformation on misperceptions, video-plus-text disinformation turns out to increase misperceptions directly or indirectly through anxiety. Video-plus-text disinformation (vs control) showed a significant interaction with perceived issue relevance; that said, the difference in anxiety

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decreased between those with low and high perceived issue relevance in the video-plus-text disinformation. Implications are discussed in light of the realism heuristic, affect heuristic, and modality-biased processing in explaining the emotional impact of multimodal disinformation.

Keywords
Affect heuristic, anxiety, misperception, multimodal disinformation, perceived issue relevance, realism heuristic

As misleading content continues to proliferate the digital ecosystem, the perceived authenticity of information online is under serious strain (Törnberg, 2018). Digital platforms have benefited malicious actors by allowing them to create and disseminate disinformation (Lai, 2022), another term used for false claims delivered with deliberate malice. Although the spread of disinformation is not a new phenomenon, the affordances of digital information settings arguably magnify the impact of disinformation. For example, the absence of traditional journalistic gatekeeping functions (Bode and Vraga, 2015) and the impersonation of alternative journalism (Robertson and Mourão, 2020) have increased the deleterious impact of digital disinformation on democratic discourse. Even more so, affordances in digital editing tools and artificial intelligence (AI)-based manipulations have paved the way for increasingly more realistic multimodal manipulations, such as deepfakes (e.g. Dan et al., 2021). Disinformation in the context of infectious disease outbreaks has particularly been a relevant problem, as it is associated with misperceptions about health science and is related to non-compliant health behaviors (Chen et al., 2021). Considering that substantial disinformation raising skepticism about the efficacy of the flu vaccine is disseminated in digital media-driven ecosystems (Gandhi et al., 2020), in addition to the persistent circulation of seasonal influenza, we specifically look at the impact of multimodal disinformation on flu vaccine misperceptions.

The current investigation focuses on multimodal disinformation in the form of the image- and video-based disinformation as these modes of disinformation provide a strong feature of realism (Sundar et al., 2021). Multimodal disinformation is defined as intentionally deceptive information that relies on texts augmented with images or audiovisual formats like videos to present inauthentic content in seemingly realistic ways (e.g. Dan et al., 2021). The effects of multimodal disinformation found in extant research (e.g. Lee and Shin, 2022; Sundar et al., 2021) can be explained in terms of the *realism heuristic*, a heuristic stemming from the cognitive psychology literature, which suggests that more realistic information—information with richer modalities—is perceived to be more credible (Sundar, 2008). As prevalence of deepfakes (i.e. synthetic media in which a person's face or body is superimposed by someone else's) are rising in digitalized environments (Lee and Shin, 2022), visuals seemingly can play a central role in disinformation (Brennen et al., 2021) and have been shown to be more emotionally engaging while offering more direct indexicality (i.e. accurate descriptions of perceived reality) than text (Messaris and Abraham, 2001). Despite this prior work, it is vital to more directly assess the impact of multimodal disinformation on users in order to understand how to instill resilience against misleading content presented in diverse modalities.

One of the influential factors that helps to explain the vast impact of disinformation is emotions (Bago et al., 2021; Lee, 2022; Martel et al., 2020). For example, the *affect heuristic* is an inborn tendency for individuals to engage in intuitive decision-making with little or no cognitive effort, relying simply on emotional states (Finucane et al., 2000). Despite a large body of work exploring the impact of emotions on various health decisions, knowledge is lacking about how multimodality used in disinformation may intensify emotional states, which in turn may contribute to shaping misperceptions. Given the increasing uses of multimodality in disinformation, there is an urgent need to examine whether the integration of multimodality in disinformation is more persuasive than unimodal approaches and, if so, whether emotions play a role therein. This study specifically centers on anxiety as an emotional response that explains potential effects of multimodal disinformation on health attitudes, given that anxiety is a decisive factor that has been shown to shape health-related misperceptions in prior work (Pan et al., 2021; Sallam et al., 2020).

In addition, we aim to add to the extant literature by proposing that the effects of multimodal disinformation on misperceptions can be contingent on users' perceived issue relevance, the extent to which users view a health issue as personally relevant to their own experience (Petty and Cacioppo, 1979). Although people with high perceived issue relevance are more likely to scrutinize the disinformation content given their high motivation for controlled processing of the content (Lee and Kim, 2016; Tandoc et al., 2020), it is currently unclear whether individuals with high perceived issue relevance may respond similarly to multimodal disinformation by curbing anxiety arousal. If multimodal disinformation is more likely to foster an emotional response like anxiety which can subsequently impede the evaluation of the truthfulness of the information, it could also weaken (or have no impact at all) the ability of users with high perceived issue relevance to identify false claims. Therefore, it is of considerable importance to revisit the role of perceived issue relevance as an individual difference to provide a more comprehensive picture of when and how individuals become more vulnerable to disinformation with a multimodal presentation.

In summary, this study extends the literature on disinformation in at least two ways. First, to identify the impact of multimodal disinformation, we experimentally compare the influence of text-only, image-plus-text, and video-plus-text disinformation on both anxiety and subsequent health misperceptions. Second, we further explore the extent to which personal issue involvement relevant to the topic of disinformation would attenuate or amplify the potentially profound effects of multimodal disinformation on misperceptions. Given that misleading claims which espouse anti-vaccine narratives are neither unintentional nor simply erroneous but are often motivated by politically-oriented goals to de-mobilize support for vaccination and mobilize opposition to official authoritative sources (Broniatowski et al., 2018), we focus on disinformation about the issue of the flu vaccine and expand the current literature in light of the modality effects of disinformation on misperceptions.

Multimodality in health disinformation and the realism heuristic

In a digital media-driven landscape, visuals and audio have become common components in information presentation. As digital technologies have advanced, disinformation often features a sophisticated format that relies on multimodality including images, texts, audio, or a

combination of these modalities as a video (Brennen et al., 2021). The power of multimodal disinformation can be explained by the *multimodal framing theory* which postulates that the integration of multimodal components alongside texts increases the fast, automatic processing of the message content (e.g. Geise and Baden, 2015; Powell et al., 2015, 2019).

