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The Persuasive Power of Data Visualization

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Abstract—Data visualization has been used extensively to inform users. However, little research has been done to examine the effects of data visualization in influencing users or in making a message more persuasive. In this study, we present experimental research to fill this gap and present an evidence-based analysis of persuasive visualization. We built on persuasion research from psychology and user interfaces literature in order to explore the persuasive effects of visualization. In this experimental study we define the circumstances under which data visualization can make a message more persuasive, propose hypotheses, and perform quantitative and qualitative analyses on studies conducted to test these hypotheses. We compare visual treatments with data presented through barcharts and linecharts on the one hand, treatments with data presented through tables on the other, and then evaluate their persuasiveness. The findings represent a first step in exploring the effectiveness of persuasive visualization.

Index Terms—Persuasive visualization, elaboration likelihood model, evaluation

1 Introduction

Recent years have witnessed a remarkable increase in the adoption of visualization as a means to convey messages through data. Popular and respected venues such as *The New York Times* and *The Guardian* have already popularized the idea of using data visualization to convey a powerful message, and an increasing number of scientists, journalists, activists, and businesses are following a similar path.

However, as visualization as a communication tool gains popularity, it is necessary to better understand how it impacts and influences people. Does graphical presentation of data make a message more persuasive? This and other similar questions are crucial as data visualization is often employed with the implicit or explicit assumption that graphical representation has a powerful persuasive effect on a target population.

Human rights advocates and activists are increasingly tapping into the power of data visualization as a way to influence and persuade their audience. Tactical Technology Collective, an organization that helps campaigners and activists use technology in their work, has extensively used and researched visualization as an instrument of influence in activism. Their recently published book "Visualizing Information for Advocacy" discusses and proposes strategies to transform messages into powerful advocacy visualizations [1], but more empirical, rigorously examined evidence is needed to support or revise claims about the persuasive effect of visualization.

In this paper, we take a first step toward an evidence-based analysis of visualization persuasiveness. *Persuasion* has been defined as "human communication designed to influence others by modifying their beliefs, values, or attitudes" [36]. In our work, we study persuasion as *change in attitude*. *Attitude* has been regarded as the general evaluations people hold in regard to themselves, other people, objects, and issues [34]. While persuasion has been the object of extensive research in psychology [29], little evidence exists regarding the effect of visual data presentations on persuasion. Several angles of attack are possible to investigate such a broad research question. This work focuses on those cases where visualization is used with an *explicit intent* to persuade through a carefully crafted message that includes pieces of evidence. It's important to point out that this is neither the only way one can see visualization as having a role in persuasion, nor the only way persuasion can be defined (for instance, persuasion is often regarded in terms of behavioral change; an area where visualization can play a major role through data tracking and visualization [9].

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We also deem important to clarify that by studying the effect of visualization on persuasion we by no means intend to imply, through our studies and results, that it is always ethically acceptable or even desirable to manipulate people's opinion through visualization. Rather, we believe further advancements in this area need to go hand-to-hand with further research on visualization misuse and its well-known powerful effects in terms of misrepresentation, disinformation, and even deception [23, 15, 18]. Research like that carried out in this study can help us shed light on how persuasion through visualization works and hopefully prevent or mitigate malevolent use.

In our work, we proceed from the basic research question: *"Does graphical depiction of data have a more persuasive effect than textual or tabular information?"*. More precisely, following the tradition of the Elaboration Likelihood Model (ELM) of persuasion (explained in more detail in Section 2.1), we sought effects of visualization on *attitude change*, that is, the change of attitude on a proposed topic before and after being shown a persuasive message.

We ran several crowd-sourced randomized controlled experiments in which we progressively learned how to measure the effect of visualization on persuasion. Our final experiments, based on 3 carefully selected topics, show a consistent trend that graphical information (data presented through charts) is more persuasive than textual information (data presented through tables) under certain conditions and that persuasion is heavily modulated by initial attitude. Our qualitative analysis of participants' responses to our open-ended questions reveals interesting possible explanations and patterns, which we describe later.

