Nudging with Narrative Visualization: Communicating to a Young Adult Audience in the Pandemic

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Effective narrative visualization communicates information by integrating story-telling and data visualization in a comprehensible, compelling manner. The compelling aspect of effective narrative visualization consequentially results in the potential to shift the attitude of an audience. However, there is much to understand about how narrative visualization can best be designed to influence target audiences. This paper focuses on an empirical experiment where we examined the effects of two communication strategies - anthropomorphism and personal identification - on a young adult audience. In particular, we wanted to understand which strategy, when integrated into narrative visualization, can nudge a specific audience's attitude towards greater consideration in the context of the COVID-19 pandemic. Our results indicated that the personal identification communication strategy was the most successful in nudging participants. This study contributes a better grasp of how technologies such as narrative visualization, using different communication strategies, can deliver more targeted messaging.

CCS Concepts: • **Human centered computing → Visualization**; Empirical studies in visualization; Visualization theory, concepts and paradigms

Additional Key Words and Phrases: Narrative visualization, data storytelling, nudging, young adults, anthropomorphism, role enactment, health communication, COVID-19

1 Introduction

Narrative visualization is an increasingly popular communication medium. It combines data visualization and storytelling techniques to engage readers with complex issues. For example, it has been used to explain the effects of climate change and inflation [1, 2]. Despite the widespread adoption of narrative visualization to communicate critical information, there is limited empirical

evidence about how its design can impact audience attitude. Empirical evidence suggests that narrative visualization can persuade an audience and solidify their prior beliefs [3-6]. What is lacking is empirical research into targeted narrative visualization designed for a specific audience with an explicit aim.

Viewing visualization can influence an audience, which could have tangible results if extrapolated to the population level. In this work, we refer to a deliberate shift in audience attitude as a 'nudge.' Stemming from behavioral psychology, nudging is a friendly push to encourage desired behavior [7]. Nudging and visualization have historically had negative connotations, where nudging has been described as a tool for audience manipulation [8]. We believe nudging can potentially have a positive impact, specifically when communicating critical health messaging. In this study, we examine the effects of two communication strategies integrated into narrative visualization to nudge a young adult audience.

We selected young adults as our target demographic because they are identified as a group with a propensity for low compliance with public health measures, such as curbing the spread of COVID-19 [9-12]. Several studies have demonstrated that community rather than personal preservation may motivate young adults' adherence to virus mitigation measures [13, 14]. By appealing to a young adult's altruistic intentions, we examined the effects of targeted narrative visualization on altering their attitude.

The first of the two communication strategies that we investigated was anthropomorphism. This strategy replaces visualized data with images of people and leverages the audience's motivation to support their social circle and broader community. Differentiating our study from previous research exploring this topic, we have incorporated detailed imagery that reflected the target demographic and appealed to their frame of reference [15]. The second communication strategy we studied was derived from game theory, specifically role enactment [16]. In this strategy, we posit that interactive role enactment will increase empathy in the target audience. Essentially, this means a viewer imagines themselves as a character in the narrative presented, where, using interactivity, they are personally involved with the narrative. Previous research has shown that role enactment does increase willingness to help users. However, this has yet to be evidenced in the context of narrative visualization [16, 17].

In this work, we present an empirical experiment with 1084 young adult participants where we investigated nudging with narrative visualization. Our results suggest that the personal identification communication strategy can significantly influence the attitude of a young adult audience compared to integrating no communication strategy. Our primary contribution is a deeper understanding of how targeted communication strategies integrated into narrative visualization have the potential to influence audience attitude. This paper concludes with design recommendations for authors of narrative visualization, who, we believe, could benefit by adopting a targeted approach. Finally, we contribute to the ever-evolving visualization research field by adding nuance to the conversation surrounding narrative visualization and highlighting the importance of considering the target audience in narrative visualization design.

2   Related Work

We focus on related work in two areas: (1) communication strategies in narrative visualization and (2) nudging and health communication.

2.1 Communication Strategies in Narrative Visualization

Research into narrative visualization has grappled with comprehending and distinguishing this form of visualization. Previous studies have mapped the design space [18-21], described the design process [22-24] and examined implementations [25, 26]. While largely focusing on authoring, relatively few studies investigate the audiences' perspective. Some notable exceptions include empirical experiments on the role of prior knowledge [3] and the effect of narrative visualization structures [4, 5]. Our work aims to highlight the important consideration of the audience. More specifically, how narrative visualization designers might design more effectively by speaking to a particular audience.

A growing body of research has explored the unique power of narratives to shape human opinions and behavior [27]. Narratives operate through "an integrative melding of attention, imagery, and feelings [27]." Combined with data visualization, narrative rhetorical techniques can significantly affect end-user interpretation [19]. Hullman et al. proposed a framework for visualization rhetoric [19]. This framework identified narrative rhetorical techniques that authors integrated intentionally and unintentionally within the editorial layers of narrative visualization. Individualization techniques, within the 'linguistic-based rhetoric' editorial layer of the framework, are most closely aligned with our study goals; however, as recognized by Hullman et al., narrative visualization is a complex interplay of rhetorical techniques [19]. Our work acknowledges the power of visualization rhetoric, where we aim to give greater control to authors of narrative visualization over the underexplored dimension of audience interpretation.

To achieve our aim, we integrated two communication strategies into narrative visualization. Interchangeable with the term 'communication strategy' is the term 'narrative pattern.' A narrative pattern is described as a "low-level narrative device that serves a specific intent [28]." Some examples of alternative communication strategies include asking the audience to 'make a guess' about visualized data or open data exploration, where the audience can explore a complex interface. While both the aforementioned strategies can engage the reader, they do not emotionally connect with the reader. In this study we focus on communication strategies hypothesized to induce an empathic reader response [28].