Here, we understand multimodal framing as the combined emphasis on interpretation patterns in the textual and (audio)visual presentation of information or news coverage (e.g. Powell et al., 2015). Whereas the textual framing component helps to emphasize a certain problem's definition, moral evaluations, causal interpretations, and/or treatment recommendations (Entman, 1993), (audio)visual frames may consist of denotive characteristics (i.e. the presence of an expert source), connotative features (i.e. stereotypical depictions of doctors), and/or symbolic-semiotic characteristics (i.e. the camera angle used to depict an expert) (see Powell et al., 2019). Multimodal framing theory postulates that the textual component may have different effects on recipients when compared to audio-visual features (e.g. Powell et al., 2015). Whereas texts may directly convey interpretations and herewith affect attitudes, visuals that offer a more direct index of reality are more likely to evoke emotions and behaviors (Powell et al., 2015). In this paper, we extrapolate multimodal framing theory to disinformation. Multimodal disinformation may consist of exploiting the power of multimodal framing by manipulating the verbal and/or audio-visual components of information to covertly deceive recipients and affect their interpretations in a goal-directed manner (also see Hameleers et al., 2020).

Aside from automatic processing, multimodal disinformation also bears a high resemblance to reality (Yadav et al., 2011). Therefore, when applied to the context of disinformation, multimodal disinformation can amplify a truth bias in receivers' interpretation of information as authentic (Powell et al., 2015). This relates in particular to the *realism heuristic* (i.e. "if something seems real, then it is credible"; Sundar, 2008) which suggests that, in contrast to misleading claims presented via a leaner modality (i.e. a less complex, simpler modality), the claims presented in multimodality are likely to be processed more easily and automatically—this is primarily attributed to the realistic nature of multimodality leading users to invest less cognitive effort when evaluating the veracity of information (Sundar et al., 2021). The activation of the realism heuristic when seeing multimodal information is much more likely to be problematic for false claims than accurate information. For example, Hameleers et al. (2020) found that multimodal disinformation with texts and visuals was perceived to be more credible than textual disinformation, while the persuasive effects of multimodality were not so pronounced when applied to fact-checking information.

This potential bond between multimodality and misleading content suggests that multimodal disinformation is perceived to be more credible than disinformation with a leaner modality. Yet, there is a shortage of research exploring whether the realism heuristic of multimodal disinformation is activated through emotional arousal that individuals may experience. The underlying role of emotional arousal in enhancing the influence of multimodal disinformation is implicated by prior work in two distinct ways: First, disinformation is commonly known to utilize intuitive emotional appeals to persuade audiences (Fong et al., 2021; Gerts et al., 2021). This emotional nature of disinformation is contagious to audiences, arousing negative emotions such as fear among audience members (Van Prooijen, 2018). Second, a concrete description of a mediated event in multimodal

disinformation is processed primarily through fast and subconscious routes which require less interpretation (Powell et al., 2019; Sundar et al., 2021). To process many different modalities (e.g. audio, visual) embedded in the information, a greater cognitive allocation is needed for encoding the message, which incurs cognitive overload (Lang, 2000). Existing research has demonstrated modality-biased processing, meaning that video modality is more deleterious for depth of processing compared to leaner modalities (Fisher et al., 2019). This suggests that emotions, particularly those which are instinctive reactions that require less cognitive effort to scrutinize the veracity of information, can be more likely to be aroused when seeing multimodal disinformation compared to disinformation with leaner modalities (Powell et al., 2019).

Among distinct emotions, anxiety deserves particular attention in the current context. Broadly speaking, existing literature has suggested that emotions play a role in influencing attitudes about health behaviors. For example, certain emotions (e.g. anticipation, sadness) are prominent in vaccine-related discussions on social media (Lyu et al., 2021), while emotions such as anger are a pertinent factor explaining the extent to which (often politicized and polarized) misinformation about flu vaccination impacts vaccination behaviors (Kim et al., 2021). While the role of these distinct emotions should not be underestimated, focusing on anxiety in this study can provide greater insight into examining misperceptions shaped by the richness of disinformation. For example, the *vividness* and *concreteness* of video-based disinformation (Lee and Shin, 2022) helps to emphasize the side effects of the flu vaccine, which may can amplify concerns about the vaccination via the evocation of mental imagery. People may, therefore, more readily imagine that they are likely to experience such side effects (i.e. susceptibility) and that the risks of vaccine can be high (i.e. severity) as depicted in videos with audio-visual testimonies, eliciting a subsequent increase in anxiety. This elicitation of anxiety is problematic considering that during risky situations in which public confidence in science is undermined, the prevalence of anxiety can augment the power of misinformation, complicating the efforts to inoculate the public against certain illnesses like the flu (Lee et al., 2021).

Based on the effects previously discussed, we, therefore, expect that multimodal disinformation will trigger more direct anxiety than text-only disinformation among recipients. If disinformation-making claims about the side effects of the flu shot are provided with concrete audio-visual testimonials of real human beings, audiences' anxiety levels are likely to be aroused, which may suppress the cognitive ability to authenticate those claims. By comparison, textual information is more likely to be processed cognitively and slowly, which would likely preclude the activation of anxiety. Taking this into consideration, Hypothesis 1 (H1) is proposed:

> *H1*. A higher level of anxiety will be shown among individuals exposed to multimodal disinformation (i.e. video-plus-text disinformation and image-plus-text disinformation) and text-only disinformation, compared to those in the control condition, respectively. Such differences in anxiety will be the largest in video-plus-text disinformation (vs control), followed by image-plus-text disinformation (vs control), and text-only disinformation (vs control).

