Trust and Recall of Information across Varying Degrees of Title-Visualization Misalignment

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ABSTRACT

Visualizations are emerging as a means of spreading digital misinformation. Prior work has shown that visualization interpretation can be manipulated through slanted titles that favor only one side of the visual story, yet people still think the visualization is impartial. In this work, we study whether such effects continue to exist when titles and visualizations exhibit greater degrees of misalignment: titles whose message differs from the visually cued message in the visualization, and titles whose message contradicts the visualization. We found that although titles with a contradictory slant triggered more people to identify bias compared to titles with a miscued slant, visualizations were persistently perceived as impartial by the majority. Further, people's recall of the visualization's message more frequently aligned with the titles than the visualization. Based on these results, we discuss the potential of leveraging textual components to detect and combat visual-based misinformation with text-based slants.

CCS CONCEPTS

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

KEYWORDS

Visualization title; confirmation bias; misinformation

1 INTRODUCTION

Although the public longs for unbiased news coverage of political issues, many people have expressed dissatisfaction with current news media delivery [22]. Journalists frequently use headlines to frame a controversial issue in a slanted manner, resulting in news bias [1]. For example, the same news story was titled as "Israeli police shoot man in east Jerusalem," "Jerusalem driver shot after ramming pedestrians: police," and "Jerusalem car 'attack' kills baby at rail station" in three different news sources [30]. With the major source of news consumption shifting from offline sources (e.g., television, newspapers) to online sources (e.g., online news sites, social media) [22], headlines are becoming more provocative and eye-catching, and misinformation is spreading faster [29, 35]. Clickbait headlines are one example of such eye grabbing headlines that are intentionally vague or involve hyperbolic qualifiers that diverge from the tone and sometimes the content of the corresponding article. Although clickbait headlines might indeed attract more viewers, they have been shown to decrease the perceived source credibility [16].
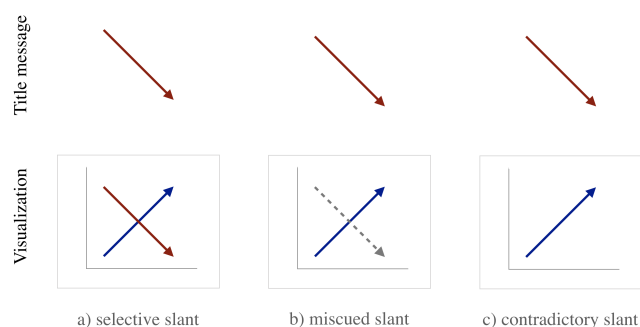

Figure 1: Three types of title slants that are misaligned with the message of the visualization in different degrees. The title emphasizes the decreasing trend while the visualization a) displays the two trends equally, b) visually cues the increasing trend, or c) only shows the increasing trend.

While people are cautious and skeptical of the messages in clickbait titles, a recent study by Kong et al. showed that people were less aware of the bias in the title of a data visualization and they remembered the biased title [17]. Many viewers trusted the overall message of the titled visualization. They believed data visualization is based on data and data is not biased. However, the biased title of these visualizations influenced people's recall of the message by emphasizing one aspect of the visualization [17]. Since a title could lead people to focus on and recall a specific part of the visualization, we asked – do people's perceptions of impartiality and the influence of the title persist when viewers see a greater degree of misalignment between the visualization and the title, for example, when the visualization and the title contradict each other?

In this paper, we extend Kong et al.'s work to examine the issues of trust and bias with different degrees of misalignment between a visualization and its title. We define three types of misaligned slants in visualization titles: selective slant, miscued slant, and contradictory slant (See Figure 1). A title with a selective slant only covers one side of the story while the visualization presents both sides equally (Figure 1a). This is the setup used in Kong et al.'s study. A title contains a *miscued slant* when the visualization emphasizes one side of the story through visual cues but the title's message addresses the other (less emphasized) side of the story (Figures 1b, 2a and 2c). In addition, we study titles with a *contradictory slant* where the information conveyed in the title is not presented at all in the visualization (Figures 1c, 2b, and 2d).

We wanted to study 1) whether people would notice the discrepancy between title and data visualization content if the message of the title blatantly misaligned with the message in the visualization, and 2) how the misaligned titles would affect how people recall and trust the information. In our study, we used three variables to measure trust: the perceived credibility, the perceived bias, and the appropriateness of the title. The perceived credibility of information is related to the perceived bias, but is also influenced by other factors such as accuracy, trustworthiness, and completeness of the information [21]. This research goal leads to the following research questions.

When viewing a visualization with a title that contains a miscued slant or a contradictory slant,

RQ1a) How does the message of the title influence people's recall of the information?

RQ1b) How does the degree of misalignment between title and visualization influence people's recall of the information?

RQ2a) How does the misalignment of the title and the visualization influence people's perception of bias?

RQ2b) How does people's perception of bias differ when the titles are consistent with their prior attitudes on a topic verses when the titles are inconsistent with their attitudes?

RQ3) How does the discrepancy between the message of the visualization and the message of the title affect the perceived credibility of the data, visualization, and title?

We replicated the study procedure from Kong et al.'s study and modified the visualization-title conditions to address these questions [17]. We found that the recalled messages were more frequently aligned with the title than with the visualizations in both the miscued and contradictory slant conditions. The majority of the people perceived the information as neutral (or unbiased) in both conditions as the visualization was showing data (i.e., statistics cannot be biased). We found that people were more likely to call the information biased and perceive the data, visualization, and title as less credible when they saw a title with a contradictory slant, compared to a title with a miscued slant. Based on the significant effect of titles on the recalled main message, the perceived bias, and the perceived credibility of the visualization, we call for further research on textual components of visualizations and conclude with a discussion on leveraging textual components to detect and combat visual-based misinformation involving text-based slants.