It has been suggested that data visualization designers anchor their graphics in empathy by creating a visual connection between abstract data and living human beings [29]. More generally, replacing abstract data with icons or pictographs is called ISOTYPE design. ISOTYPE designs are shown to increase data comprehension and end-user engagement [30]. Data comprehension and end-user engagement are similar but nevertheless, separate aims to affect an empathetic response. One empirical study into empathy in visualization, which replaced abstract data with human-like icons, was not successful in increasing a significant empathetic response [15]. Earlier studies found that compared to a chart, showing pictures of orphan children to potential charity donors had a positive effect on donation amounts [31]. Moreover, data visualization videos using icons or pictographs are shown to encourage viewer engagement [7]. When portraying health data, data visualization videos, including humanoid cartoon characters, were found to increase viewer enjoyment and improve viewer perceptions toward a topic when compared to regular data visualization videos [5]. At its most basic level, empathy means eliciting an affective response to someone else's experience.

We differentiate our study from previous anthropomorphism work by including photographic imagery that reflects the intended audience. One study that mapped the design space of anthropomorphism and graphics, termed 'anthropographics,' highlighted the lack of empirical evidence, including end-users [32]. As first suggested by Morais et al., we hypothesize that

photographs of *relatable* people can elicit an empathetic response greater than that of abstract data [32]. Our study is an effort to address the lack of empirical evidence in a newly established research area consisting of anthropomorphism and graphics. Throughout the remainder of this study, we term this communication strategy 'anthropomorphism.'

Narratives involve sharing the perspective between the reader and the featured characters portrayed in the narrative. Role enactment occurs when the reader "imagines themselves as the characters and temporarily replaces their real-life identities and roles with the characters [16]." This cognitive process may enhance the persuasiveness of a narrative because individuals are likely to feel a sense of responsibility for the character. In mobile applications, role enactment is shown to encourage physical activity [33]. In the context of serious games, it has been evidenced that role enactment increases the gamer's willingness to help [16]. In the aforementioned study, a game was devised concerning a humanitarian scenario, which measured willingness to help by an amount that would be hypothetically donated. A further study using the same scenario found that adding interactivity significantly increased the amount that would be donated [17].

Interactivity facilitates a reciprocal communication pathway with the narrative, where the reader is required to actively engage and identify with characters. The term *interactive* is widely agreed to be ambiguous and confusing. We adopt a well-researched, albeit broad definition by Perin et al. [34]. According to Perin et al., interaction is "the interplay between a person and a data interface involving a data-related intent [34]." Fundamental to the elaboration likelihood model, it is hypothesized that interactivity increases the persuasiveness of the message [35]. While the advantages of interactivity are often touted, it is essential to consider its cost. It has been hypothesized that offering too many interactions may increase interface complexity and distract from messaging comprehension [36].

Message personalization via interactive role enactment is yet to be fully explored in the context of narrative visualization. Earlier research has proven that personalization is successful in narrative visualization that projects a patient's prostate cancer risk or when integrated into learning tools [37, 38]. In marketing and communications theory, a personalized message is generally considered more efficacious than non-personalized messages [39]. Our adopted definition stems from the work of Petty et al., who describe it as "a match between a message and certain characteristics of a message recipient [40]." We empirically investigate personalization, using role enactment, interactively integrated into narrative visualization as a communication strategy. Throughout the remainder of this study, we term this communication strategy 'personal identification.'

2.2 Nudging and Health Communication

Thaler and Sunstein introduced the concept of nudging in their book 'Nudge: improving decisions about health, wealth and happiness' in 2008 [7]. It is a concept based upon the adaptive design of a decision environment, also known as 'choice architecture.' A nudge can consist of three heuristics: anchoring, representativeness and availability. We will focus on the *availability* heuristic. We present an example of risk so that the audience is reminded of the risk [7]. Previous studies on the effects of nudges with a risk aversion approach in the health domain have had positive results [41, 42].

In the context of COVID-19, the UK government actioned a specialized group of behavioral psychologists named the 'Nudge Unit [43].' The Nudge Unit, during the first outbreak of COVID-19, introduced concepts such as singing 'Happy Birthday' when washing your hands. The ethics of pushing members of the public to make choices desired by the government has been the subject

of debate, where the differentiation between an individual's autonomy and 'oughtonomy' are blurred [44, 45]. Often implemented for profitable gains by private companies, commercial nudging can subvert the aim of aiding the public to make healthy decisions [46]. Nefarious nudges have been described in relation to data visualization [8]. Data visualization authors have power over how audiences make use of data [47]. The onus is on the author to ethically dictate the veracity of the data represented. Correll advocated for an ethical approach to data visualization, where authors must avoid breaches of harm and consent [47].

If the messaging seems to impinge too much on the freedoms of the reader, it may trigger a defensive response. Known as psychological reactance, this occurs when individuals perceive that their freedom is threatened, and try to re-establish their freedom [48]. Health messages specifically can have an unintended consequence of psychological reactance, where for example, smokers counter-argued anti-smoking messages and reinforced their habit [49]. Strongly held beliefs toward a topic cannot be swayed, despite the presentation of data visualization displaying contrary information [50]. In this study, we do not aim to change audience attitude completely, indeed such an aim might result in the opposite effect. Instead, our goal is to find evidence of a slight to moderate attitude shift that indicates a 'friendly push' or, as otherwise described, a nudge.

3 Context, Audience and Intervention

To achieve our goal of investigating the targeted design of narrative visualization to nudge a young adult audience, we designed four narrative visualization conditions on the topic of the spread of COVID-19 and the importance of wearing a mask.