Anxiety as affect heuristic in disinformation about the flu vaccine

Medical disinformation often manifests as unfounded medical conspiracies, perpetuated in fearmongering vaccine-related misleading stories online (Parks, 2021), or other false narratives about unproven medical therapies (Baig, 2019). The circulation of these false claims around the flu vaccine, often presented in a format of legitimate medical news on social media (Zadrozny, 2019), has become a major obstacle to flu vaccination uptake (Guidry et al., 2020). Furthermore, disinformation on social media often strategically uses emotional cues to entice users' attention (Germani and Biller-Andorno, 2021; Zhang et al., 2021). Anxiety is one of the common emotions featured in health disinformation (Harvey et al., 2019); anti-vaccine actors employ anxiety-inducing techniques to foster strong emotional responses among users and engagement with disinformation (Sun et al., 2022). Disinformation manipulated to amplify concerns related to vaccination may be particularly detrimental to people with skepticism toward the efficacy of the flu vaccine.

Focusing on anxiety in examining the psychological effects of health disinformation is especially meaningful in terms of the *affect heuristic*, which presumes that individuals tend to make judgments simply based on feelings they experienced (Finucane et al., 2000; Slovic et al., 2007). From this standpoint, the anxiety experienced by seeing disinformation about the flu vaccination may serve an important role in the formation of misperceptions. Adding to existing research which has found that reliance on emotion increases misperceptions (Martel et al., 2020), the potential detrimental role of anxiety is specifically stated in Nyhan and Reifler's (2012) study: people who "feel a lack of control" might "compensate with strategies that lead to greater acceptance of misperceptions" (p. 17). In a similar vein, recent evidence has linked anxiety about health issues with health disinformation acceptance—this is explained under the assumption that individuals experiencing anxiety might be less likely to process disinformation through central routes that could contribute to examining the plausibility of the false claims systematically (Pan et al., 2021).

In addition, we expect that anxiety triggered by multimodal disinformation may be positively linked with misperceptions. Research has found that emotionality, overall, can result in individuals having more misperceptions about various topics (Martel et al., 2020). Anxiety, in particular, is known to be associated with a higher likelihood of misinformation acceptance (Pan et al., 2021), and has been shown to undermine the effectiveness of corrective interventions (Lee, 2022). As multimodal information has a stronger effect on emotions than text, and as these triggered emotional responses are found to correspond to subsequent beliefs (Powell et al., 2015), the mediating role of anxiety may be most pronounced for multimodal disinformation. Against this background, we expect that exposure to the image or video-based disinformation about the side effects of the flu vaccine will increase the level of anxiety which will in turn increase misperceptions:

H2. Anxiety will mediate the effect of different modality types of disinformation (vs control condition) on misperceptions, such that anxiety elicited by video-plus-text, image-plus-text, and text-only disinformation will be positively associated with misperceptions about the flu vaccine.

Perceived issue relevance in perceiving multimodal disinformation

According to appraisal theories of emotion, negative emotions are more likely to be triggered when individuals perceive that an issue is personally relevant to them (Lazarus, 1991; Smith and Ellsworth, 1987). Interchangeably used with the term *issue involvement* in some research (e.g. Lu, 2019), perceived issue relevance refers to "the extent to which the attitudinal issue under consideration is of personal importance" (Petty and Cacioppo, 1979: 1915). Persuasion literature has discussed the extent to which perceived issue relevance is associated with individuals' depth of information processing; the more people perceive an issue to be personally relevant, the higher the likelihood they will engage in thoughtful scrutiny of arguments in a message (Petty and Cacioppo, 1986). In contrast, individuals who consider an issue to be less important to themselves tend to focus more on peripheral message cues, such as structural components of the message (e.g. Lee and Kim, 2016; Metzger et al., 2010).

We suspect that users' perceived issue relevance can elicit different levels of anxiety depending on multimodal components of the disinformation. Multimodal disinformation research which examines the impact of perceived issue relevance on attitude persuasion has found that individuals with low levels of perceived issue relevance tend to report higher credibility ratings of false news stories presented in the video format—this falls in contrast with effects in regard to the audio or text-formatted content, which tended to gain higher credibility ratings among those with *higher* perceived issue relevance (Sundar et al., 2021). This suggests that disinformation with richer modalities can strengthen the heuristic processing of the content, particularly when users perceive the issue to be less relevant to themselves. Other research has found that such heuristic appeals of multimodal information (e.g. using graphics in the news) can enhance engagement in news elaboration processes among those with higher issue involvement (Lee and Kim, 2016). These findings may indicate that, in the context of disinformation in which cognitive reflection is needed to detect misleading claims, multimodal presentations of disinformation to individuals lower in perceived issue relevance may induce anxiety by hindering elaborative thinking about the content. Based on the affect heuristic, it follows that this heightened anxiety is likely to make people judge incorrect information to be truthful.

In view of this literature, the current research proposes a moderated mediation model of multimodal disinformation on misperceptions. More specifically, we predict that multimodal disinformation will elicit higher levels of anxiety, which will cultivate misperceptions—however, we predict that this indirect effect will be strongest for those who are low in perceived issue relevance (moderation of the multimodal disinformation-anxiety link).

H3a. The effect of multimodal disinformation (vs control condition) on anxiety will be moderated by perceived issue relevance, so that lower levels of perceived issue relevance will correspond to stronger effects on anxiety.

H3b. The anxiety triggered by exposure to multimodal disinformation will subsequentially affect misperceptions.

Method

Study design and participants

The current study aims to explore the effects of multimodal disinformation about the topic of the flu vaccine. We conducted a randomized between-subjects online experiment examining attitudes toward the flu vaccine. Our design employed one factor (modality of disinformation) with three types of disinformation and a control group: (a) video-plus-text disinformation ($N = 101$) vs (b) image-plus-text disinformation ($N = 103$) vs (c) text-only disinformation ($N = 104$) vs (d) control (unrelated information; $N = 105$). Data were collected after receiving institutional review board (IRB) approval. Participants were limited to those currently residing in the United States given the particularly partisan nature of the flu vaccine in the United States which has emerged during the COVID-19 pandemic, as well as the fact that flu vaccine knowledge has been influenced by the spread of misinformation on social media (Enten, 2021; France-Presse, 2020).