We believe this study represents an important first step towards evaluating visualization's impact. While visualization research has made tremendous progress in helping us understand how visual encoding may affect the accurate perception of quantitative information and trends, there is a lack of understanding of how visualization impacts people's opinions and attitudes when they are exposed to visual presentations of data [20]. Also, by running multiple experiments on persuasion and perfecting the methodology for such tests, we hope our work can be taken as an example for running multiple additional studies to replicate, extend, perfect, or refute our results.

In the following section, we review relevant existing research in persuasion, including persuasion research on user interfaces. In Section 3, we describe the rationale for our experiment, including important information about the ELM and how it influenced our design choices. Section 4 describes our pilot studies and what we learned from them. Section 5 describes our final user study. Section 6 describes the results we obtained, followed by the qualitative analysis in Section 7. We summarize our findings and discuss open issues in Section 8.

2 Related Work

Persuasion has been the subject of extensive research in social psychology. While it is beyond the scope of this paper to provide a complete overview of research in persuasion, in the following section, we describe aspects of the research on persuasion and communication relevant to visualization. We also review more recent literature on the role of user interfaces in persuasion. Finally, we briefly review research on the study of impact in visualization.

2.1 Persuasion and Communication

Communication methods and their attributes have been studied extensively to understand the mechanisms of persuasion. Persuasion researchers typically focus on aspects of the persuasive message and aspects of the receiver to understand how these interact and lead to attitude change. The most established theoretical model of persuasion is the Elaboration Likelihood Model (ELM) of persuasion, which was developed by Petty and Cacioppo in the early 1980s [33]. The model describes persuasion as a dual process in which the nature of persuasion depends on the receiver's elaboration of the persuasive message, and refers to elaboration as "the extent to which a person scrutinizes the issue-relevant arguments contained in the persuasive communication."

When elaboration is high (*and thus occurs through the "central-route"*), persuasion depends on the argument's central characteristics, primarily its quality and strength. When elaboration is low (*and thus occurs through the "peripheral-route"*), the receiver reverts to cognitive heuristics, which rely on the message's peripheral characteristics like credibility of the source and aesthetic factors. The amount of elaboration and, thus, whether the persuasive process takes place more through the central or peripheral route, depends in turn on the receiver's motivation and ability to process the message. Motivation depends largely on the topic's personal relevance, and ability depends on whether the receiver is able to process the message without excessive cognitive effort.

In order to study the role of visualization in persuasion, we need to tap into persuasion research that analyzes how different ways to convey a persuasive message lead to different outcomes. Surprisingly, the role of argument type in the formation and development of attitudes is not very well studied [29]. Recent experimental studies show that statistical evidence can be more persuasive than anecdotal and causal evidence [13, 12], but limited information exists on how visual representation can impact attitude change. The only study we found that explicitly considers the role of visualization in this context is "Opening the Political Mind?", a working paper on the effect of visualization on factual misperceptions [28]. The study shows that exposing people to graphical information has significant effects on correcting factual misperception and, interestingly, has a larger effect on those who are presented with information that goes against their own belief.

2.2 Persuasion in User Interfaces

Persuasion has been the subject of numerous investigations in human-computer interaction. The early work of B.J. Fogg and his team paved the way to the study of web credibility and technologies that lead to *behavioral* change [10, 8, 9]. More pertinent to our research is the study of user interfaces as *communication* channels to promote persuasion as *attitude* change. Virtual characters, embodied agents, and speech interfaces have been studied in numerous experiments to understand the impact digital interfaces have on persuasion. For instance, Zanbaka et al. studied the role of gender and realism in the persuasiveness of a virtual cat agent [39]; Schulman and Bickmore studied the effect of fidelity to human conversation of an embodied agent to engage a user in a persuasive dialogue [35]; Stern et al. studied the persuasiveness of synthetic speech versus human speech [37]; and Mullenix et al. studied the effect of gender in voice-based interfaces on their degree of persuasion [24].