2 RELATED WORK

Digital Misinformation

With the popularity of information sharing on social network sites, several misleading news, including rumors on the Boston bombing suspects, have gone viral before being disconfirmed [29]. Research has shown that these misleading information often outpace the truth [35], which may have a detrimental influence on people's beliefs and attitudes. The growing number and influence of digital misinformation has led to research in various aspects of the subject including educating about misinformation [27], the role of journalists in spread and correction of online rumors [28], the detection of misinformation through headlines [3] and through collective attention patterns [23], and ways to debias through correction [19, 38]. However, existing work has mainly focused on text-based misinformation, and limited work has been done on visual-based misinformation. Extending the body of knowledge to visual-based misinformation is crucial as images and visualizations are more shareable and are actively being used as persuasive methods for misinformation [11].

Researchers have begun studying misinformation in images since they are prominent in the internet culture and are easy to manipulate [13]. Hemsley and Snyder began exploring misinformation through data visualization in their work "Dimensions of Visual Misinformation in the Emerging

Media Landscape" [14]. They define misinformation as "information that is 'objectively incorrect'" while emphasizing the difficulty in assessing misinformation in the space of visualizations. Even factually accurate information can mislead the public through statistical manipulations and carefully selected representations of the data [18]. In this paper, we use a more flexible definition of "misinformation" to include information that leads to misperceptions about the facts, regardless of the objective accuracy of the data. We focus on data visualizations in our work as Hemsley et al. did and cover two dimensions mentioned in their work: naive interpretation and the context of presentation. In our case, the interpretations are not naive due to the lack of training, but rather due to a heavy reliance on external sources (i.e. textual components) for interpretation.

Borkin et al.'s study on visualizations showed that people fixated heavily on the title of a visualization, and the descriptiveness of the title influenced the likelihood of recalling the main message correctly [2]. Kong et al. studied the influence of titles on the recall of the main message of a visualization and found that slanted titles could lead individuals to take away the exactly opposite message from the same visualization [17]. Their study involved two visualizations that presented data on the same topic from two perspectives (See Figure 2), and the visualizations were accompanied with one-sided titles that focused on only one perspective of the story. Their results showed that participants interpretation of the visualization generally aligned with the message of the title. Moreover, their results showed that the biased influence of slanted titles go by unnoticed, and people view a data visualization as neutral regardless of the slant of the title. These results are disquieting since, unlike clickbait titles where people are aware of its potential bias and are able to correct their misleading messages after reading the full article, slanted titles may have a lasting influence on people's recall of the information.

We build on Kong et al.'s study on visual misinformation by examining titles that explicitly misalign with the visualization. We consider the results from Kong et al. [17] as a baseline condition with the mildest slant, where very few people detected bias. By adding more extreme conditions, we hope to survey the extent of misinformation that is possible before viewers become aware of the bias in the information.

Confirmation Bias and Visualizations

Social cognition studies have shown that prior attitudes play an important role in information processing [6, 20, 24]. While researchers have explored various aspects of cognitive biases in visualizations including the anchoring effect [5], the attraction effect [7], and the four perspectives of bias [36], we focus on confirmation bias in this paper. Confirmation bias is "the seeking or interpreting of evidence in ways that are

partial to existing beliefs, expectations, or a hypothesis in hand" [24], and has been named as one of the key problematic aspect of human reasoning [10]. Nickerson's classical study on confirmation bias [24] showed that people give a preferential treatment of evidence supporting existing beliefs, look primarily for positive cases, underweigh negative disconfirmatory instances, and see in data the patterns for which they are looking regardless of the true patterns. All of these behaviors of confirmation bias are applicable for inferring data from a visualization and a title that show two sides of a controversial topic.

Confirmation bias can affect both the production and the consumption of data visualizations. Prior work showed that when people were asked to compose a neutral title for a visualization, some of the resulting titles contained slants that gave undue weight to the side that matched their beliefs [17]. This shows the potential influence of confirmation bias on the production of titles, which is problematic considering the rise of active sharing and consumption of news through social media where layman write titles and descriptions for a post. While Kong et al. searched for cognitive bias in interpreting visualizations with slanted titles, they did not find any influence of attitude on visualization interpretation and perception of bias in their work, mainly due to people's extensive trust in data visualization [17]. In our work, we investigate whether confirmation bias exists when people view visualization titles with a greater misalignment. We hypothesized that the conflicting messages between the title and the visualization will result in a confirmation bias as they give room for people to select the evidence that matches their current belief and dismiss the other as being biased.

3 METHOD

We closely followed the methodology previously used by Kong et al. in their second experiment [17] in order to compare our study results with their reported results. However, because their study focused on selective slants in titles while our study focuses on the miscued and contradictory slants in titles, we altered the visualizations in order to create the miscued slant condition and the contradictory slant condition. In this section, we describe the whole study procedure and the modifications to the original study in more detail.