3.1 Context: Mask Wearing to Curb COVID-19 Transmission

It was necessary to select a topic that was widely known so that the participants of the study were aware of the data and had formed an opinion prior to the experiment. COVID-19 undoubtedly touched the lives of all people living in the UK at the time of this study. In this study, we present the risk of spreading COVID-19 when not wearing a mask. Mask-wearing could be considered a provocative topic. In the United States, for example, mask mandates symbolized authoritarianism [51]. It is, however, a convenient topic as relative to other virus intervention measures, mask-wearing is unobtrusive to an individual's daily life [52]. They are credited with globally preventing infections and, ultimately, the deaths of multitudes of people [52-54]. Wearing a mask is evidenced to be beneficial in fighting respiratory infections, such as COVID-19, that are transmitted through droplets and aerosols [55, 56].
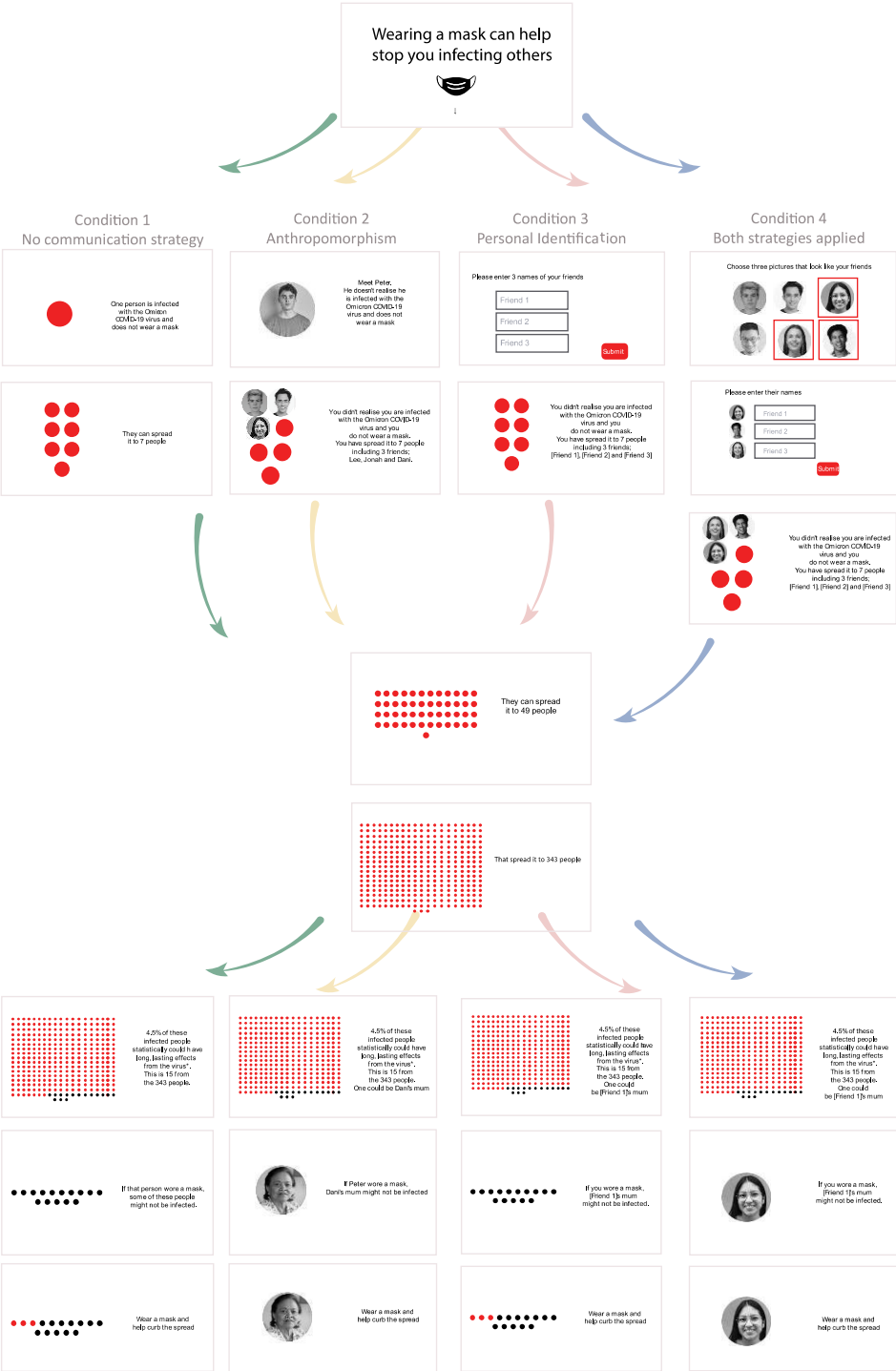
Fig. 1. Flow diagram containing narrative visualization designs of the four experiment conditions.

3.2 Audience: Young Adults

Our target audience was selected for their unique characteristics, which resulted in a propensity for low compliance with public health measures [9-12]. Young adults have unique practical characteristics such as a higher likelihood of communal living arrangements and casual employment conditions without sick leave [9]. These practical characteristics are challenging to alter. Their unique psycho-social characteristics, however, might benefit from a targeted health messaging approach [9-11]. For example, a lack of engagement in public health messaging means young adults are least likely to recall public health guidance [11]. Particularly in the context of epidemics, young adults are shown to feel a sense of social responsibility to the vulnerable members of their community [13, 14].

One specific consideration is that the health behaviors of young adults are deeply influenced by their peers [57]. Where their perceived social norms of others are essential antecedents of health-related behaviors [58]. In a study on the effects of anti-drug messaging, it was found that young audiences were more persuaded by messages that emphasized the social impact than the physical effects of drug use [59]. A later study found that adolescents were persuaded by antismoking advertising that emphasized social disapproval rather than health risks [60]. We therefore framed our message by highlighting social relationships, which are important to a young adult audience, with the consequences of infecting an older adult. We hypothesized that these aspects would speak to this demographic.