Participants were recruited in May 2021 via Amazon Mechanical Turk (MTurk). Despite recent concerns over using MTurk as a data collection tool (Kennedy et al., 2020), researchers have suggested that including validity indicators such as HIT requirements or screening questions (e.g. English-speaking participants only) may provide more quality data (Chmielewski and Kucker, 2020). Therefore, participants in this study were pre-screened based on several questions asking for eligibility (over 18 years old, U.S. residents, Facebook users), and only those with HIT approval rates above 90% were invited. Stimuli were designed on Facebook, as it is one of the most popular social media platforms where U.S. adults receive news (Shearer and Grieco, 2019) and has simultaneously faced harsh criticism for mishandling disinformation (Zuckerman, 2021). A total of 413 participants completed the study (completion rate: 91.0%). Table 1 shows the demographic characteristics of the final sample of participants.

Stimuli

All the stimuli used for this study were designed on a Facebook platform, and disinformation in our study was guised as news. A claim identified as factually incorrect regarding the flu vaccine was used across the conditions, except for the control group. The control condition was designed to assess the differential effects of the modality of disinformation compared to a baseline situation where no such disinformation is provided. Given that the disinformation topic about the flu vaccine in and of itself could raise anxiety levels to some extent, we included the pure control to contrast the impact of disinformation with different formats on anxiety against the pure control. In addition, given that people encounter both disinformation and other unrelated posts in the real social media environment, the inclusion of the pure control was useful to enhance the ecological validity of the study design. To control for any unexpected effects that originated from the mere activity of reading a news article on social media, we provided a random news article to the control group—a real story about finding a long-lost wallet—that is unrelated to the flu vaccine. The false claim in the disinformation conditions was presented either via a video with text (video-plus-text), an image with text (image-plus text), or text

Table 1. Demographic characteristics of the participants.

Category	*N*	Percentage
Gender		
Female	232	56.2%
Male	168	40.7%
None identified	13	3.1%
Education		
Did not finish high school	1	0.2%
High school diploma or equivalent	30	7.4%
Technical or vocational school after high school	13	3.2%
Some college, no degree	73	18.1%
Associate's or 2-year college degree	35	8.7%
Four-year college degree	162	40.2%
Graduate or professional school after college, no degree	21	5.2%
Graduate or professional degree	68	16.9%
Total	**413**	**100%**
	M	*SD*
Age (years)	39.73	13.16
Political ideology (1 = *liberal*, 7 = *conservative*)	3.57	1.85

SD: Standard deviation.

alone (text-only). All stimuli including the video and the posts used for the control condition can be found on Open Science Framework (OSF): https://osf.io/csh6y/?view_only=d5ca5c3fc69346f1bd9e06d5e10b351a.

The false claim stated that flu vaccines can cause flu and other severe side effects, one of the widespread misleading claims on this issue. The fictitious source *News for Health* was used in all disinformation manipulations. The post contained testimonials of a medical doctor and other people (fictitious names were used for the interviewees) about the side effects of the flu vaccine, which were borrowed from YouTube.[1] We have chosen to focus our manipulation on side effects of a flu vaccine as this corresponded with the general theme of much of the health-related disinformation found on social media platforms. We refrained from more "extreme" disinformation claims that, for example, cultivate conspiracies about vaccines, or expressed severe doubts on the overall effect of vaccines, as these more extreme views are likely more heavily influenced by ideological extremity or cynical attitudes.

The original video clips were edited for the video-plus-text condition, and the total length of the final video used for the main study was 34 seconds. Figure 1 displays the posts used for the text-only, image-plus-text, and video-plus-text conditions. In fact, the manipulation check was not necessary in this case, given that intrinsic features of the stimuli (i.e. the disinformation format) were independent of participants' perceptions (see O'Keefe, 2003). However, for a robust check, we asked whether participants in each disinformation condition accurately identified the disinformation format they saw at the end of the study. The results of a crosstab analysis showed that 88 participants in the text-only disinformation condition correctly answered that the message they saw did not contain

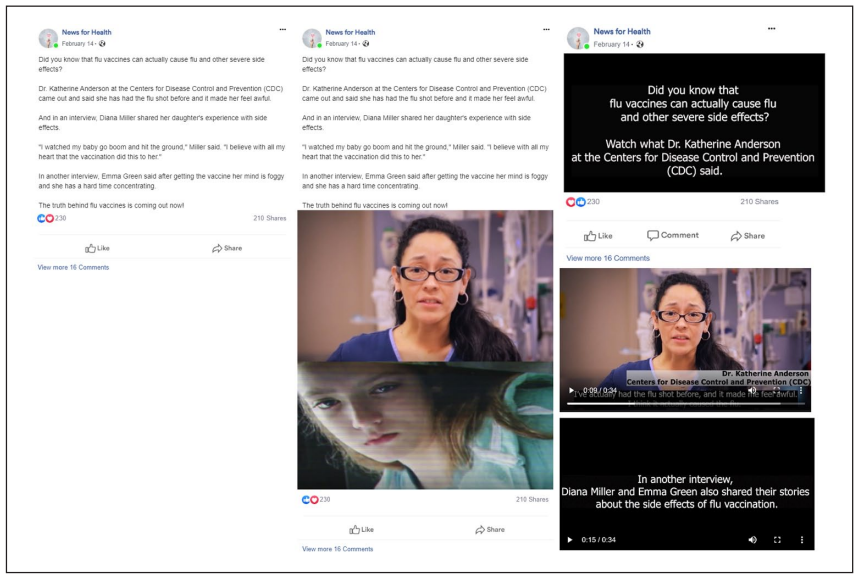

Figure 1. Text-only (left), image-plus-text (middle), and video-plus-text (right) Facebook posts.
Participants in the video-plus-text condition watched the 34 second video; the post used for the control condition (unrelated to the topic) can be accessed via OSF.

any image or video but only contained text, 101 participants in the image-plus-text condition remembered accurately that the message they saw contained any images, 95 participants in the video-plus-text condition identified accurately that the message they saw contained a video. Although not all participants provided an accurate answer, a Pearson chi-square test showed that participants in each disinformation condition responded to the recall question about the disinformation format at a statistically different level, $X^2(4) = 486.37$, $p < .001$.