Participants

We conducted the survey on Qualtrics and recruited 100 participants per condition. Through Qualtrics, we ensured that our participants were a representative sample of the U.S. population in age, gender, household income, education, and ethnicity. We had 45 males and 55 females in both conditions. The mean age of participants was 46 years (σ = 16.35) in the miscued condition and 48 years (σ = 15.82) in the contradictory condition. As we collected responses, we
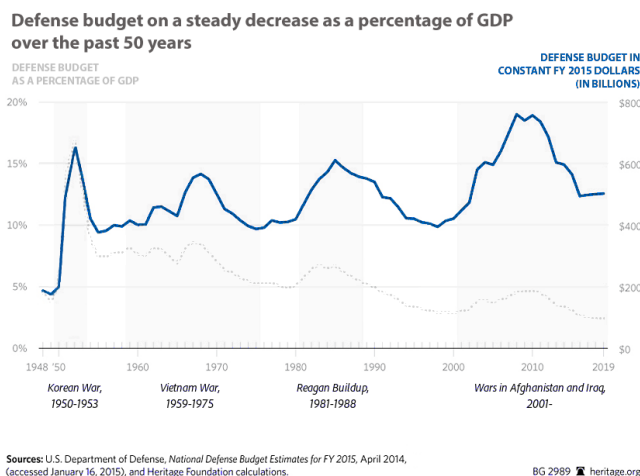
(a) Military visualization with a supporting title (miscued)
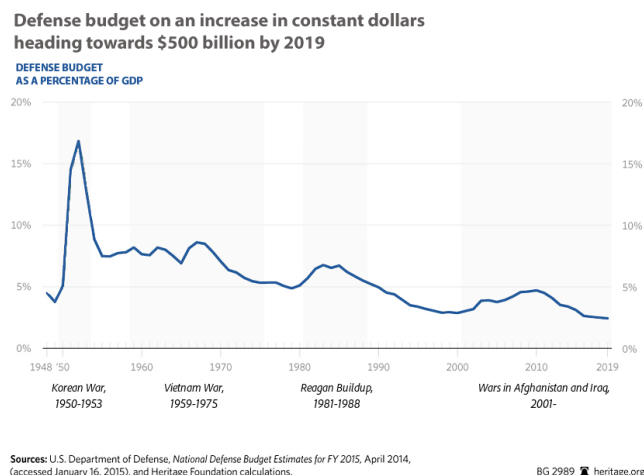
(b) Military visualization with a non-supporting title (contradictory)
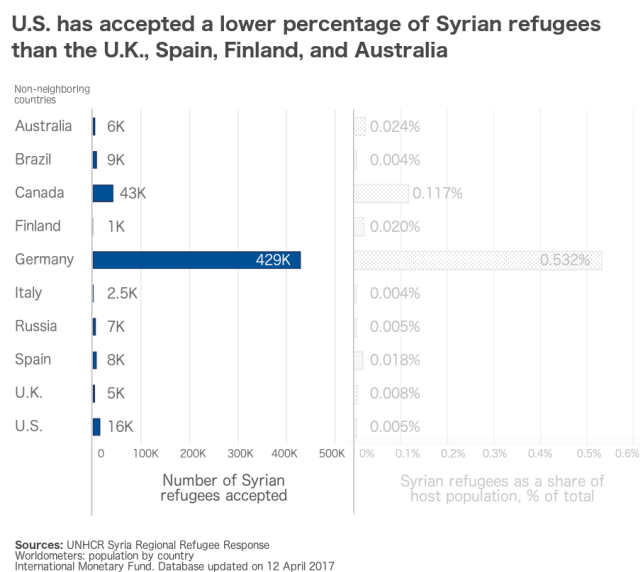
(c) Refugee visualization with a supporting title (miscued)
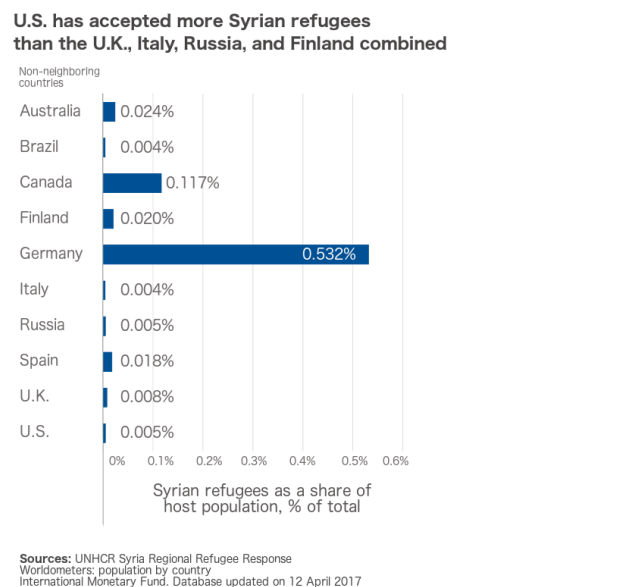
(d) Refugee visualization with a non-supporting title (contradictory)

Figure 2: The visualizations and titles in the study. The left side shows the visualizations in the miscued condition with supporting titles. The supporting sides are de-emphasized in the visualization as a light grey dotted line or dotted bars while the non-supporting sides are visually cued by a dark solid color. The right side shows the visualizations in the contradictory condition with non-supporting titles.

removed responses that failed an attention check question or contained gibberish texts. Each experiment took approximately 15 minutes, and the participants were paid $6 for their participation.

Degrees of Misalignment: Miscued and Contradictory

We used the same two visualizations as Kong et al. [17] – one on Syrian refugees accepted in non-neighboring countries and one on the U.S. military budget over the last 50 years (Figure 2). As stated in the introduction, we aimed to

study whether people would notice the discrepancy if the message of the title blatantly mismatched the cued message in the visualization (See Figure 1b and c). Thus, we modified each visualization so that the visualization and the title contained misaligned messages. These misaligned conditions were motivated by Ecker et al.'s work [9] that examined the misalignment of emphasis in headlines and a corresponding news article. The article contained two stances on an issue (the expert opinion and the general perception) while the headline emphasized the general perception. Eckert et al. considered this selective emphasis in the title as misleading since it was undermining information that deserved more emphasis, the expert opinion. We constructed the misaligned emphasis in the visualization setting through the miscued and contradictory slant conditions.

For the *miscued slant* condition, we visually cued the side on an issue that was not addressed in the title. For example, we visually cued the increasing trend of the military budget in constant dollars while the title highlighted the decreasing trend of the budget in terms of GDP (See Figure 2a). We created the contrast by desaturating and changing the fill to a dotted pattern for the uncued message to make the uncued visual content still visible, but not as prominent. In this manner, we established a mismatch between the message of the visualization and the message of the title.

The *contradictory slant* condition was more extreme in the disparity between the message in the visualization and title. We completely removed the side mentioned in the title from the visualization. Continuing the previous example, the title mentioned the decreasing trend of the budget in terms of GDP but only the increasing trend in constant dollars was visible in the visualization (See Figure 2). The mismatch was more subtle for the refugees example since it dealt with percentage and absolute number and did not involve increasing and decreasing lines, which are perceptually distinctive.