3.2 Intervention: Narrative Visualization

This section describes the narrative visualization variations we designed and used in our experiment. The dataset the narrative visualization variations were based upon consisted of recent research into the effects of the Omicron strain of COVID-19 and the likelihood of contracting long COVID [61, 62]. Members of the research team who are qualified in the area epidemiologically verified the accuracy of the visualized data. It should be noted that this study was undertaken in September 2022, where the dataset presented will likely be outdated, as is the ever-changing context of COVID-19. The narrative visualization design is an interactive article that is based primarily on scrolling and has been observed to be a popular form of COVID-19 visual communication [63].

The first from the four conditions was a control condition, and it did not contain a targeted communication strategy. This narrative visualization opened with a title screen and an illustrated face mask. The title was adjusted for maximum impact, which is in line with research suggesting that a visualization's title deeply influences reader recall [64]. The title spoke directly and imperatively to the audience, stating, "Wearing a mask can help stop you infecting others." Furthermore, the color palette selected for its specific affective response. Research suggests that red and black insight a 'disturbing' response from the reader [65].

The user was then required to scroll down, and the visualized data was revealed sequentially. The user was presented with a hypothetical scenario about an infectious individual with the Omicron variant of COVID-19. This particular variant, at the time of writing, had an estimated basic reproduction number of six to eight [61]. A basic reproduction number denotes the expected number of cases directly generated from a single case. Accordingly, we chose a basic reproduction number of seven in the midpoint of this range to use in our communications. To express the uncertainty of the situation, we repeatedly highlighted the hypothetical nature of the narrative. The core message was that if an individual does not wear a mask, they could spread the virus to many people. This was illustrated in three steps, where infections increased exponentially, from

seven to 49 to 343. The final screen showed that 4.5% of those infected could have "statistically have long, lasting effects from the virus." This is 15 people out of the 343 overall amount of infected people. To add credibility and trust to the visualization, we referenced the source of the 4.5% statistic in the narrative visualization [62]. The 4.5% long COVID statistic is a direct finding of a large UK-based study [62]. It is, however, representative of one study only, and statistics regarding long COVID may vary. To maintain consistency between conditions, the narrative visualizations presented in conditions two, three and four had the same title and structure as the first condition.

The second condition contained the anthropomorphism communication strategy. To apply this strategy, images of young adults replaced dots and were given generic, culturally appropriate names, e.g. Peter. The images featured were bought from iStock photo and copyright provided [66]. All images were converted to greyscale to diminish the affective response from certain colors that were not in our chosen color palette. Considerations were taken to present images of young adults who were familiar with the target demographic located in the UK. In the final screen of this condition, the dots were replaced by a photograph of a woman who was described as the mother of one of the portrayed characters.

The third condition contained the personal identification communication strategy. After the initial title screen, the user was asked to input three names of their friends. We clearly stated that the names of their friends would not be stored, and privacy concerns availed. The inputted names of their three friends would appear throughout the text of the narrative, including the final screen. In the final screen, the text integrated the name of one of their friends' names stating it could be this friend's mother who may be at risk of long COVID.

The fourth condition contained both anthropomorphism and identification strategies. Similar to condition three, the user was requested to input three friends' names. In addition, they needed to select images of their friends to correspond with their names. This final screen used one of the selected friend images and stated that it was their mother who was infected with long COVID. See Figure 1 for a diagram of narrative visualization conditions.

4 Research Method

We conducted a crowd-sourcing platform study to test which communication strategy was most effective at nudging an audience. Please refer to the supplemental material[1] for raw data and narrative visualization source code.

4.1 Experiment Design

In our study, we employed direct attitude measurement to measure the effectiveness of a nudge. While other forms of measuring affect on audiences, such as persuasiveness, could be used, we selected direct attitude measurement because it has a singular pursuit of measuring audience attitude [67]. This paper defines attitude as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor [68]." Direct attitude measurement asks participants explicitly about their attitude toward a topic and has been widely used in psychology and the behavioral sciences [69]. This approach does, however, have several limitations. For example, participants might not have formed an attitude toward a topic and could potentially respond using random selections; this is known as random response bias [70]. Another concern is the possibility of impression management, where a participant misrepresents their

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[1] https://osf.io/fykwv/?view_only=465f6221b5c04fbdb964b3425b04098d

attitude to appear favorable to the researcher [69]. To address the former limitation, we have used a universally known topic. To address the latter, we have implemented an anonymous survey.

Multiple models of attitude have been proposed; some examples include the Vector Model, the Cognitive-Affective-Conative Model and the ABC model [71-73]. Generally, all these models have similar components. The most influential of these models is the ABC model [68]. This model has three components: the affective component, the behavioral component, and the cognitive component. The affective component is the emotional response of the participant. The behavioral component consists of actions or observable responses regarding a topic. Finally, the cognitive component refers to a participant's thoughts and beliefs about a topic. All components collectively form an individual's attitude, and therefore, we added them together to measure an overall attitude toward a topic [68].

In our survey, we ask Likert scale questions corresponding to each ABC component to calculate an overall attitude score. We score responses from strongly disagree (+6) to strongly agree (+12). Recoded for ease in interpretation to strongly disagree (+1) to strongly agree (+7). To measure the effect of the narrative visualization, we compare the participant's attitude scores pre-stimulus and post-stimulus. The difference between the pre-stimulus attitude score and the post-stimulus attitude score determined the success of the nudge. It was deemed effective if it was statistically significant compared to the other experiment conditions.