Procedures

Upon accessing the study, participants were asked to complete the informed consent document. Next, they answered screening questions to ensure all participants were over the age of 18 and current Facebook users. Participants who met the eligibility criteria were directed to answer questions about their prior issue beliefs and perceived issue relevance regarding the flu vaccine. Thereafter, participants read the instruction which asked them to imagine that they were browsing online and came across some news stories going viral. The instruction asked participants to pay attention to the news story presented on the next screen and turn on their audio before proceeding further. Participants were then randomly assigned to one of the four conditions: video-plus-text, image-plus-text, text-only disinformation, or the control condition. In each experimental condition, people viewed a Facebook post that provided a false claim in different formats (video, image, text) related to the flu vaccine—this contrasted with the control condition where participants read a

random new story unrelated to the flu vaccine. Participants were forced to stay on the stimuli screen for at least 20 seconds to make sure they read or watched the given post before proceeding to the next questions. The average length of time participants spent on the stimuli was 49.53 seconds ($SD = 45.17$). After viewing the stimuli, participants were directed to the post-manipulation survey, which included measurements of emotions and misperceptions toward the flu vaccine. Finally, participants answered questions about other demographic variables such as gender and education. Participants were debriefed that the messages they saw for the flu vaccine were factually incorrect and thanked for their participation.

Measures

Anxiety (post-treatment variable). To measure anxiety, we asked participants to indicate the extent to which they experienced the following feelings (Leary et al., 2007): (a) tense, (b) worried, and (c) anxious. The items were measured immediately after the Facebook posts were presented. Each item ranged from 1 = *I do not feel this at all* to 7 = *I feel this intensely* ($\alpha = .96$, $M = 2.25$, $SD = 1.79$).

Misperceptions (post-treatment variable). The items for misperceptions included the following statements that were measured on a 1–7 Likert-type scale (1 = *completely disagree*, 7 = *completely agree*): (a) Flu vaccinations involve major health risks, (b) There are important unknown side-effects of flu vaccinations, and (c) People can get seriously ill from a flu vaccination ($\alpha = .93$, $M = 2.90$, $SD = 1.73$). These items were selected to reflect misperceptions about vaccine harms, which not only tapped popular misperceptions identified by the Centers for Disease Control and Prevention (CDC) but were also mentioned in our experimental stimuli.[2]

Perceived issue relevance (pre-treatment variable). Before the exposure to experimental stimuli, we asked participants how relevant the flu vaccine topic was to them[3] on a 7-point scale (1 = *not at all relevant*, 7 = *extremely relevant; M* = 4.25, *SD* = 2.03). To reduce any demand effects, we also asked about their perceived issue relevance for other filler topics, including immigration policy, COVID-19 vaccination, and gun control policy.

Prior issue beliefs (pre-treatment variable). To control for the effect of general prior beliefs regarding the flu vaccine, we asked participants to indicate the extent to which they believed each of the following statements on a 7-point scale (1 = *completely false*, 7 = *completely true*): (a) Flu shots come with severe side-effects, (b) I would get a flu vaccine every year to stay safe (reverse-coded), (c) Flu vaccines are dangerous, and (d) Flu vaccines can cause more severe effects than the virus they protect against ($\alpha = .82$, $M = 2.57$, $SD = 1.48$). These items were borrowed from the CDC website[4] and selected to match the stimuli content as close as possible. The low mean value indicates that participants' levels of misperceptions regarding the flu vaccine were significantly lower than the midpoint (4) of the scale we used, $t(412) = -19.66$, $p < .001$.

Results

Correlations among measured variables

The zero-order correlations among measured variables showed that anxiety was positively correlated with misperceptions ($r = .53$, $p < .001$) and prior issue beliefs ($r = .35$, $p < .001$), but not with perceived issue relevance ($r = -.01$, $p = .78$). Misperceptions were negatively related with perceived issue relevance ($r = -.16$, $p = .001$) but positively related with prior issue beliefs ($r = .74$, $p < .001$). There was also a significant negative relationship between perceived issue relevance and prior issue beliefs ($r = -.35$, $p < .001$). Given the significant correlations with prior issue beliefs, we controlled for the effects of prior issue beliefs by including them as a covariate in all of the subsequent analyses.

Hypothesis test results

For testing our hypotheses and research questions, we used Hayes' PROCESS macro (Hayes, 2017) with 10,000 bootstrap samples in R. H1 and H2, which predicted the effects of different types of disinformation (vs control), were altogether tested using PROCESS Model 4.

H1 predicted that the largest difference in the level of anxiety will be shown between the video-plus-text disinformation and the control condition. As there were four conditions (video-plus-text vs image-plus-text vs text-only vs control), three dummy-coded variables were created for each of the disinformation types using the control condition as the reference group. Results revealed that, compared to the control condition, each mode of disinformation showed a higher level of anxiety after controlling for prior issue beliefs (text-only: $b = 1.11$, $t = 4.95$, $p < .001$, image-plus-text: $b = 1.07$, $t = 4.74$, $p < .001$, video-plus-text: $b = 1.11$, $t = 4.92$, $p < .001$). The unstandardized beta coefficient for each mode of disinformation (vs control) in this case did not show large differences from one another. Therefore, considering that we do not find a modality-specific effect of disinformation exposure, H1 was not supported.

In regard to H2, each mode of disinformation (vs control) showed a significant mediation effect on misperception via anxiety (text-only vs control: $b = 0.32$, standard error [SE] = 0.07, 95% confidence interval [CI]: [0.18, 0.47], image-plus-text vs control: $b = 0.30$, $SE = 0.08$, 95% CI [0.17, 0.46], video-plus-text vs control: $b = 0.32$, $SE = 0.08$, 95% CI [0.17, 0.50]). Ostensibly, H2 was not supported, because the mediations for each type of disinformation (vs control) were significant in positive directions without showing much difference. However, when scrutinizing these indirect effects further, the results of the relative total effects showed that the effects of the text-only disinformation (vs control; $b = 0.49$, $t = 3.11$, $p = .002$) and video-plus-text disinformation (vs control; $b = 0.68$, $t = 4.23$, $p < .001$) on misperception were significant but image-plus-text disinformation (vs control) did not have a significant effect ($b = 0.24$, $t = 1.48$, $p = .14$). Considering that the direct effect on misperceptions was significant only for the video-plus-text disinformation (vs control; $b = 0.36$, $t = 2.39$, $p = .02$), but neither for the text-only disinformation (vs control; $b = 0.18$, $t = 1.18$, $p = .24$) nor the image-plus-text disinformation (vs control; $b = -0.07$, $t = -0.45$, $p = .65$), the results altogether indicated that the video-plus-text disinformation produced the strongest effect on misperceptions.