We originally designed the study with only the miscued slant condition. However, through our pilot study, we learned that most of the people were still not aware of the inconsistency between the chart and the title. We strengthened the visual cue by making the lines or bars a lighter shade, and added a severely misaligned condition where the title-matching content was removed all together. This study was between-subject as each participant was assigned to one of the two conditions. One participant saw two visualizations with slightly misaligned titles or two visualizations with severely misaligned titles. The order of the visualizations were randomized to prevent any ordering effect.

Each visualization had two potential titles, one supporting and one non-supporting title. A supporting title (e.g., "Defense budget on a steady decrease as a percentage of GDP over the past 50 years") supported the corresponding issue (e.g., "The United States should increase its military

budget to maintain its competitive advantage against countries like China and Russia."). See Figures 2a and 2c for more examples of a supporting titles and Figures 2b and 2d for non-supporting titles.

Study Procedures

Our study included six stages: 1) pre-experiment attitude and demographic surveys, 2) a preview of the visualizations and factual questions, 3) a recall question on the main message, 4) consistency and impartiality questions, 5) the title recall stage, and 6) the credibility stage. Stages 1 - 5 are replicates of Kong et al.'s procedure [17]. We added the credibility section to assess the perceived credibility of the data, visualization, and title. More specifically, we wanted to study whether the misalignment between the title and the visualization would affect the credibility of the visualization, title, both, or none.

Demographic and pre-experiment attitude surveys. Participants started the study by filling out a demographic survey where they indicated their gender, age, and education level. Next, they reported their attitudes on six controversial issues, two of which are visualization topics used in the study. We further asked how important the issue is to them. We changed one of the attitude survey questions in Kong et al.'s study [17], from "The United States should increase its military budget to fight ISIS." to "The United States should increase its military budget to maintain its competitive advantage against countries like China and Russia.", because the general public's perception on the Islamic State of Iraq and Syria (ISIS) had changed significantly since the time of their study. All the study materials can be found on the project website [1].

Misaligned title conditions. In total, there were eight possible visualization-title pairs – 2 visualizations (military, refugee) $\times$ 2 conditions (miscued, contradictory) $\times$ 2 titles (supporting, non-supporting). A hundred participants were in the miscued condition and a hundred in the contradictory condition. Each participant was randomly assigned to see two visualization-title pairs, one with an attitude-consistent title and the other with an attitude-inconsistent title. We used their attitude measured in the previous section to determine which title was attitude-consistent. For example, if the participant indicated that they support increasing the military budget, the supporting title was the attitude-consistent title. If they were neutral on the topic, we call both supporting and non-supporting titles attitude-irrelevant and randomly assigned one of the titles.

Recall, consistency, and perceived bias. After viewing a visualization, participants in the miscued condition answered three factual questions about the visualization that tested

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whether they could interpret both sides of the visualization correctly. Example questions for the military visualization are "What was the highest defense budget in constant dollars during the Vietnam War?" and "What is the estimated defense budget for 2019 as a percentage of GDP?" For the full list of factual questions, see the supplementary material. Participants in the contradictory condition answered two questions per visualization since the visualization only presented one side. We added factual questions to test the comprehension of the visualizations in the study and as a distractor task before the recall stage.

Then on the next page, the participants answered two open-ended questions where we asked them to recall the main message of the information provided on the topic, and anything else they learned in detail. The visualization was not visible during the recall section. This section also included post-experiment attitude questions, and an open-ended textfield where the participant indicated whether and why she was more/less likely to support the policy. The visualization reappeared on the next page, where the participant indicated whether the information was consistent with their beliefs and whether it was "Strongly biased," "Slightly biased," or "Neutral" and provided reasons for their answers. Then the visualization disappeared again, and the participants were asked to recall the titles for both visualizations.

According to the elaboration likelihood model (ELM) of persuasion [26], people sometimes form an opinion based on superficial elements of the message (i.e. the peripheral route) rather than a thoughtful consideration of the actual content (i.e. the central route). Pandy et al. [25] found persuasion through the peripheral route in the domain of visualizations where people rely on the *presence* of a data visualization as a measure of trust. As people are more likely to use the peripheral route if they lack motivation or the ability to process the message [26], we analyzed whether people's interest in the topic, visualization comprehension, or education level had an influence on their perception of bias.

Credibility Measurement. In the newly added stage, we reshowed the visualizations and asked about the credibility of the data, visualization, and title. We hypothesized that the conflicting messages might lower the credibility of the title, but the credibility of the data will remain the same. This is based on the results from Kong et al. [17] that people strongly trust data and statistical facts while some are aware of the potential bias in the title. We were especially interested in whether the perceived credibility of the visualization would align with that of data or title.

Credibility is typically measured as a multidimensional construct and different measures have been evaluated for their validity [12, 21, 37]. We chose the credibility measurement questions based on the Meyer modification of the

Gaziano-McGrath scales [12, 21]. This measurement has been used widely in many research studies including studies on online media credibility [33, 34]. Five factors are considered to measure credibility: accuracy, fairness, trustworthiness, bias, and completeness (i.e., telling the whole story). The section had a heading "Please indicated whether you agree or disagree with the following statements about the data presented above." followed by statements such as "The data is accurate."

We first measured the perceived credibility of the data, then of the visualization, and lastly of the title. For the bias factor, we used the negative form "biased" instead of "unbiased," which helped us determine whether a respondent was blindly choosing the same option for all the questions. We calculated the credibility score for each of the three components (i.e., data, visualization, and title) by taking the average of five credibility factor scores. We reverse coded the bias score for analysis (i.e., converted 1 to 7, 2 to 6, etc.) since the question was stated in the negative form.