Selective exposure of information on the web is another area in which researchers have studied the effect of user interfaces on persuasion; with the goal of using technology to promote more balanced views. Munson and Resnick, for instance, studied the effect of presenting diverse political opinions, and found that people can be described according to two main behaviors: diverse-seeking, those who welcome ideas contrary to their current beliefs, and challenge-averse, those who are not open to exploring ideas that challenge their current views [25]. Liao and Fu studied selective exposure (a form of confirmation bias) which is defined as the tendency to obtain information preferably from sources that support one's own views [11], and found that exposing users to opposing views does not necessarily reduce the effect, even though the effect may be modulated by personal involvement and perceived threat [21]. Related to our research is the finding that when personal involvement increases, information seekers may be more open to challenging views.

As mentioned above, we are not aware of studies that specifically target the effect of graphical information on persuasion. Our research and the studies mentioned above share the following aspects: (1) we use ELM as our theoretical framework of reference to study persuasion; and (2) we study persuasion as attitude change; (3) we consider the user's relationship with the discussed topic (*initial attitude*) to modulate the persuasion process.

2.3 Visualization Impact

While visualization has been the subject of numerous experimental investigations in recent years [20], there is surprisingly little research on how visualization impacts people's behavior, or attitudes, especially when used as an alternative to other communication channels.

Bateman et al. found that embellished charts may lead to increased memorability [2] of the message conveyed by the chart. Similar studies have been conducted to better understand the effect of visual embellishments, but the results are mixed: most of the time they do not seem to negatively affect the correct perception of information from the visualization [3, 38]. Borkin et al. ran a large-scale online study to identify design elements that make a visualization easier to recognize and found that aesthetic factors may play a major role [5] on which charts are more easily memorized, even though the study did not consider the actual content of the charts. Hullman et al., studied the effect of social signals on data interpretation and found that biased signals lead to biased interpretations [16].

In a study conducted with a group of medical students, Borkin et al. studied alternative designs for artery visualization. The study compared 2D versus 3D layouts and perceptually adjusted versus rainbow color scales and found a remarkable improvement in terms of correct diagnosis of heart disease [4]. In another study, Elting et al. studied the effect of visualization on decisions to stop clinical trials and found that the graphical format greatly affected the decision of the physicians [7]. While not entirely focused on visualization, Houts et al.'s review of the "*the role of pictures in improving health communication*" [14] show that visual representations as having a solid positive impact in medical communication.

Visualization does not always improve communication or understanding. For instance, Micallef et al. found that simply adding a visualization to a textual description of a Bayesian reasoning problem does not seem to bring substantial advantages [22]. However, their follow up study shows that visualizations can improve accuracy when precise estimation of statistical values is not required.

3 Study Rationale and Methods

Given the limited literature on the study of argument type [29, 31] and the impact of alternative methods of evidence presentation, as an initial step we needed a strategy for studying persuasion in the context of data visualization. Some of the key questions we were confronted with were: "*What is the role of visualization in persuasion? What do we mean when we say that visualization is more persuasive? More persuasive than what? How do we measure persuasion?*". While we did not seek to answer all these questions at once, we worked to find a suitable angle of attack for our research and decided to focus on researching the primary hypothesis that **graphical depiction of statistical information leads to increased persuasion when contrasted**

Table 1. Cover stories of the 3 topics(CIT, INC, and VG) as presented to the participants.

