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# The Axis of Misinformation: Evaluating the X axis and Y axis of Misinformative Graphs

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**Abstract**: *Misleading graphs spread misinformation under the guise of scientific legitimacy. While researchers have evaluated the importance of x axis and y axis truncation, there is currently limited research comparing properly scaled informative infographics and improperly scaled misinformative infographics. By comparing infographics that spread correct information and infographics that spread misinformation, we may better understand the presentation of x/y axis truncation to spread misinformation. Anti-vaccine graphic misinformation is a current and present health danger. While vaccines are safe and prevent the spread of disease, anti-vaccine rhetoric is effective at dissuading parents from vaccinating their children. Specifically, anti-vaccine organizations argue that vaccines recommended for children, such as the Measles, Mumps, and Rubella (MMR) vaccine, are directly dangerous. The use of misleading graphs further lends credibility to anti-vaccine beliefs. Understanding the use of a truncated x/y axis when spreading misinformation about vaccines allows information seekers to avoid misinformation.*

**Keywords**: misleading; infographics; anti-vaccine; health; belief; social;visual

## Introduction

Truncating the x axis and y axis ((x/y axis) of a graph is a common method of deception (Lo, 2022). While truncating the x or y axis of a graph may be used to make information more accessible or readable, malicious designers may use truncation to manipulate or deceive viewers (Correll, 2023). Often, graphic designers know that truncating x/y axes or changing the interval scales will result in confusion and misinformation (Few, 2004). As a result, malicious users truncate an x or y axis to spread misinformation. When malicious users spread misinformation about a controversial, commonly misunderstood topic, people may believe this misinformation, to their own detriment. Evaluating elements of an infographic that spreads information and comparing them to that of an infographic that spreads misinformation informs both designers and consumers. Although current academic and industry research has correctly identified x/y truncation, or the manipulation of the x or y axis of a graph, as a popular and effective form of misinformation, this research is still limited.

Vaccine misinformation is a current and present danger, in both visual and verbal form. Specifically, these messages may be spread in print, on websites and in social media (Burki, 2019). In the case of vaccinating children, someone who believes misinformation may delay or prevent their child from receiving beneficial vaccinations. For the purpose of this paper, I used the term childhood vaccines to represent vaccines that the Center for Disease Control (CDC) recommends for children at or under the age of 10 (Center for Disease Control, 2019; U.S. National Library of Medicine, 2020). These vaccines include the Mumps, Measles, and Rubella (MMR) vaccine, the chickenpox vaccine, the hepatitis A and B vaccine, the inactivated polio vaccine, the influenza vaccine, the tetanus, diphtheria and pertussis (tDap) vaccine and the Human Papillomavirus (HPV) vaccine. Childhood vaccines are safe and beneficial (Geoghegan, 2020). I chose to conduct a case study evaluating the graphic tools used to spread misinformation about childhood vaccines. I selected 40 information visualizations from a website that spread correct information about childhood vaccines and a website that spread misinformation about childhood vaccines. I found that misinformative infographics often used line graphs and bar charts to spread misinformation about the ingredients of vaccines. I also found that the main forms of x/y manipulation used were improper y axis, improper x axis.

## Literature review

The literature review section discusses current research on graph design, misinformative graph design, general misinformation about childhood vaccines and visual information and misinformation about childhood vaccines.

Truncation of an x axis or y axis is a useful means of making a graph more accessible. For example, truncating a y axis by not beginning at zero under certain circumstances is beneficial (Correll, 2023). In the context of discussing Covid-19 cases, a y axis that begins at year 0 would result in confusion. Franconeri et al (2021) discussed x and y axes, explaining that graph designers must consider the context of their data: when presenting temperature, an x axis or y axis should not end in 0, as temperature can be negative. Unfortunately, this truncation may also be performed to deceive.

When evaluating misinformative graph design, manipulation of the x/y axis is common. Lauer and O'Brien (October 2020) discussed deceptive tactics in graphs, identifying manipulation of the x/y axis as particularly concerning. They further conducted a study and found that distorted x/y axes resulted in participants misinterpreting the information (Lauer, December 2020). Pandey et al., (2015) explained that graphic designers may distort x/y axes by "changing the minimum and maximum values presented on the scale" (p. 1472). Fan et al., (2022) designed a tool meant to annotate a line chart: one of its features was to detect y-axis truncation and inversion. Camba et al., (2022) defined truncation of an axis as "starting the axis from a value that is not zero…a well-known deceptive practice for exaggerating differences" (p. 117). They further explained that this distortion is particularly dangerous, as most graphic designers are aware of its impact. Therefore, malicious designers understand the importance of distorting the axis to spread misinformation.