H3a and H3b were investigated together with a moderated mediation model using PROCESS Model 7. H3a postulated that issue relevance would moderate the effect of multimodal types of disinformation (vs control) on anxiety. H3b predicted that this moderation effect would be further associated with misperceptions. The tested moderated mediation model included three different dummy-coded types of disinformation (vs control) as the independent variables, anxiety as the mediator, misperceptions as the dependent variable, and perceived issue relevance as the continuous variable moderating the relationship between disinformation type and anxiety. Results showed support for a significant moderated mediation model, but only for the comparison between video-plus-text disinformation and the control group (see Table 2 for the regression results; see Figure 2 for the model illustration; index of moderated mediation = -0.06, $SE = 0.04$, 95% CI [-0.14, -0.002]), meaning that the indirect effect of video-plus-text (vs control) on misperceptions via anxiety varied depending on the level of perceived issue relevance. Specifically, there was a significant negative interaction effect between video-plus-text disinformation (vs control) and perceived issue relevance on anxiety ($b = -0.22$, $t = -2.02$, $p = .04$). A simple slope analysis investigating the effect of video-plus-text disinformation (vs control) at $M \pm 1SD$ levels of perceived issue relevance showed that the difference in anxiety between video-plus-text disinformation and the control was weaker as perceived issue relevance increased ($b = 0.53$, $t = 5.56$, $p < .001$ for low involvement; $b = 0.38$, $t = 5.67$, $p < .001$ for moderate level of involvement; $b = 0.23$, $t = 2.44$, $p = .02$ for high involvement; see Figure 3 for the interaction plot). This evidence is consistent with H3a. Finally, anxiety was linked with a greater rate of misperceptions ($b = 0.28$, $t = 8.85$, $p < .001$). The relative direct effect of video-plus-text disinformation (vs control) on misperceptions was also significant ($b = 0.36$, $t = 2.39$, $p = .02$), which offers support for H3b.

Additional analyses

As all the main analyses above included the comparison with the control group, we further examined if any other significant differences in anxiety and misperceptions exist between the disinformation groups to probe the modality effects of disinformation more closely. Two analyses of covariance (ANCOVA) were conducted with three disinformation conditions (video-plus-text, image-plus-text, text-only disinformation) as the independent variable, anxiety and misperceptions as two separate dependent variables, and prior issue beliefs as the covariate. Results revealed that anxiety was not significantly different between the disinformation groups, $F(2, 304) = .02$, $p = .98$, $\eta_p^2 = .00$, but misperceptions were different between the groups, $F(2, 304) = 3.33$, $p = .04$, $\eta_p^2 = .02$. Upon conducting Sidak pairwise comparisons, a significant mean difference in misperceptions between video-plus-text ($M = 3.22$, $SD = 1.86$) and image-plus-text ($M = 2.75$, $SD = 1.70$) was shown ($p = .03$), but no significant effect was found comparing difference in misperceptions between the video-plus-text and text-only conditions ($M = 3.03$, $SD = 1.74$; $p = .64$). No significant difference was found between the image-plus-text and text-only conditions ($p = .35$).

Discussion

The findings of this study contribute to the current understanding of the potential effects of multimodal disinformation on anxiety arousal and misperceptions in several different

Table 2. Regression results for the moderated mediation model

Predictors	Mediator variable = Anxiety	
	b	*SE*
Constant	0.16	0.22
Comparison 1: Text-only disinformation vs. Control	1.12***	0.22
Comparison 2: Image-plus-text disinformation vs. Control	1.11***	0.22
Comparison 3: Video-plus-text disinformation vs. Control	1.14***	0.22
Perceived issue relevance	0.25**	0.08
Perceived issue relevance × Comparison 1	-0.18	0.11
Perceived issue relevance × Comparison 2	-0.13	0.11
Perceived issue relevance × Comparison 3	-0.22*	0.11
Prior issue beliefs	0.48***	0.06
F (R^2)	13.87*** (.22)	
Predictors	Dependent variable = Misperception	
	b	*SE*
Constant	0.24	0.14
Comparison 1: Text-only disinformation vs. Control	0.18	0.15
Comparison 2: Image-plus-text disinformation vs. Control	-0.07	0.15
Comparison 3: Video-plus-text disinformation vs. Control	0.36*	0.15
Anxiety	0.28***	0.03
Prior issue beliefs	0.74***	0.04
F (R^2)	142.21***(.64)	

SE: standard error.
Perceived issue relevance was grand-mean-centered; *$p < .05$; **$p < .01$; ***$p < .001$.

ways, primarily through the lens of the affect heuristic (Finucane et al., 2000; Slovic et al., 2007) and realism heuristic frameworks (Sundar, 2008). Of note in the current study's findings is, first, that anxiety plays a prominent role in explaining the power of health disinformation. This finding extends previous research, offering an implication that curbing public panic evoked by misleading claims should be taken into consideration in disinformation scholarship. As a case in point, public health crises are often surrounded by disinformation that strategically harnesses negative emotions and takes advantage of people's emotional arousal, an approach which can potentially make individuals come to endorse/believe in misleading content (Chou and Budenz, 2020; Lee, 2022; Paschen, 2019). The affect heuristic framework (Finucane et al., 2000; Slovic et al., 2007) provides additional insight into the role of anxiety, given that people might be prone to using an