After the credibility questions, we asked two questions on the appropriateness of the title, "Do you find the title appropriate for this visualization?" and "Write the most appropriate title for the visualization." We wanted to study whether the appropriateness of the title was directly correlated with the perception of bias, and whether it would influence the credibility of different components.

Analysis

To investigate whether the recalled messages aligned with the message of the title or the message of the visualization, two of the authors read over the results and established categories for the recalled messages. The same researchers categorized the reasons for bias to understand why people consider information in the study as impartial or biased. After coding the first twenty responses for each variable, they met to discuss the differences and coded another set of twenty responses. One response could contain several categories, and all of the categories had to match to count as an agreement. An interrater reliability analysis using the Kappa statistic was performed on the second set of codings to determine consistency among raters. After establishing a high reliability ($\kappa = .82$, $z = 38.3$, $p < .001$), one of the coders continued to code the rest of the responses. Two of the recalled messages were removed from the analysis because they covered the wrong visualization.

4 RESULTS

The general topic recalled more than specific messages in title and visualization

In the miscued condition, participants whose answers simply reflected the general topic (N=105; 53%) surpassed those

Table 1: The number of participants in the miscued slant and contradictory slant conditions who wrote the main messages in the recall phase that is neutral or align with the message in the title or the visualization.

Condition	Recalled main message alignment		
	Topic	Title	Visualization
Miscued	105	68	27
Contradictory	93	64	41

whose answers aligned with the material covered in the titles (N=68; 34%) and those whose answers aligned with the visually cued information (N=27; 14%) as shown in Table 1. This pattern of recalling the main message as the general topic (N=93; 47%) more than the title (N=64; 32%) and visualization (N=41; 21%) was also seen in the contradictory condition.

Titles influence recalled messages

RQ1a). How does the message of the title influence people's recall of the information?

We first introduce the major categories for the recalled messages, and explain how the distribution of the categories differed based on the slant of the title (supporting vs non-supporting) and between conditions (miscued vs contradictory). The major categories for the refugee visualization were *topic* (e.g., "It shows a graph of the syrians relocation all over the world"), *low* (e.g., "That U.S received less Syrian refugees than other countries"), *more* (e.g., "US has admitted more refugees than other countries"), *number* (e.g., "Displays number of refugees being accepted into various countries"), and *percentage* (e.g. "how much percentage of the syrian refugees did the countries accept"). The main categories for

Table 2: The recalled main message categories: the distribution of the categories differed based on the slant of the title.

	Title seen			
refugee categories	supporting		non-supporting	
low	40	33%	9	7%
topic	34	28%	49	37%
number	16	13%	23	17%
percentage	11	9%	10	7%
more	2	2%	25	19%
military categories	supporting		non-supporting	
topic	36	29%	31	28%
decrease	28	23%	22	20%
war	12	10%	3	3%
percentage	8	6%	11	10%
increase	5	4%	13	12%

the military visualization were *topic* (e.g. "it was about military spending over the years"), *increase* (e.g. "Our budget keeps getting high year after year"), *decrease* (e.g. "Our military budget has decreased over the years"), *percentage* (e.g. "steady rate of military spending as percentage of GDP"), and *war spikes* (e.g. "That the budget fluctuates up a great deal during wartime").

For people who saw the refugee title emphasizing that the U.S. has accepted a lower percentage of Syrian refugees (i.e. the supporting title), the top categories for the recalled messages were *low* (N=40; 33%), *topic* (N=34; 28%), and *number* (N=16; 13%) (Refer to Table 2). The category *low* is aligned with the message of the title seen, while *number* aligned with the message of the visualization since the visualization showed that the U.S. accepted more Syrian refugees than other countries in raw numbers. The top recalled message categories for people who saw the non-supporting title for refugees were *topic* (N=49; 37%), *more* (N=25; 19%), and *number* (N=23; 17%). The distribution of the top five categories differed significantly based on the slant of the title seen (χ^2 = 42.60, df = 4, p < 0.001).

The influence of titles on the recalled message was less dramatic for the military visualization although the distribution of the categories still differed significantly based on the message of the title (χ^2 = 10.07, df = 4, p = 0.039). People who saw the supporting title for the military visualization that emphasized the decrease of budget in terms of the GDP included the *topic* (N=36; 29%), *decrease* (N=28; 23%), and *war spikes* (N=12; 10%) in their recalled main messages. People who saw the non-supporting title included the *topic* (N=31; 28%), *decrease* (N=22; 20%), and *increase* (N=13; 12%).

Degree of misalignment influences recalled message

RQ1b). How does the degree of misalignment between title and visualization influence people's recall of the information?

Although people's recalled messages aligned the most frequently with topic, then the title, and less often with the visualization for both conditions, there was a significant difference between the two conditions in terms of the distribution of the main messages (χ^2 = 5.902, df = 2, p = 0.05) (See Table 1). People were more likely to refer to the general topic in the miscued condition while they were more likely to rely on the visualization for the contradictory condition. One possible explanation is that the simplicity of the visualization in the contradictory condition (Refer to Figure 1c) enables people to remember the information from the visualization better. On the other hand, people in the miscued condition still see the data associated with the title in the visualization and may have a more general understanding of the topic by balancing the messages of the visualization and the title.