Topic	Cover story
CIT	The creation of the federal corporate income tax occurred in 1909, when the uniform rate was 1% for all business income above $5,000. Since then the rate has increased to as high as 52.8% in 1969, and the single rate has become eight different rates for different income levels. Proponents of lowering the corporate tax rate to create jobs argue that it incentivizes job creation in the United States instead of overseas, encourages increased investment in research and infrastructure, and passes savings on to consumers through lower prices. Opponents of lowering the corporate tax rate to create jobs argue that it results in more profits for corporations without affecting job creation, and that unemployment rates were the lowest in recorded US history during the time when corporate income tax rates were highest. **Sources** : ProCons Website
INC	Policy-makers in the United States have argued for decades about whether stricter use of imprisonment leads to a decrease in crime. Proponents of stricter incarceration argue that people respond to punishment, and that the threat of incarceration helps prevent crime. Opponents argue that higher imprisonment rates have not led to lower crime rates, and that prison is not an effective deterrent. **Sources** : Stuart Henry, "On the Effectiveness of Prison as Punishment"
VG	A video game is an electronic game that involves human interaction with a user interface to generate visual feedback on a video device. Controversies over video games center on debates around video game content and the potential for it to negatively impact player attitude and behavior. Since the early 1980s, video games have become part of the political discourse with advocates emphasizing their nature as an expressive medium (protected under the freedom of speech laws of many countries), and detractors promoting various theories that video games are harmful for society and thus subject to legislative oversight and restrictions. **Sources** : Wikipedia

with non-graphical representations of the *same* data. This hypothesis was an articulation of what we identified as an implicit or explicit assumption in much of the existing data visualization work aimed at persuading an audience.

In order to research this hypothesis, we designed an experiment based on the measurement of attitude change. Attitude change research aims at recording changes in attitude as an effect of exposure to a persuasive message. Following the ELM [33] and numerous studies that use ELM as the main theoretical framework of reference [39, 35, 37, 24, 21], we structured our experiment around the following steps: (1) *Topic description:* A brief and neutral description of the topic under discussion is provided to the participant; (2) *Pre-treatment attitude:* Attitude towards the topic under discussion is recorded *before* the participant is exposed to the persuasive message; (3) *Persuasive message:* The participant is presented with the persuasive message; (4) *Post-treatment attitude:* Attitude towards the topic under discussion is recorded again *after* the participant is exposed to the persuasive message. Attitude change is measured as the difference between the post-treatment and pre-treatment attitude.

Three main experiment design choices are confronted for this kind of study: a selection of one or more topics to test, an effective mechanism to measure attitude and attitude change, and a persuasive message. The persuasive message is the element of our experiment where alternative treatments are provided and compared.

3.1 Topic Selection

Several factors are important in selecting the topics to be used in the experimental study: the selected topic should not be too complex; they should stimulate a certain degree of interest/involvement and, most of all, they should not be too polarizing. Topic polarization is especially important and challenging. Early on in our pilot studies we realized the need to use topics that do not evoke extreme initial attitudes in the population. As Hoeken suggests, [12], "*It is much more difficult to change an existing belief than to form a new belief*"; therefore it is important to select topics about which a significant proportion of the participants do not have a strong existing belief or prior opinion. Both very negative and very positive attitudes may lead to little observed change: the former because people with strong beliefs do not change their opinions easily, the latter because there is not much more to be persuaded when a participant is already strongly in favor of a given persuasive message. There are also practical purposes for not selecting an extremely polarized subject pool: if too few participants change their opinion one may be left with little discriminatory power to compare alternative treatments in the study.

Following a methodology similar to the one used by Liao and Fu [21], we pre-tested several topics before including them in the study. The test included 7 candidate topics selected from two main sources. One source is the *ProCon.org website* which lists examples of issues under debate, providing equally weighted arguments and collected evidence in favor and against them. The second source is our group of human rights experts from the NYU School of Law (paper co-authors) who collected issues relevant to human rights in the United States about which statistical data was available. In selecting the topics, we took into account the need to provide topics people could easily understand once they were given a description (i.e., we discarded topics that were too technical or of limited interest for the population at large) and the need to have compelling evidence in the form of data to be converted into charts for our experiments.