Skew in graphs contributes to the belief in and spread of visual misinformation. O'Sullivan et al., (2021) found that distorting x/y axes in graphs is an effective method of spreading misinformation. Yang et al., (2021) argues that when a graph's x/y axis is truncated, individuals are confused. Specifically, when presented with a graph that contained a truncated y-axis, participants "judged differences between bars to be substantially larger" (p. 301). They deemed this incorrect judgement the *truncation effect*. Lo et al., (2022) identified current misinformative visualizations, finding that truncated x/y axis was the most common method of visual misinformation. However, most studies disagree on the severity of truncating a graph's axis. For example, when evaluating the impact of a truncated axis, Driessen et al., (2022) found that truncating the y axis of a line chart had no effect on participants' understanding of the graph's contents. Conversely, when evaluating participant interaction with graphs that contained a truncated y-axis, Yang et al found that all participants thought that the differences between bars and values were larger than they were. Calzon (2021) explained that using a specific time period for an x axis may be a form of misinformation: trends look different when expressed over a month's time or expressed over a year's time. In these latter two examples, truncation of an axis resulted in information seekers' potential belief in incorrect information.

Researchers also discuss the importance of x/y axis manipulation and truncation. Specifically, x/y axis manipulation or truncation may result in an incorrect perception of data (McCready, 2023, Pollicy, 2020; Krystian, 2023; Kwapien, 2015). McCready et al., (2023) stated that using time as an x axis may show an improper relationship before two elements, or a year may be selected strategically (McCready, 2023). Conversely, Pollicy explained that only using one year rather than several may also spread misinformation (Pollicy, 2020). Time may not have an effect on an element. This connection is problematic, as it could result in an incorrect perception of cause and effect. Dual-axis manipulation is another major concern in graph manipulation (Krystian, 2023). Kwapien (2015) also explained that starting the x-axis or y-axis at a specific, irrelevant year or date may be an example of visual deception. While understanding the importance of the x/y axis is necessary, a case study may also provide more insight into its implementation.

Anti-vaccine misinformation is difficult to disprove. Lewandowsky et al., (2012) identified misinformation about vaccines as a health danger, stating that refusing a vaccine may cause personal and societal harm, as: "many parents decided not to immunize their children, which has had dire consequences for both individuals and societies, including a marked increase in vaccine-preventable disease and hence preventable hospitalizations, deaths" (p. 107). Geoghegan et al (2020) identified several reasons for vaccine hesitancy such as the presence of aluminum in vaccines, and the presence of chemicals such as mercury. They explained that safe low levels of aluminum are in vaccines, and the form of mercury in vaccines is safe. The presence of these chemicals has no associated risk of developing autism. Researchers and doctors often try to counteract misinformation by presenting facts about vaccines. Unfortunately, when presented with a booklet meant to present and debunk vaccine misinformation, participants believed the myths and vaccine misinformation (Pluviano, 2019). Krishna and Thompson (2021) found that the anti-vaccine movement is effective because the movement is supported by celebrities and anti-vaccine objections are diverse, including arguments about vaccine safety. They also stated that using humor may be beneficial when trying to convince people to vaccinate their children. Anti-vaccine messages are also spread on both websites and social media. Burki (2019) explained that "the advent of social media has offered an unprecedented opportunity to amplify and spread antivaccination messages" (p. 258). Furthermore, researchers disagree about the efficiency of visual information meant to communicate the benefits of vaccines. Pluviano et al (2017) explained that current strategies to spread vaccine information and dispel vaccine misinformation (including strategies that use images and photos) often result in reinforcement of vaccine misinformation. Ecker et al (2023) argued that presenting participants with correction of vaccine misinformation reduced their belief in the misinformation. Dixon et al (2015) found that images may help effectively communicate correct information about vaccines to people with both a scientific and non-scientific background. Conversely, Nyhan et al (2014) found that expressed belief in a disproved vaccine/autism link increased in parents presented with an image of a sick child. More research into visualization techniques for graphs that contain vaccine information and vaccine misinformation is necessary. The following questions were developed for this study:

1. How do the subjects and presentation of information visualizations and misinformation visualizations differ?
2. How do the x/y axes of informative visualizations and misinformative visualizations differ?
3. How prominent is the truncated x/y axis in graphs that contain misinformation about childhood vaccination?