The purpose of the intervention was to nudge participants using the *availability* heuristic [7]. Here, people assess the likelihood of risk by asking how readily examples come to mind. Using this premise, we presented an example of COVID-19 spread to remind participants by reinforcing their beliefs and improving their accurate probability judgment. It is therefore required that participants have prior knowledge of the topic, so that they can be reminded of the topic. To investigate prior knowledge, we asked three questions. Prior knowledge is an important factor in attitude formation. Earlier research has shown that it is not possible to completely change the attitude of participants when they are presented with narrative visualization, particularly when it is a strongly held belief [3, 50]. We desired that participants did not have a strongly held *negative* attitude toward the topic, where a slight positive attitude shift would be unlikely. Furthermore, by analyzing prior knowledge, we are able to clarify whether participants have yet formed an attitude on the topic. We deliberately chose a well-known topic; however, the threat of random response bias remained [70].

4.2 Survey Design

Our survey instrument was iteratively developed. The interdisciplinary research team had multiple discussions, which resulted in three major iterations. Our primary goal was to develop a comprehensive survey instrument to evaluate audience attitude accurately. We further refined our survey by seeking feedback from external sources. At the conception stage, our study was presented at an academic symposium where we asked students in the target demographic for feedback on the survey questions, experiment conditions and research method. In accordance with their feedback, we enhanced the experiment conditions by re-wording questions. The next step was a small series of end-user tests following the think-aloud protocol, where users spoke aloud about their experience while using the survey instrument. Finally, we ran a pilot on the Prolific crowd-sourcing platform to determine technical soundness [74]. For the pilot, we allocated 10 participants per condition. Ethics approval was received from our organization.
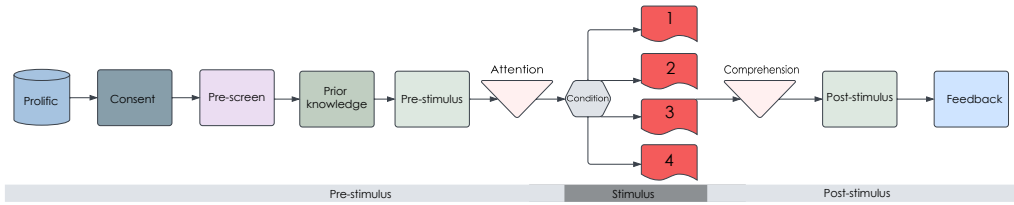
Fig. 2. Study procedure: Prolific platform; consent form; pre-screen question; prior knowledge questions; pre-stimulus attitude questions; attention check, narrative visualization conditions 1,2,3,4; comprehension check; post-stimulus attitude questions and feedback question.

4.3 Experiment Procedure

Our experiment procedure consisted of three phases (see Figure 2): pre-stimulus, stimulus, and post-stimulus.

4.3.1 Pre-stimulus. The participants were directed from the crowd-sourcing platform (Prolific) to the survey platform [74]. They were then asked to consent to the experiment and were validated using a pre-screener demographic question. This question verified that the participant was 18-25 years old. Then, they were presented with three prior knowledge Likert scale questions. These questions ascertained the prior knowledge and beliefs of the participants. These questions were as follows: *Do you believe that wearing a mask is an effective component of curbing the spread of COVID-19? Do you believe that COVID-19 is spreading quickly in the community? Do you agree that it should be the choice of the individual to wear a mask?* We could calculate an overall prior knowledge score by adding these Likert scale questions together. This prior knowledge score is a co-variate required for our statistical analysis. We then asked three pre-stimulus attitude questions. These questions correspond to the three components of attitude: affect, behavior and cognition (ABC). These questions were all on a Likert scale varying from strongly agree to strongly disagree. We calculate their pre-stimulus attitude score by adding affective question + behavioral question + cognitive question. Our ABC questions were as follows: Affective - *Do you feel it is your civic duty to wear a mask?* Cognitive - *Do you believe that long COVID is a serious risk to people in your community?* Behavioral - *How likely are you to wear a mask in a public place such as a shopping center?* Before viewing the stimulus, participants were asked an attention check question. The participants that answered the consent form in the negative, failed the demographic question, attention check question or let the survey time-out were deemed invalid, and replacement participants were found.

4.3.2 Stimulus. Participants were randomly assigned one of four narrative visualization conditions. The narrative visualization was embedded into the Qualtrics survey platform using an iFrame. The narrative visualizations were hosted on an external server using jQuery JavaScript framework to achieve the functionality of communication strategy.

4.3.3 Post-stimulus. We asked a comprehension check question directly after the stimulus to verify if the participant had comprehended the narrative visualization. From the above data story, what is the percentage of infected people that will have long-lasting effects from the virus? The participant was then asked the same attitude questions as pre-stimulus. The sum of these Likert scale questions determined our post-stimulus attitude score. The final question was a qualitative feedback question.

4.5 Participants

We recruited 271 participants for each condition through a reputable UK-based crowd-sourcing platform, Prolific [74]. Using Prolific's pre-screening tool, we constrained the participation of young adults between the ages of 18 and 25 who were in the UK. Using Prolific's study distribution tool, we randomly allocated a balanced gender sample to each condition. This meant that the platform allocated an equal number of males and females to each condition. Our participant sample size resulted from a power calculation with a goal of a 90% confidence level and a 5% margin of error. The population was calculated based on the young adult population size in the UK in 2021 (4.9 million [75]). Our ideal sample size was calculated at approximately 271 participants per condition; therefore, with four conditions, our total ideal sample size approximated to 1084 participants.

5 Research Results: Quantitative Analysis

We first introduce our hypotheses. Then, we present a comparative analysis of the communication strategies and an analysis of the attitude shift per condition.