We tested the 7 topics by running a study on Amazon Mechanical Turk with 150 participants who reported to be United States residents and whose previous task approval rate was at least 99%. The participants were randomly assigned to one of the 7 topics from the treatment pool so that each one was shown only one persuasive message, and could participate in the study only once. All participants were shown a short introductory paragraph, or cover story, about the topic followed by the attitude questionnaire in which we asked them to report their opinion on a 7 point Likert scale (-3 to +3). For each of the topics we segmented the scale into three buckets:

- **Negatively Polarized (NP):** attitude range {-3,-2}
- **Neutral/Weakly Polarized (NWP):** attitude range {-1,0,1}
- **Positively Polarized (PP):** attitude range {2,3}

We ranked the topics based on the percentage of participants belonging to the NWP category and selected the following three top topics - *Corporate Income Tax* (CIT): "Lowering federal corporate income tax rate creates jobs", *Incarceration* (INC): "Incarceration does not reduce crime rates". *Video Games* (VG): "Violent video games do not contribute towards youth violence". It is worth noticing that while the cause-and-effect narrative gives an impression that an objective truth may exist for each topic, all the selected stories could be presented with arguments in favor or against the advocated position as evidence exists in support of both positions.

For each persuasive message, we collected necessary evidence as a series of cause-and-effect statements alongside data and statistics supporting those statements. Data and statistics were collected from the above mentioned sources and, in some cases, from research papers or publications they cited. The cover stories for each of the selected topics are presented in Table 1.

3.2 Attitude Measurement

Several methods exist to measure attitude (for a complete discussion see [6]). The two main established methods are *semantic differential scales* [30], a series of bipolar adjectives presented to elicit repeated judgments on the same concept, or *single-item scales* which use one single scale [34] to capture the attitude. We opted for a single-item scale that plainly addressed the main question we wanted to ask (e.g., "*To what extent do you agree that lowering the federal corporate income tax rate creates jobs?*"). Early on in our pilot studies, we realized that using a single item scale has the advantage of reducing the burden on memory when the participants need to express their opinion again in the post-test questionnaire, thus making the measurement more reliable. Furthermore, previous attitude change studies have found high correlation between answers in multiple items scales, thus making the use of one single scale both effective and efficient for our purpose [21].

It is also worth pointing out that while attitude change can be measured in *absolute* rather then *relative* terms (see [33, p.27]), that is, without a pre-test attitude question, we preferred to use a pre/post mechanism to make sure we could segment and study participants with negative, positive and no attitude change.

Table 2. Treatments of the 3 topics (CIT, INC, and VG) as presented to the participants.