(a) Miscued slant condition
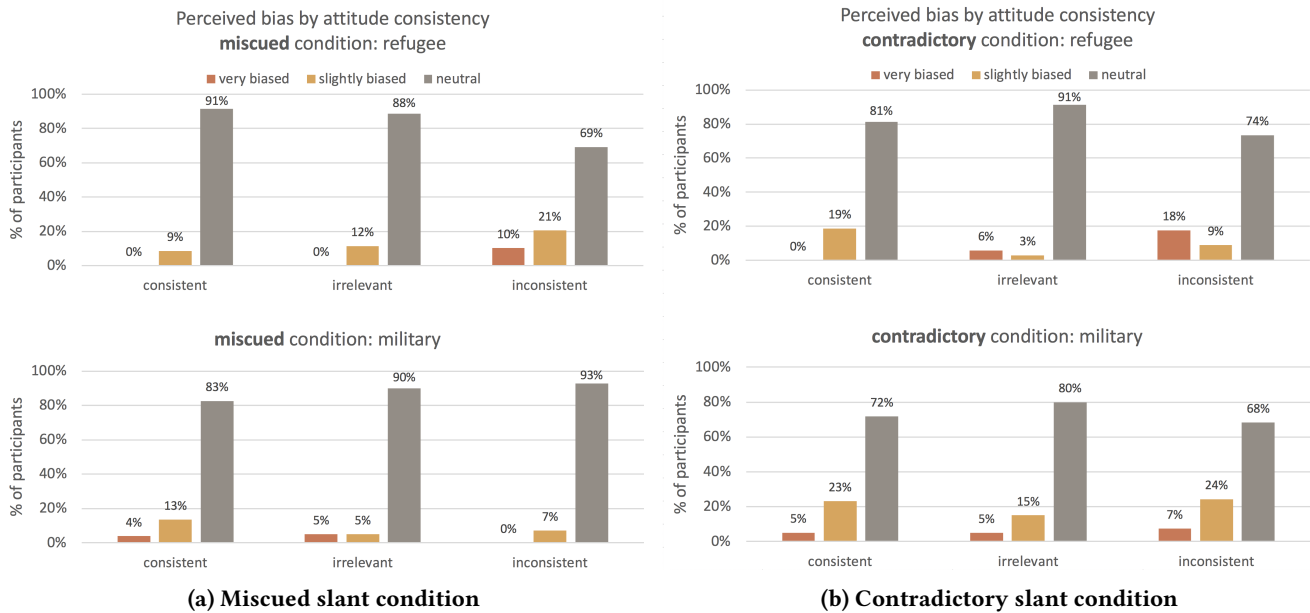

(b) Contradictory slant condition

Figure 3: The perceived bias by attitude-consistency for the two conditions. People were most aware of the bias for the military visualization in the contradictory condition.

Low awareness of bias despite misalignment

RQ2a) How does the misalignment of the title and the visualization influence people's perception of bias?

Despite the blatant slant in the title, the majority of the people (72-87%) in all conditions reported that the information was neutral. The rate was close to that in the original study (80-89%) showing that in general, the degree of misalignment does not influence on people's awareness of the bias in the information as much as we had expected. The main reasons for rating the information as impartial were that it was presenting *facts and statistics* (N=112; 23%), not having enough *prior knowledge* on the topic (N=42; 14%), and the *neutral* presentation of the material (N=28; 9%). An example for each category are "It just provides facts not an opinion" for *facts and statistics*, "I don't know anything about this topic. Any answer with the word bias would indicate knowledge. Therefore, neutral seems to be the better choice for me." for *prior knowledge*, and "It's not for or against its only information" for *neutral*. While most people reported the information as impartial, 28% of the people in the contradictory slant condition reported the military visualization as "very biased" (N=6) or "slightly biased" (N=22) which is significantly higher than the number of people in the miscued slant condition who stated the visualization was "very biased" (N=3) or "slightly biased" (N=10) (χ^2 = 6.915, df = 2, p = 0.03).

This increased awareness of bias in the contradictory condition was not shown for the refugee visualization. One of

the reasons for the difference in the results between the visualizations might be due to people's aptitude in perceiving the increasing or decreasing trend in a line chart compared to evaluating the sum of bars in a bar chart. All participants who found the military budget information "very biased" had seen the decreasing trend in the visualization, which is easier to discern in a chart than a fluctuating increase. Thus detecting a contrast between a title that states an increase in budget while seeing a decreasing trend might have been easier than checking whether the number of refugees in four different countries are in fact lower than the number of refugees in the U.S.

We also analyzed the effect of the participant's interest in the topic, visualization comprehension, or education level on the perception of bias. People got 74% of the questions correct on average (s.d. = 15%) in the miscued condition and 89% (s.d. = 18%) correct in the contradictory condition. Linear regression analysis was used to test if the importance of the issue to the participant, their comprehension scores, or education level significantly predicted participants' ratings of bias. The results of the regression for the refugee visualization indicated that *the importance of the issue* significantly predicted the perception of bias (F(1,198)=4.852, p = 0.03, R^2 = 0.024). None of the factors were predictive of the perceived bias for the military visualization.

Perceived credibility by visualization			
refugee	data	visualization	title
miscued	4.86	4.84	4.74
contradictory	4.31	4.19	4.02
military			
miscued	4.90	4.82	4.72
contradictory	4.36	4.29	3.99

Table 3: The perceived credibility of data, visualization, and title by visualization and conditions. The scale ranges from 1 (low credibility) to 7 (high credibility).

Attitude-consistency influences the perceived bias

2b) How is attitude-consistency of the title associated with perception of bias?

The perceived bias for refugee visualization was influenced more by the attitude-consistency of the title than its misalignment with the visualization. People were more likely to report the information as very biased or biased if the title was inconsistent with their belief than when it was consistent. Running a Chi-squared test on the attitude-consistency of the titles and the perceived bias showed a significant effect in both the miscued (χ^2 = 9.575, df = 4, p = 0.048) and contradictory (χ^2 = 11.546, df = 4, p = 0.021) conditions.

Perceived credibility varies for data, visualization & title

RQ3) How does the discrepancy between the message of the visualization and the message of the title affect the perceived credibility of the data, visualization, and title? How is attitude-consistency associated with perception of credibility?