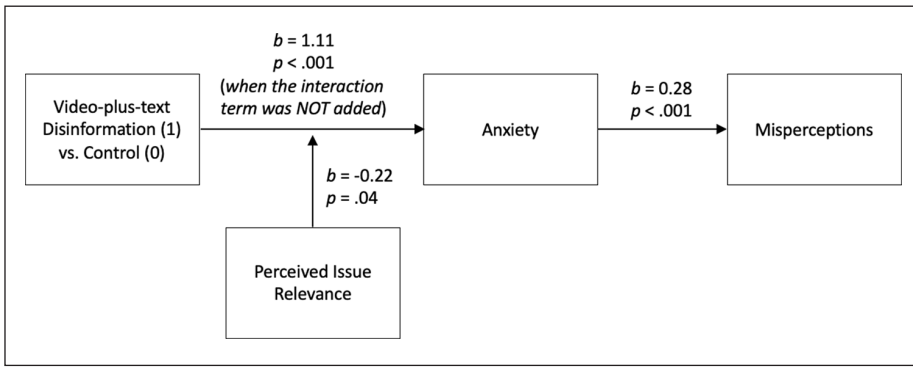

Figure 2. Moderated mediation model for the effect of video-plus-text disinformation on misperceptions via anxiety.

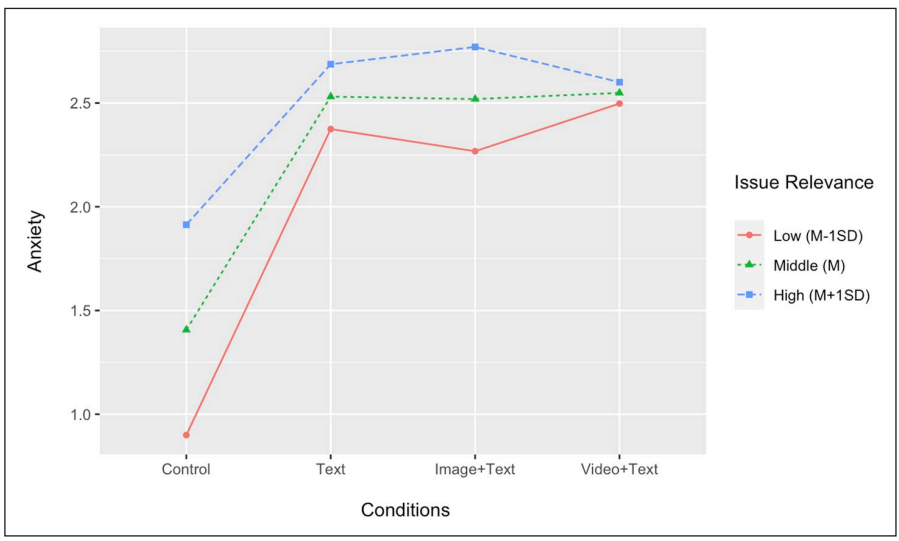

Figure 3. Interaction plot for the effect of disinformation types and perceived issue relevance on anxiety.

automatic emotion-driven decision system that eventually increases vulnerability to disinformation. Based on the current work, anxiety appears to be a key psychological mechanism that explains the influence of health disinformation on misperceptions.

Examining the effectiveness of multimodality of disinformation presentation provides several significant implications. First, we found that, relative to the control condition, video-plus-text, image-plus-text, and text-only disinformation about the flu vaccine engendered similar levels of state anxiety which exerted subsequent influence on misperceptions. Although disinformation (regardless of its modality) in our study appeared to

drive misperceptions via anxiety in a similar way on the surface, a closer investigation of the mediation effects depicts a more complex picture, suggesting that psychological mechanisms underpinning the effects of different disinformation modality types may differ. For example, our results showed that anxiety served as a significant mediator between disinformation and misperceptions in our text-only condition. However, while this indirect effect rendered the direct effect of disinformation on misperceptions nonsignificant, this was not the case in the video-plus-text condition, where the direct effect remained significant. This suggests that, in the case of a video-plus-text modality, anxiety may not be the sole factor that contributes to the insidious effects of multimodal health disinformation. Put differently, there could be other psychological factors, in addition to anxiety, that contribute to the formation of misperceptions in response to video-plus-text disinformation. In contrast, the non-significant total effect and direct effect within the mediation results regarding image-plus-text disinformation portrays a different story that there might be other mechanisms that prevent users from falling for the misleading content, potentially offsetting the impact of anxiety on increasing misperceptions.

The aforementioned finding regarding image-plus-text disinformation is worth noting, as it sheds different insights into modality-biased processing and realism heuristic. As previous research has suggested, the presence of multimodal information has been attributed to triggering mental shortcuts in judging information authenticity (Lee and Shin, 2022). In such cases, users are likely to respond to the content emotionally as an instinctive reaction (Slovic et al., 2007). However, our results suggest that simply adding multiple modalities (e.g. adding images to texts) might not necessarily elicit heuristics that could serve as potential drivers for misperceptions. One alternative explanation could be that the use of images in our disinformation stimuli distracted users (rather than aided in disinformation processing), and this might have prevented them from being fully immersed in the misleading content.

Another interpretation is based on the design of our image-plus-text disinformation. Although misleading posts on social media often embed texts directly in images to capture users' attention, image-plus-text disinformation in the current study presented images and texts separately (i.e. images at the bottom and texts above in the disinformation post). In this case, it could be possible that users might dissociate images from textual context. If this were the case, it would likely result in a loss of users' attention to texts after expending cognitive effort to infer the meanings of images. Unlike images which allow users to connect to texts unless direct cues that indicate contextual information is presented, text-only disinformation provides direct verbal cues that might induce disinformation-relevant thinking. Although texts are generally known to be perceived as abstract and require more interpretation (Molina and Sundar, 2019), texts used for disinformation would be written in a way that makes it easier for users to follow the misleading story. Therefore, this might propel users' emotional responses and engagement with the misleading content subsequently.