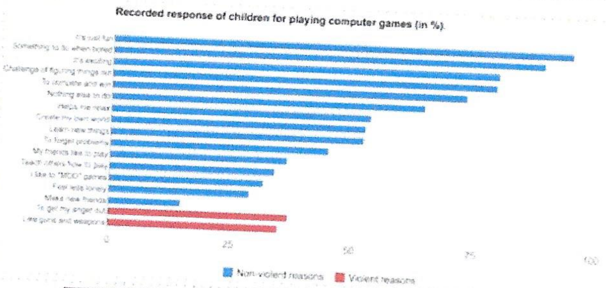
Topic	Treatment
CIT	**Evidence 1** - High corporate income tax may not ensure low unemployment rate. It was found that China maintains a lower statutory corporate income tax as well as unemployment rate than the US. The **[charts/tables]** below show a comparison between the statutory corporate income tax and unemployment rates in the US and China. **Evidence 2** - High corporate income tax rates encourage US companies to relocate their employees overseas and increase the overseas employment instead of investing into expansion and employment in the United States. The **[charts/tables]** below show how three major multinational companies, Walmart, Cisco and Intel, adopted this strategy between 2003-2006 when the effective corporate income tax in the US was increased. **Evidence 3** - The average five-year unemployment rate decreased from 1987-1991 after the United States lowered its top corporate income tax rate through the Tax Reform Act of 1986 (implemented in July 1987). The **[charts/tables]** below provide supporting statistics. **Sources** : Tax Policy Center website, Bureau of Labor Statistics website, Wikipedia, Tax Foundation website, PricewaterhouseCoopers LLP report.
INC	**Evidence 1** - The total amount of violent crime increased in the United States between 1971 and 2005 with inconsistent increase and decrease across years during this period. However, the incarceration rate grew much faster than the crime rate. The supporting statistics are presented in the **[charts/tables]** below. **Evidence 2** - Evidence suggests that marginal decreases in crime rates in U.S. states in recent decades bear no clear relation to increased incarceration. For example, states with above average increases in incarceration saw a significant rise in incarceration and a slight decrease in crime between 1991-1998. States with below average increases in incarceration saw a marginal increase in the rate of incarceration and comparatively more decrease in crime during the same period. The supporting evidence is shown in the **[charts/tables]** below. **Evidence 3** - The United States has the highest incarceration rate in the world. Despite this, the United States has a higher homicide rate than comparable countries. The same was observed in 2011, when the homicide rate in the US was higher than the other Western countries. The supporting statistics are presented in the **[charts/tables]** below. **Sources** : FBI website, BJS website, Sentencing Project website, International Centre of Prison Studies, UNODC
VG	**Evidence 1** - In a 2007 scientific study conducted by a group of researchers in the Unites States, 1254 children (53% female, 47% male) were asked if they play video games or not. To 1126 children who reported playing video games, 17 possible reasons for playing video games were presented. The children then selected one or more reasons for playing video games. It was found that the majority of children play video games for recreational purposes rather than violence inciting reasons. The statistics of the survey are shown in the **[charts/tables]** below. **Evidence 2** - It was found that the video games sales quadrupled between 1995 and 2008, whereas the overall juvenile crime and juvenile murder rates declined. The supporting evidence is shown in the **[charts/tables]** below. **Evidence 3** - In another study conducted in 2005, a comparison between juvenile crimes and video games sales in the Unites States and Japan was performed. The results showed that more juvenile murders happened in the United States as compared to Japan, whereas the per capita video games sales in Japan was much higher than that in the United States. The findings of the study are shown in the **[charts/tables]** below. **Sources** : FBI website, Entertainment Software Association website, Computer Entertainment Supplier's Association (CESA), Japan's Ministry of Justice website

3.3 Treatments

In order to investigate the relationship between visualization and persuasion, we had to develop persuasive messages that allow the comparison of graphical versus non-graphical depiction of information. There are many ways one can structure a persuasive message supported by pieces of evidence. Early on in our pilot studies, we experimented with multiple solutions. For instance, we tried messages based exclusively on data and statistics or messages with textual explanations intertwined with statistical evidence. We also tried multiple ways to present data, with text, tables and multiple visual representations (e.g., statistical charts and maps). We came to the conclusion that a persuasive message needs at least the following components: (a) *contextual information* to provide an introduction to the evidence presented through data and statistics; (b) the *evidence itself* (often made of numbers and trends like *"during this time X increased and Y decreased"*) and (c) the data provided in support of the evidence.

The data presentation element is where alternative representations can be used to test the persuasive power of visualization. In our final experiment, we decided to present data in *tabular* versus *graphical* format. Tables, by depicting information mainly through text, limit the number of graphical inferences one can readily make and in general are processed sequentially with limited support for pattern recognition. Charts and graphs, on the other hand, allow patterns to be detected at a glance and, as such, may lead to more persuasive messages through a higher information transfer or through "vividness". Vividness is an often cited factor in persuasion research that describes the degree to which a message and its format "attracts and holds people's attention and excites the imagination [26]. In turn, the treatments we built for the study mimicked real-world scenarios where a message needs to be conveyed through a narrative supported by a combination of explanatory text and accompanying images.

The three topics we selected were presented in a web page using a consistent organization and structure. The structure consists of a title and 3 pieces of evidence structured according the schema presented above: context (text), evidence (text+numbers/trends), and presentation (table or charts according to the treatment). The text we used in all persuasive messages is presented in Table 2. Data presentation for a piece of evidence in one of our persuasive messages is presented in Figure 1.