We performed a two (conditions) × three (credibility scores) MANOVA on the data, visualization, and title credibility scores and found that the alignment of title and visualization has a significant impact on the credibility for both the refugees visualization (Wilks's lambda = 0.914, F(3,196) = 6.148, p < 0.001), and the military visualization (Wilks's lambda = 0.917, F(3,196) = 5.926, p < 0.001). The univariate ANOVA tables showed that there is a significant difference between the misalignment conditions for the credibility of each component (i.e. data, visualization, and title). Data, visualization, and title were all seen as less credible when there was a bigger visualization-title misalignment as shown in Table 3.

When examining the effect of attitude-consistency on the perceived credibility, we found that the credibility scores of all three components were lower when the title was attitude-inconsistent compared to when they were attitude-consistent or irrelevant (See Table 4). However, the effect of attitude-consistency on the perceived credibility was shown to be not statistically significant through running MANOVA. Although there was a bigger difference in credibility based on the attitude-consistency for the refugee visualization in both the miscued (Wilks's lambda = 0.896, F(6,190) = 1.78, p = 0.10) and contradictory conditions (Wilks's lambda = 0.910, F(6,190) = 1.52, p = 0.17), the differences were still not statistically significant.

To determine whether the perceived credibility differed for the three components, we conducted a repeated measures ANOVA with a Greenhouse-Geisser correction. The results showed that the credibility scores differed statistically significantly between data, visualization, and title for the refugee visualization (F(2, 398) = 12.742, p < 0.001) and the military visualization (F(2, 398) = 6.7, p = 0.0014). Overall, data was perceived as the most credible, followed by the visualization, then the title (See Figure 4). When the visualization-title misalignment increased, the credibility of the title suffered the most, with its credibility score decreasing by 0.72 for the refugee visualization and 0.73 for the military visualization. The title credibility score dropped 0.55 points for both visualizations, and the visualization credibility score dropped by 0.65 and 0.53 for the refugee visualization and the military visualization, respectively. After rating the credibility of each component, participants evaluated the appropriateness of the title. As each participant indicated the appropriateness of the refugee title *and* of the military title, there were 200 responses for each condition. In the miscued condition, 158 of the responses (79%) stated that the title is appropriate (Table 5). The number significantly decreased for the contradictory

Table 4: The perceived credibility of data, visualization, and title by condition and the attitude-consistency. The scale ranges from 1 (low credibility) to 7 (high credibility).

Perceived credibility by condition			
miscued	data	visualization	title
consistent	5.04	5.10	4.92
irrelevant	4.93	4.78	4.87
inconsistent	4.76	4.60	4.44
total	4.90	4.82	4.82
contradictory			
consistent	4.70	4.64	4.28
irrelevant	4.29	4.31	3.96
inconsistent	4.10	3.96	3.75
total	4.36	4.29	3.99

Perceived appropriateness of the title

(% of participants who found the title appropriate)

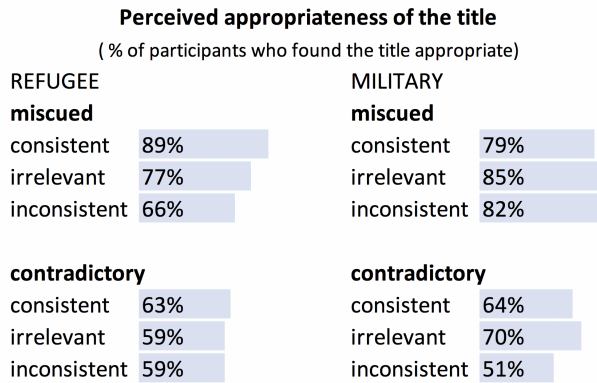| REFUGEE		MILITARY	
miscued		**miscued**	
consistent	89%	consistent	79%
irrelevant	77%	irrelevant	85%
inconsistent	66%	inconsistent	82%
contradictory		**contradictory**	
consistent	63%	consistent	64%
irrelevant	59%	irrelevant	70%
inconsistent	59%	inconsistent	51%

Table 5: The perceived appropriateness of the title: people were more likely to perceive the title as inappropriate if it contained a contradictory slant.

condition where 120 responses (60%) stated that they found the title appropriate (χ^2 = 17.03, df = 1, p < 0.001). Although people were more likely to consider a title as appropriate when it was consistent with their attitude than when it was inconsistent, the difference was not statistically significant (χ^2 = 4.1585, df = 2, p = 0.125).

5 DISCUSSION

In this section, we discuss how visualization titles influence trust and confirmation bias when people obtain information from visualizations. Then, we reevaluate the role of titles in visualization interpretation and discuss the potential of leveraging textual components to detect and combat visual-based misinformation with text-based slants.

Trust and Confirmation Bias

Prior research has shown mixed results on the effectiveness of visualizations on persuasiveness [8, 31]. While Tal and Wansink's results showed that even trivial graphs increased the persuasiveness of an advertisement [31], these results were not repeated in Dragicevic and Jansen's series of four replications, which showed a small effect of graphs in data comprehension but no effect on persuasion [8]. In regards to trust in the domain of data visualization, Hemsley wrote that "[t]he test of authenticity and legitimacy is often reduced to a question of aesthetics" [14]. Kong et al.'s experiment found that people trusted the data visualization to be neutral despite the slants in the visualization titles [17]. While their study examined the influence of the misalignment between people's attitude and the title on the perceived bias, we examined an extra factor – the misalignment between the visualization and the title. Although neither of these two factors were enough by themselves to break people's trust, the combination of visualization-title misalignment

and attitude-inconsistency made some people aware of the bias.