## Methodology

Because information seekers often believe information from a source that they deem trustworthy, choosing a trustworthy website from which to obtain the graphs was essential. While social media is currently a major source of both vaccine information and vaccine misinformation, I decided to instead use graphs obtained from organization websites. I identified two websites for organizations that discussed childhood vaccination. One of the websites discussed information about childhood vaccines, while the other discussed misinformation about child vaccines. Both of these websites contain scientific names and cite doctors and researchers as authorities about their topic. Each of these websites use graphs as one of many methods to convey their messages. I also selected these websites because they predominantly displayed infographics. Other websites also considered did not use infographics as heavily as the two websites selected, utilizing videos or photographs instead. The organizations that sponsor these websites also have an active web presence, including Twitter handles. These websites are both highly regarded by each of their audiences.

I selected 20 informative infographics from the childhood vaccine information website and 20 misinformative infographics from the childhood misinformation website. I then evaluated the type of graph used, the subject of the graph, the subject of the x axis, the subject of the y axis, and, if present, the truncation element or misinformative design element.

**Results**

I found that the most popular graph types for both the informative graphs and misinformative graphs were a bar chart, which appeared 23 times, a line graph appeared 14 times, a bar chart with line, which appeared 1 time, a table, which appeared 1 time, and a stem and leaf plot, which appeared 1 time. I found that the most popular graph types for the informative graphs were a line graph, which appeared 10 times, a bar chart, which appeared 8 times, a bar chart with a line, which appeared 1 time and a stem and leaf plot, which appeared 1 time. I found that the most popular graph types for the misinformative graphs were a bar chart, which appeared 15 times, a line graph, which appeared 4 times, which appeared 1 time.

I next evaluated the vaccines discussed in the graphs. I found that 13 of the informative graphs discussed general vaccines, 4 of the informative graphs discussed the MMR vaccines, 1 of the informative graphs discussed the HPV vaccine, 1 of the informative graphs discussed the chicken pox vaccine, and 1 of the informative graphs discussed the flu vaccine. I found that 6 of the misinformative graphs discussed general vaccines, 5 of the misinformative graphs discussed the hepatitis b vaccine, 4 of the misinformative graphs discussed the dTap vaccine, 4 of the misinformative graphs discussed the MMR vaccine and 1 of the misinformative graphs discussed the flu vaccine.

I identified the subjects of the x and y axes for both the informative and misinformative graphs. I found that the subjects of the x axes of the informative graphs were year, which appeared 9 times, month, which appeared 3 times, week, which appeared 1 time, date, which appeared 1 time, percentage of coverage, which appeared 1 time, age of child (in months), which appeared 1 time, type of vaccine, which appeared 1 time, year of birth, which appeared 1 time, age (months), which appeared 1 time, and age group (years), which appeared 1 time. I found that the y axes of the subjects of the misinformative graphs were year, which appeared 4 times, risk of death/risk of injury, which appeared 3 times, mortality rates, which appeared 2 times, aluminum levels, which appeared 2 times, subjects needed to detect one death/subjects in trials, which appeared 2 times, age (in days), which appeared 1 time, doses of "aluminum containing vaccines", which appeared 1 time, age, which appeared 1 time, type of vaccine, which appeared 1 time, risk, which appeared 1 time, subjects needed for trial/subjects who participated, which appeared 1 time, and risk of death, which appeared 1 time.

The y axes of the subjects of the informative graphs were percentage, which appeared 4 times, incidence, which appeared 2 times, percentage of vaccine coverage, which appeared 2 times. vaccination coverage, which appeared 1 time, state, which appeared 1 time, number of provider sites/percentage participating, which appeared 1 time, percentage of children up-to-date regarding vaccines, which appeared 1 time, completely vaccinated children/% of the target population, which appeared 1 time, number of vaccines administered, which appeared

1 time, age in years, which appeared 1 time, percent vaccinated, which appeared 1 time, percent of unvaccinated, which appeared 1 time, rate per 100,000 population, which appeared 1 time, number of cases, which appeared 1 time, and incidence by 1,000 people, which appeared 1 time.