Notably, the results about the effects of video-plus-text disinformation indicate that video can be a powerful means to deliver misleading content, which resonates with what previous research found (Lee and Shin, 2022; Sundar et al., 2021). The findings that video-plus-text disinformation increased misperceptions both directly and indirectly via anxiety can be explained in terms of the realism heuristic, such that

misleading stories can be perceived as realistic when presented in a video format. Furthermore, employing multimodalities in a video might appeal more directly to users' senses (Sundar et al., 2021), leaving less room to evaluate the authenticity of the content analytically.

The moderating effect of perceived issue relevance on the multimodal disinformation-anxiety link offers a more nuanced perspective to understanding the effects of multimodal disinformation. Users with low perceived issue relevance responded to video-plus-text disinformation at similar levels of anxiety as those with high perceived issue relevance. Given the inherent nature of multimodal disinformation that facilitates automatic processing (Powell et al., 2019), video-based disinformation in this study might serve as a powerful anxiety catalyst which can, in turn, influence misperceptions by overriding individual differences in perceived issue relevance. At least in part, disinformation presented in a video format could be effective at engendering automatic reactions among users with low perceived issue relevance who might initially be indifferent to the flu vaccine issue. This expands on previous work which has found that users are not likely to actively respond to disinformation (e.g. take actions to correct disinformation) if the issue is not personally relevant to themselves, as they tend to be emotionally detached from it (Tandoc et al., 2020). However, we can interpret from our findings that users with low relevance may also react with anxiety to a similar extent as those with high perceived issue relevance, particularly when seeing video-based multimodal disinformation. Given our findings, future research should examine whether individuals who do not feel personally connected to a topic of disinformation might be motivated to correct the misleading claims when presented in a multimodal format. Furthermore, understanding such a mechanism could be expanded upon by identifying whether users with high misperceptions due to realistic depictions in multimodal disinformation are less motivated to correct the misleading claims.

Limitations and future directions

The findings of this study should be interpreted in light of several limitations. First, this study was not able to examine whether multimodality employed in disinformation also curtails the willingness to actively correct misleading claims—subsequent research should seek to explore whether the effects found in the current study may lead to corrective action on the part of the message audience. Second, this study focused on anxiety, but there could be other emotions aroused by disinformation exposure. For instance, people who oppose disinformation might experience anger when seeing it, particularly if presented in a multimodal form, or disgust if the messaging discusses potentially upsetting outcomes of an illness—in fact, both of these emotions have been implicated as potential outcomes of engaging with disinformation in prior work (see Vosoughi et al., 2018). Another limitation pertains to the possible floor effects based on the relatively low level of anxiety, prior issue beliefs, and misperceptions. Although this might raise a concern to some extent, the significant results are still worthy to note, given that our experimental study is based on one-time exposure to a message. In the real world, the effect we found regarding health disinformation is likely to be increased with repeated exposure to similar content.

In addition, we call on future research to provide a more comprehensive picture of the individual differences that may directly or indirectly affect the persuasiveness of multimodal disinformation. Although perceived issue relevance has been regarded as a decisive factor of content-based persuasion both in general (Petty and Cacioppo, 1986) and in particular with health risk messaging (e.g. Ahn, 2015), the inclusion of other relevant individual differences (e.g. motivation, ability, and perceived knowledge) to expand our model might be worthy of consideration. Also, although we did not measure pre-existing attitudes toward the CDC that was mentioned in our disinformation stimuli, prior attitudes toward such expert sources mentioned in disinformation could serve as another moderator for the effects of multimodal disinformation. The use of the single item to measure issue involvement was another major limitation. Future research could use multiple items of perceived issue relevance for more reliable results.

A final limitation concerns the focus on disinformed claims on side-effects of flu medicine. Although we stayed as close as possible to examples of actual disinformation on the topic, while not emphasizing conspiracy theories or more severe claims delegitimizing established truths, the selection of claims may impact results. For example, disinformation claims emphasizing that vaccines are biological weapons that are made to control the world population may instill higher levels of anxiety, or resistance among certain parts of the population. However, using more *modest* manipulations, our experiment already demonstrated effects of multimodal disinformation on anxiety and misperceptions. We leave it up to future research to assess the differential effects of varying claims, perhaps by varying levels of perceived plausibility or extremity. Finally, our findings should be replicated in other health contexts and outside of the United States, which would altogether enhance the external validity of our experiment.

Conclusion

Despite the limitations, the current findings carry significant insight in several ways. The findings underscore that users may not necessarily respond to misleading content emotionally and accept it just because multiple modalities are employed in the disinformation. Instead, disinformation may be more powerful if the employed modalities are perceived to be immersive, leaving less cognitive room for users to detach themselves from the false story. Importantly, disinformation presented in a video format is the most concerning, given that it may result in instinctive reactions irrespective of how users are involved in the issue. In the digitalized media environment where disinformation is conveyed through various modes of presentation, researchers and practitioners should provide cues that shift recipients' attention to accuracy judgments (e.g. Pennycook et al., 2021) before immersing themselves in misleading stories.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2021S1A5C2A02088387).

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Notes

1. Original links: https://youtu.be/YNd6Hvgitwo; https://youtu.be/y7Tc3eR4nH4 A pretest was not conducted because only small parts of each video (rather than the whole video per se) were used and edited by the researchers. In addition, we used these videos which had low salience and popularity at the time of the study to reduce the likelihood that participants might already have encountered them. However, we acknowledge this as a limitation, given that there might be possibilities that some participants might have been already familiar with the message content.
2. https://www.cdc.gov/flu/prevent/misconceptions.htm
3. Using a single item for perceived issue relevance could be seen as problematic as it may be seen as lacking reliability. However, a single item was thought to be efficient in this case where perceived issue relevance was measured for other filler topics as well; in other words, measuring multiple items for each topic repetitively would make participants feel fatigued. In addition, single-item measures can be comparable to multiple items if they are used for constructs that "have a simple, clear object" (e.g. a flu vaccination issue) and "a single-meaning attribute" (e.g. relevance; Bergkvist, 2015: 246; also see Bergkvist and Rossiter, 2007).
4. https://www.cdc.gov/flu/prevent/misconceptions.htm

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