The perceived credibility of the information significantly decreased when the title was misaligned with the participant's existing attitudes in both the miscued and the contradictory conditions (Figure 4). Similarly, the perceived impartiality also decreased when the title was misaligned with the viewer's attitude in both conditions (See Figure 3). The influence of attitude-inconsistency of the title on people's trust is interesting for two reasons. First, it reveals a confirmation bias in interpreting and receiving information from visualizations. Second, it shows that people are more likely to dismiss information as less credible when the *title* is attitude-inconsistent than when the *visualization* is attitude-inconsistent. Since all the titles in our study were misaligned with the visualization, the participants saw either an attitude-inconsistent *title* or an attitude-inconsistent *visualization*. Thus, this decrease of the perceived credibility and impartiality of the information when the *title* was attitude-inconsistent occurred despite the fact that the visualization was attitude-consistent. In other words, the perception of trust seems to depend more on the content of the title than that of the visualization. One notable exception arose when a participant, who saw an attitude-consistent title that emphasized the increasing military budget matched with an attitude-inconsistent visualization that showed the decreasing trend, wrote that "[the graph] is trying to look like spending is going down by choosing a measure that will produce a trend line that decreases. It also shows a narrow range of values, 0-20%, to exaggerate the effect." By calling the attitude-inconsistent graph biased and supporting the message in the attitude-consistent title, this respondent shows how confirmation bias can lead some people to cherry pick the part of the visualization that matches their attitude when the visualization and title convey opposing messages.

People's trust and the impact of the title on the textual-visual story decrease overall when there is a great discrepancy between the title and the visualization. While 65% of the recalled main messages reflected the material covered in the titles with selective slants in Kong et al.'s study [17], our result shows the decreased influence of titles when they have a miscued (34%) or a contradictory slant (32%). However, the number of the recalled messages that aligned with the message of the titles (133 out of 398) was still greater than the number of messages that aligned with the message in the visualization (68 out of 398). This shows the powerful influence of titles on visualization interpretation. People also persisted to believe the information as neutral regardless of the misalignment between the title and the visualization while the credibility of the individual components of the visualization decreased with the increase in visualization-title

misalignment. Overall, our study results confirm our hypothesis that readers heavily rely on the title while obtaining information from data while they trust *data* visualization. So even when a textual component of a visualization is miscued or contradictory, it is likely that people will not call out a visualization as biased as long as the source and the presentation of the information are credible.

The role of text on visual-based misinformation

We re-examine the role of text in narrative visualizations. Hullman and Diakopoulos's work on visualization rhetoric introduce textual annotations as one of the four editorial layers [15]. Although previous research has shown the influence of titles on visualization interpretation [2, 17], the results were not as salient because the titles they studied were aligned with the visualization. Through studying titles whose messages differ from those of the visualization, we have found that the titles have a stronger manipulation effect than we might have supposed. Textual annotations are not mere sidekicks that assist data visualizations that convey information; they can be *the storyteller* with the visualization there to back up the credibility of its message.

In Hemsley and Snyder's [14] discussion on the spread of visual misinformation, they mention that users who share content "can alter the content in subtle and unsubtle ways such that they are coproducers of the meaning of the artifact for the next generation of audiences who encounter the visualization." One way of altering the meaning of the visualization is through including their own text with the repost to frame the artifact or prime the audience [32]. The result of this study implies that one could be as effective in transforming the message of the visualization by altering the text description as altering the visualization itself. Considering the amount of research on deceptive visualization and the rise of research in visual misinformation, we call for future research to explore the domain of textual components of visualizations given the significant effect of text on visualization interpretation and the prominence of sharing of visualizations on social media with alternative texts and framings.

Based on the persistent trust in the visualization title – even despite their misalignment with visualizations – and the presence of confirmation bias in our results, we discuss different ways social network platforms can detect and combat the spread of visual-based misinformation. First, using existing algorithms for clickbait titles and misleading headlines [3], the site can detect whether a visualization title or text description accompanying a visualization contains charged words. Based on the existing frames for visualization titles [17], researchers can apply natural language processing methods to identify potential signs of slants. Upon detection of bias, we suggest providing additional information to raise people's awareness rather than removing the original content as such censorship is intertwined with ethical issues. For example, a note could appear above the post to indicate potential bias or an alternative title can be presented along with the original title. Future work is needed to explore and evaluate other approaches to handling visualization posts with potential bias.

Other directions for future work include further investigating the effect of text by removing the contextual information of the data. As Boy et al.'s work found that removing extra contextual information and making the text drier affect people's empathy [4], it would be interesting if a similar effect would be seen in how people trust and recall text over visuals. Another research direction is unpacking *why* readers rely on the titles for retrieving the main messages. One potential explanation is that they see the title as providing an easy and reliable summary of the information as a person has already invested time in analyzing and interpreting the information for them while they see the graph as more neutral because it is generated by a computer.

6 LIMITATIONS

Although we closely replicated Kong et al.'s study [17], our results might not be directly comparable to theirs due to the time gap between the two studies. The climate of digital information on controversial issues has changed greatly over the last two years, and people have been more aware of potential bias in general during our study. The amount of engagement with the visualizations might have affected the results as well given the limited time and attention participants invested for the study. Also, since our study only involved two visualizations, the results may not generalize to other visualization types. Our results showed a difference in the influence of title attitude-consistency on the perceived bias for a line chart, where the trends are visually clear, and bar chart, where the trends are harder to observe visually. Future research should explore how the influence of textual components varies by chart types and the visual complexity. Lastly, we did not have a baseline condition where the title and the visualization were aligned. Thus we do not know what people recall as the main message of a visualization in a no-mismatch condition. Due to this lack of a baseline, we were unable to measure the exact impact of the visualization-title mismatch on people's recall of information.

7 ACKNOWLEDGEMENTS

8 CONCLUSION

In this study, we examined visualization titles with miscued slants and contradictory slants. We found that the titles influenced the recalled main messages despite their misalignment with the message of the visualization. Although people's perceived bias increased when there was a greater degree of misalignment, the majority of the people still viewed the information as impartial. Lastly, the perceived credibility of data, visualization, and the title was high for the miscued slant condition, but the credibility decreased for all three components when the visualization was paired with a title that contained a contradictory slant. Based on these results, we discussed the influence of visualization titles on trust and recall of information in visualizations, and conclude with suggestions on detecting and dealing with visual-based misinformation given the significant role of text in visualization interpretation.

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