The y axes of the subjects of the misinformative graphs were causes of mortality, which appeared 2 times, micrograms of aluminum, which appeared 2 times, number of subjects, which appeared 2 times, milligrams of aluminum in bodies, which appeared 1 time, age in years, which appeared 1 time, aluminum limit, which appeared 1 time, milligrams of aluminum in vaccines, which appeared 1 time, percent of flu vaccine failure, which appeared 1 time, percent of population with hepatitis b, which appeared 1 time, number of people per 1,000,000, which appeared 1 time, mortality rate per population, which appeared 1 time, mortality rate of children, which appeared 1 time, number of people in general, which appeared 1 time, number of people per 100,000, which appeared 1 time, number of people per 10,000, which appeared 1 time, mortality of measles, which appeared 1 time, and percent of risk, which appeared 1 time.

The misinformative elements of the misinformative graphs were improper y axis, which appeared eleven times, improper x axis, which appeared five times, confusing key, which appeared two times, improper axes, which appeared one time and projected values, which appeared one time.

## Discussion

I now discuss the subjects of the graphs, the methods of visual misinformation used, the differences between visual information and misinformation and the current disconnect between industry and academic research.

### *Subjects of the Graphs*

Evaluating the subjects of the graphs shows that childhood vaccination is a multifaceted discussion.

I found that both the informative graphs and misinformative graphs discussed general vaccines the most. This is particularly interesting, as it shows that there is often no specific childhood vaccine either supported or opposed. Rather, the set of childhood vaccines are controversial. Both sets of graphs discussed the same vaccines: general childhood vaccines, MMR vaccine, tDap vaccine, and flu vaccine. The informative graphs discussed the HPV vaccines, while the misinformative graphs discussed the hepatitis B vaccine. Overall, the informative graphs discussed specific vaccines less than the misinformative graphs. I also found that the second-most prominent vaccine discussed in the misinformative graphs was the hepatitis B vaccine, while the second-most prominent vaccine discussed in the informative graphs was the MMR vaccines.

The subjects of the x axes were diverse. Although both graphs shared the same most popular subject: year, their subjects largely differed. Specifically, the subjects of the x axes of the informative graphs were time-specific: month, week, or date. Other subjects of the x axes of the informative graphs focused on the logistics of vaccine distribution, discussing type of vaccine or percentage of coverage. The subjects of the x axes of the misinformative graphs were also time-specific: age (in days) and age. However, the more prominent subjects discussed the presence of aluminum in vaccines and the alleged necessity of more drug trials. The subjects of the y axes of both the informative and misinformative graphs of were varied. No subject appeared more than 4 times. Overall, the subjects of the informative graphs were more aligned with the importance of vaccine coverage and children vaccinated, while the subjects of the misinformative graphs focused more on chemicals in vaccines, overall mortality rates and subjects testing vaccines. This is particularly interesting, as these two subjects, as they show a direct result of vaccine misinformation: when people believe vaccine misinformation, they will not vaccinate their children. Therefore, vaccine rates will decrease. These subjects show the diverse nature of vaccine discussion, as well as the different types of information and misinformation.

*Methods of Visual Misinformation*

The most prominent methods of visual misinformation were selection of an improper x or y axis. Finding the types of misinformative elements used in each of the graphs allowed me to further evaluate the presence of visual, graphic misinformation. Each of these methods used are effective forms of misinformative graph design. An improper x axis is misleading, as it may compare two disparate elements and present an incorrect connection. Presenting an independent element as dependent on another element is an effective method of misinformation (Calling Bullshit: Misleading Axis, 2019). With regards to an element such as time, showing inconsistent year intervals or improper future projection will result in the spread of misinformation. An improper y axis is misleading because it may present the effect of a dependent variable as larger than it really is (Breevoort, 2020; Correll, 2023). Confusing key and improper scale are also types of graphic visual misinformation. Confusing key will result in an information seeker misunderstanding a graph's data or seeing a trend where there is none. When both axes are skewed or inappropriate, viewers are further confused (Grootendorst, 2021; Misleading Graphs: Real Life Examples, 2023). Comparing two elements that have no relation is a particularly insidious form of misinformation. Finally, projecting values in the future is another form of misinformation: the future has not happened yet. Therefore, while projections are valuable for estimation, these projections must be accompanied by contextual statements about their status as projected rather than past. Each of these methods of visual misinformation are dangerous: they clearly and effectively communicate misinformation.