5.1 Hypotheses

We expected to observe differences between the four conditions with respect to attitudes toward mask-wearing. Specifically, our hypotheses were as follows:

H0 There is no association between narrative visualization that integrates a communication strategy and attitude change.

H1 Narrative visualization with anthropomorphized data will have a higher positive attitude change in participants toward mask-wearing in young adults compared to a narrative visualization without anthropomorphized data.

H2 Narrative visualization that integrates personal identification will have a higher positive attitude change in participants toward mask-wearing in young adults compared to a narrative visualization without personal identification.

H3 Narrative visualization that integrates personal identification and anthropomorphized data will have a higher positive attitude change in participants toward mask-wearing in young adults compared to a narrative visualization without combined communication strategies applied.
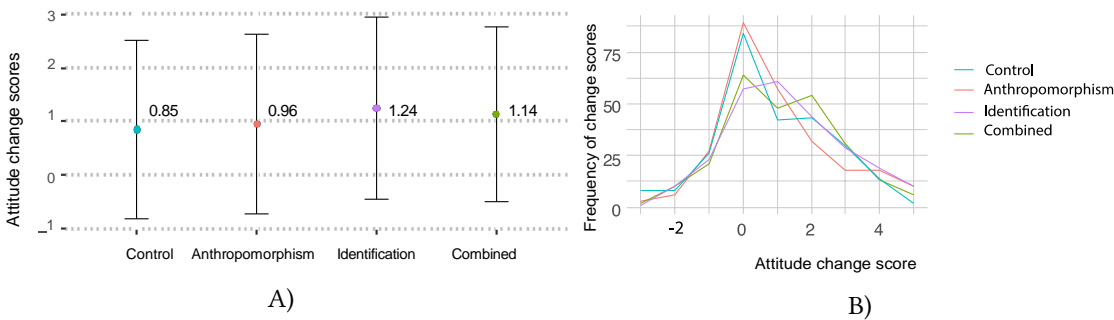

Fig. 3. A) Means comparison of attitude change scores standard with error bars, B) Frequency of attitude change difference per condition

5.2   Analysis of communication strategies

Of the 1084 participants (271 per condition), 18 failed the comprehension check. Our total number of valid participants equaled 1066. To investigate which experiment condition had the greatest effect, our dependent variable needed to be the attitude difference score. This was calculated by subtracting the post-stimulus attitude score from the pre-stimulus attitude score. We identified outliers in the attitude difference score data using the inter-quartile range rule. This procedure normalized the data so that the attitude score scale was between a minimum of -3 and a maximum of 5. After this procedure, a Gaussian-like distribution was achieved in our attitude score data, which was assessed for near homoscedasticity. The number of participants after removing outliers was 1021.

To investigate if there was a statistically significant difference between groups, we performed a one-way between-groups analysis of variance (ANOVA). The result showed statistical significance with a confidence level of 95%, $F(3,1017)=2.91$, $p=0.03$. Post hoc analysis using Tukey's adjusted post hoc test for multiple comparisons found that the mean value of attitude change score was significantly higher for *personal identification* compared to *control* ($p = 0.03$, 95% C.I. = [-0.77, -0.02]). Other comparisons did not show statistically significant differences in mean attitude change scores. **H2** is therefore affirmed due to the significantly higher positive attitude change score compared to the *control* condition.

We found that participants' prior knowledge was present and leaned toward a favorable agreement with the narrative visualization's data. The mean of the combined prior knowledge score was 14.80, with a standard deviation of 2.12. When noting that the median was 15, the mean displayed a positive tendency. To factor prior knowledge as a co-variate, we ran a one-way analysis of covariance (ANCOVA). The result suggests a similar effect even when controlling for prior knowledge, $F(3,1016) = 3.03$, $p < 0.02$. The impact of the prior knowledge on results using Cohen's d effect size guidelines is small $\eta2 =.00$. We can, therefore, conclude that prior knowledge does not significantly influence the effect of the intervention.

Figure 3:A shows the mean of attitude change per condition. The mean of the *anthropomorphism* condition (m=.96) is only slightly higher than the mean of the *control* condition (m=.85), and the difference is not statistically significant (p=0.87). This suggests that narrative visualization with anthropomorphism applied is not observably more effective in changing attitudes compared with a narrative visualization that has no communication strategy applied. Therefore, the experiment results do not support **H1**.

The mean of the *combined* condition (m=1.14) is lower than the *personal identification* condition (m=1.24). The attitude change score is not significant between the *control* condition and the *combined* condition (p=0.19). We cannot support **H3** where the *combined* communication strategies of anthropomorphism and personal identification do not significantly increase positive attitude scores relative to individually applied strategies.

5.3   Analysis of Attitude Shift

Figure 3:B illustrates the frequency at which different attitude change scores appeared per condition. We can observe that most participants (294 or 28%) did not alter their attitude, resulting in 0 for their attitude change score. The *personal identification* condition positively altered 163 participants' attitudes by 1 or greater, where 61 participants had a +1 attitude change score. In comparison the *control* condition positively altered the attitude of 131 participants, *anthropomorphism* 135, and *combined* 152.
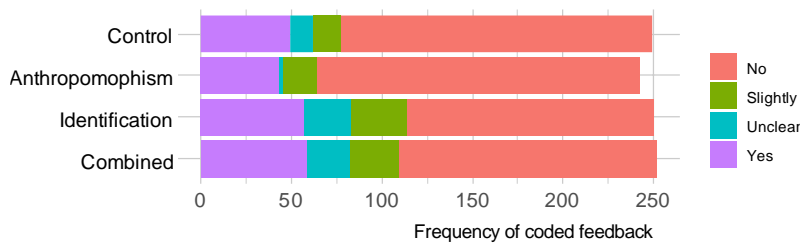
Fig. 4. Stacked bar chart showing the frequency of each feedback coded as yes, no, slightly or unclear, per condition

6 Research Results: Qualitative Analysis of Audience Feedback

We asked participants *has your opinion on mask wearing changed after viewing the data story? Why or why not?* Responding to the question was not mandatory; from the 1066 participants who answered the survey without failing the comprehension check, 993 wrote a feedback response. Our goal was to shed light on the cognitive or affective processes that participants drew upon when interacting with each narrative visualization condition. To qualitatively analyze our data, we adopted a top-down priori approach and an inductive theming approach [76]. We determined upper-level over-arching categories for each response, then inductively coded lower-level themes. Two coders independently coded responses, and any inconsistencies were discussed. Firstly, we coded each response as either yes, no, slightly or unrelated. From the 993 responses, 630 said no, their opinion had not changed. 207 responses said their opinion had changed. 91 reported that their opinion had changed slightly, and a further 65 gave feedback that did not clearly answer the question.

6.1 Positive opinion change

Of the 207 participants who indicated their opinion had positively changed, most were from *personal identification* and *combined* conditions. This is in line with the attitude score analysis in the quantitative analysis section. See Figure 4 for a chart illustrating each feedback response sentiment per condition. We investigated the reasoning for their positive opinion change. Through iterative analysis, two primary reasons emerged: persuaded by evidence and an empathetic response. These reasons were not always clearly delineated, as often the evidence inspired an empathetic response. Therefore, we grouped feedback responses on whether they largely mentioned the data or focused on their personal response to it.

Participants highlighted how the data visualized in the narrative visualization persuaded their opinion. Whether abstract data is presented as a dot or an image of a person did not seem to influence the participants greatly. Some feedback responses did, however, highlight how data visualization can change attitudes through visually presenting data. "The information provided is much more powerful as it is presented visually with dots as a data story, rather than just paragraphs of information."

91 of the 207 participants directly indicated their opinion had changed due to increased empathy (44%). This was encouraging as increased empathy was ultimately the principal aim of the narrative visualization. The sentiment was exemplified in this response, "it has changed because I don't want to infect anyone's parents so I will keep others in mind and wear masks more often indoors more after reading this."

A clear feedback response referring directly to the *personal identification* communication strategy was apparent 22 times compared to the *anthropomorphism,* which was referred to 4 times.

One example where *anthropomorphism* was acknowledged was when a participant referred to the character's name that appeared in the narrative visualization. This could indicate an affiliation with the story portrayed; "Knowing Dani's mum caught the virus due to incompetent behavior is unforgiving in her late age." The lack of feedback referring to the *anthropomorphism* communication strategy is in line with our findings in quantitative analysis section, where it was not as impactful as the *personal identification* communication strategy. Participants in the *personal identification* condition described how they established an emotional connection with the narrative using the names of friends who were close to them. For example, "the data was revealing, and the connection to my friend's life made it relatable."

6.2   Negative or negligible opinion change

We investigated the reasons why participants indicated they did not change their opinion. The most frequently mentioned reason for the lack of opinion change was that the participant was already aware of the data presented. Prior knowledge accounted for 288 of 630 (44%) of participants, indicating they did not change their opinion in the qualitative feedback question. For example, "No, I was already taking my precautions and the story validated my decision to wear masks in public."

In the analysis of feedback responses we found instances of reactance, for example; "I don't like the guilt tripping, I feel like I would be less likely to wear a mask." We expected to observe these phenomena, and evidence from our data suggests it is rare [48]. We found 11 instances that suggested reactance from 993 responses (1%).

7   Summary of Results

The data suggested that *personal identification* interactively integrated into narrative visualization, was the most effective strategy to nudge a young adult audience compared to other communication strategies. The significant difference we observed was between the *control* condition and the condition that had the *personal identification* communication strategy applied (p = 0.03). All other condition pairs were not significant.

We measured prior knowledge to ensure that the participants were aware of the topic and did not hold strong negative beliefs regarding the topic. We found that prior knowledge was present, leaned toward a positive perception of mask-wearing and did not influence the effect of the applied intervention. We analyzed the frequency of attitude change scores; most participants did not change their attitude. We observed that the *personal identification* communication strategy increased the attitude of the largest number of participants, where 165 of the participants indicated a positive increase in attitude score. Our qualitative data analysis investigated the reasoning behind the quantitative results. The qualitative data analysis suggested that the *personal identification* communication strategy resulted in an affective, empathetic response from participants.

8   Discussion

In this section, we provide recommendations on communication strategy integration based on our study. We then discuss the ethical ramifications of nudging with narrative visualization and the phenomena of reactance.

8.1 Recommendations for communication strategy integration

Personal identification is the key to reaching a young adult audience. In the *personal identification* communication strategy, we asked young adults to identify data points using the names of their friends. The names of their friends then appeared throughout the narrative, placing the participant within the narrative. We hypothesized that young adults would be influenced by their altruistic motivations to protect their community, where an affective, empathetic response would be evoked through a deliberate process of role enactment. The qualitative data suggested that, in many instances, this was the case. For example, "I felt that using my friends names worked better, especially as the 'mum' was a parent who has just been diagnosed with a health issue."

Other less contentious topics would result in different attitudinal change outcomes. Nevertheless, based on our results, our study joins the growing set of studies that found role enactment results in an affective, albeit small audience response [16, 17]. However, the size of differences should be put in their context. Attitudes towards COVID-19 are often politicized and are, at times, strongly held. Consequently, it is unlikely to observe large effects on these strongly held attitudes and small but notable effects, in this context, might be more important than they look. If an author decides to use *personal identification* integrated into narrative visualization as a manipulative tool, it necessitates increased responsibility. Authors must be cognizant of the effects their design choices may have. Our results highlight how narrative visualization authors could use the *personal identification* communication strategy to encourage prosocial decision-making, specifically in a young adult audience.