Identifying the methods of visual misinformation in these graphs clearly shows a concerning trend: although none of the elements of these graphs is particularly technical, graphic designers learn about these elements. Specifically, graphic designers learn both the benefits of using these elements effectively as well as the means to spread misinformation through these elements. These elements are also relatively unknown by the public. Although people know how to obtain information from graphs, they may be underprepared for misinformative graphs.

*Identifying the Differences between Visual Information and Visual Misinformation*

I now discuss identifying the differences between visual misinformation and visual misinformation. The informative and misinformative graphs had similar graph types: line graphs and bar charts were most prominent. Therefore, identifying an informative or misinformative graph based on graph type is unrealistic.

Evaluating x or y axis when determining whether to trust a graph is similarly challenging: year was the most popular topic for x axes in both the misinformative and informative graphs, while the subjects of the y axes were broad and numerous. One major difference in the informative and misinformative graphs is that of y axis subjects: the informative graphs' y axes were more focused on logistical and percentage of vaccine coverage, while the misinformative graphs' y axes were more focused on alleged danger of vaccines or alleged unnecessary nature of vaccines. This is one way that information seekers could discern between informative graphs and misinformative graphs. Therefore, information seekers must further evaluate potential source and type of misinformation. Identifying which vaccines are most prone to misinformation is relatively unhelpful, as both the informative graphs and misinformative graphs discussed general vaccines most.

The most popular types of misinformative design were improper y axis, improper x axis, confusing key, improper axes, and projected values. Information seekers could potentially identify these distortions to avoid believing the misinformation in the graph. As a result, information seekers must try to identify whether graphs discuss the and whether they contain distortion.

*Disconnect between Industry Research and Academic Research*

One major concern regarding graphical misinformation, including x/y axis truncation is that of exposure. Current industry literature directed toward future graphic designers explains that x/y truncation may result in misinformation. Sources meant to aid people in designing graphs are invaluable. Unfortunately, malicious users may read these texts and utilize x/y truncation in their misinformative visualizations with the intent to deceive. Unfortunately, while academic research identifies x/y truncation as a major concern, there is no current industry or academic solution to prevent people from designing and disseminating this misinformation intentionally or otherwise.

Current education into graphic design and analysis could also focus on delving further into each type of visual misinformation, as well as how effective each type of truncation or skew is in spreading misinformation.

### Limitations and Future Research

This study contains limitations. Forty infographics is a small number. Restricting the evaluation to traditional graphs such as bar charts, and line graphs is another limitation: more research is certainly necessary to evaluate new types of graphs, including 3D models. Finally, future work could include evaluating the perception of childhood vaccinations in graphs by political party or further research into truncated x/y axis in news articles or social media.

### Conclusion

Visual misinformation is an effective communication method. Methods, such as x axis and y axis truncation, may allow information seekers to better understand graphs. Unfortunately, malicious users may manipulate graphical elements to further spread misinformation. Although graphical manipulation is common, it is still an underexplored topic. More research into the generation, dissemination and impact of these graphs is essential. After comparing 40 graphs, I found that x/y truncation is a common method of graphic misinformation. Prominent misinformative design choices were improper y axis, improper x axis, confusing key, improper axes, and projected values. I also found that the majority of the misinformative graphs discussed general vaccines, rather than any specific childhood vaccine. I also found that when evaluating whether a graph is informative or misinformative, determining if a graph has an improper y or x axis or discusses chemicals or trials in vaccination serve as major signifiers of misinformation, while a graph that discusses benefits about vaccines serves as a major signifier of correct information. X/y axis manipulation is a particularly insidious form of generating and spreading visual misinformation. While graphic designers understand the importance of proper x/y representation, malicious users use x/y truncation to spread visual misinformation. Further research into graphic misinformation, specifically x/y axis truncation, is necessary.

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