Switching abstract data with relatable imagery is not effective for nudging. Young adults did not change their attitude significantly when we applied the *anthropomorphism* communication strategy relative to other conditions. We hypothesized that relatable imagery would result in a different outcome compared to an earlier study that showed anthropomorphism to have little effect [15]. The qualitative data analysis indicated that anthropomorphic graphics were rarely mentioned. This suggests that switching abstract data with imagery, even when the imagery reflects the audience, does not influence a narrative visualization's persuasiveness greatly. We suspect more complex communication strategies are better suited to a young adult audience. *Anthropomorphism* is an example of a communication strategy that is not adequately responsive to a young adult audience.

Combining communication strategies leads to complexity and less effective messaging: One potential theory, why the *combined* condition was less successful at nudging an audience could be that too many communication strategies result in an opaque message. This is in line with previous research where the cost of increased interactivity distracts the user from message comprehension [36]. When delivering a nudge, particularly when it is concerned with provocative topics such as mask-wearing, we recommend an approach that is explicit in its intentions. If intent is opaque, a narrative visualization is received with greater skepticism. This was exemplified by one participant's feedback who received the *combined* condition; "this just felt like more propaganda."

8.2 Reactance and ethics of nudging

Health communication can result in two different attitudinal outcomes: (a) agreement with the message's recommendations evidenced by a positive response, or (b) rejection of the message demonstrated by defensive reactance and denial. Our study found evidence of reactance where participants felt that the narrative visualization had manipulated them. This is not the desired

response from the narrative visualization, especially when participants stated they were less likely to wear a mask after viewing it.

No reactance was reported for 99% of those who participated in our study. Rather, participants indicated they were reminded of their prior knowledge. They mentioned that the evidence influenced their opinion and increased their empathetic response. Despite these seemingly desirable outcomes, they do have adverse implications. An audience's inherent trust in visualized data means falsified data might have a similar result if communicated using similar communication strategies [47]. In a study on anti-science and anti-mask COVID-19 visualizations, it was observed that conventional data visualization techniques were often implemented [77]. These so-called 'counter-visualizations' used data visualization to manipulate their audience to believe an antagonistic message to government health orders. 'Counter-visualizations' were, in some cases, quite successful at gaining traction with audiences [77]. The motivation for a nudge should be based on empirical research and expert opinion [47]. Otherwise, outcomes may not be effective or even may be harmful, as they are not built on a firm, scientific evidence base. Nudging an audience's attitude could potentially be a powerful mechanism, especially in a democratic society, and we hope that our findings are implemented ethically in the future.

9   Limitations and Future Work

Our study was limited to four experiment conditions. Each condition could be deemed not entirely orthogonal with the other conditions. This is a notorious challenge for research in visualization evaluation, where modality and messaging must vary between conditions, however, only to the extent that can be quantifiably measured. Our aim in the experiment conditions was to make each condition with as limited variation as possible. To diminish differences between experiment conditions, we deliberately did not use color photographs in the anthropomorphic conditions. The reasoning for this was to reduce affective color responses [65]. To alleviate the dilemma of photographs of hypothetical friends not representative of the participant's actual friends, we chose a representative group of images that varied between examples. It was beyond the scope of this study to ask participants to upload images of their actual friends; however, it might prove to be an interesting avenue for future research. The crowd-sourcing platform assigns participants randomly to each condition. For this reason, some conditions were assigned to participants who generally were more positive toward wearing masks before viewing the stimulus. This may have impacted our results. It should be noted that no one condition's pre-stimulus responses or prior knowledge responses indicated significant differences in attitude toward mask-wearing between groups.

A common problem for evaluation studies is the dichotomy of generalizability and localization. Our chosen topic is taboo; however, this is similar to other studies on narrative visualization that have employed controversial topics such as immigration or the opioid drug epidemic in the US [3, 4]. We desired to find a topic where the participants would have preconceived notions. Nudging an attitude requires that the participants have formed an attitude to the topic prior to the experiment. At the time of the experiment in September 2022, the topic of mask-wearing and COVID-19 resonated with those on the research team, particularly those who are epidemiologically qualified. While there are many topics, this particular one was where we had the expertise and motivation to focus on as our selected case study. Future work could explore different topics, specifically ones that are not politicized.

Other demographics outside our target of young adults may benefit from the communication strategies we presented. We deemed the two chosen communication strategies most suitable for

speaking to a young adult audience to encourage greater consideration in the COVID-19 pandemic. The necessity to limit the scope of the study dictated that we focus on one demographic. Similarly, we limited our study to participants from the UK. In the early stages of this study, we investigated other nationalities. However, it was beyond the scope of this study to investigate multiple nationalities equally. To encourage forthcoming research, we have freely shared the raw code from our experiment conditions so that it can be adapted for other audiences.

10   Conclusion

We have presented an empirical experiment investigating whether targeted communication strategies integrated into narrative visualization can nudge a young adult audience. Our chosen topic was the spread of COVID-19. This topic has the advantage of being timely and well-known to all participants. We limited our study to a young adult demographic, as they have the lowest propensity to follow COVID-19 health orders. Our aim was to apply a nudge using the availability heuristic, where we presented an example of risk to remind participants of the risk [7]. We compared four different experiment conditions. We found that interactively integrating personal identification was the most effective at nudging a young adult audience. This is because it induces an affective response in a young adult audience. These findings could be implemented with other messaging and have the potential to be quite a powerful mechanism. Even a small attitude shift could potentially translate to meaningful outcomes if extrapolated to the population level.

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