Reasons for playing video games	Agree percentage	Reason type
It's just fun	94.85	Non-violent
Something to do when bored	89.05	Non-violent
It's exciting	79.8	Non-violent
Challenge of figuring things out	79.35	Non-violent
To compete and win	73.2	Non-violent
Nothing else to do	64.65	Non-violent
Helps me relax	53.5	Non-violent
Create my own world	52.5	Non-violent
Learn new things	52.25	Non-violent
To forget problems	45	Non-violent
My friends like to play	36.5	Non-violent
Teach others how to play	34	Non-violent
I like to "MOD" games	31.75	Non-violent
Feel less lonely	29	Non-violent
Make new friends	14.75	Non-violent
To get my anger out	37	Violent
Like guns and weapons	35	Violent

Figure 1. Example of a piece of evidence (Evidence 1) from Video Games (VG) topic as presented in the treatment with charts (*top*) and treatment with tables (*bottom*).

3.4 Degree of Elaboration

An important element of the ELM is the degree of elaboration of a persuasive message. ELM posits that the degree of elaboration predicts whether the message is processed mainly through the central or peripheral route. The more elaboration the message receiver goes through the higher the likelihood he or she will carefully scrutinize the logic of the message. Two main variables have been studied as having an effect on elaboration: *involvement* and *need for cognition*.

Topic involvement is concerned with how important and interesting a given topic is for an individual. Involvement has been defined in multiple ways by persuasion researchers, often with multiple meanings [17], and is typically regarded as a multifaceted factor. In order to detect an overall involvement score, we included three questions covering: (i) the degree of interest in the topic, (ii) how much the individual feels the topic under discussion relates to her or his core values, (iii) how much the individual feels the topic under discussion might have practical implications in her or his personal life.

Need for cognition is a personality trait studied in social psychology to characterize the extent to which individuals are inclined towards effortful cognitive activities. Petty and Cacioppo define it as: "*the tendency to engage in and enjoy effortful cognitive endeavors*". They devised numerous tests to measure this trait. In our study, we use their short 18-item test [33, p.51] which they tested extensively and which is considered the de facto standard for the measurement of need for cognition.

Even though one of the previous studies [35] found no effect of need for cognition on persuasion, we reran this analysis in the hopes that the trait would be helpful in clarifying whether tabular or graphical data presentations have different effects on individuals with high/low need for cognition. In turn, the degree of elaboration can help explain if graphical or tabular information has an impact on persuasion mainly through the peripheral or central route as defined in the ELM model.

4 Progressive Hypothesis Generation

Before moving to the specifics of our study, we deem useful to briefly describe how our hypothesis on the persuasiveness of visualization came about through the development of a series of pilot studies we conducted before running the final experiment presented in this paper.

While it seems natural that visualization is a more powerful communication tool than other media such as text, we deemed important to test our intuition through a series of exploratory experiments. These studies familiarized us with the problem and helped to identify control conditions and assumptions under which a set of findings will hold true. We wanted to test our intuition that *visualization leads to more persuasive messages* and conducted pilot studies to turn this intuition into a proper experimental set up. The purpose of the initial studies were to tune up our experiments to identify important factors and clarify under what conditions visualization may be more effective than other media.

We started our analysis with a crowdsourced pilot study (with 150 participants on Amazon Mechanical Turk) on an arbitrarily chosen topic: the *Stop, Question and Frisk policy of New York City Police Department*. We created graphical (charts) and textual (tables) treatments in favor of this policy and determined persuasion as attitude change using a pre-treatment/post-treatment attitude question. The results of this pilot study gave us first evidence that visualization may have an effect on increasing persuasion likelihood. The study however had a large percentage of participants belonging to the *negatively polarized* bucket of initial attitude, where typically a large percentage of participants do not change their attitude.

These findings led to the topic selection experiment we described above and to the design of a new pilot study. We conducted another crowdsourced (50 participants) pilot study and chose a topic we knew would have a majority of participants in the NWP category (taken from [21]). The new study confirmed that visualization does have a more persuasive effect than tables when people are not strongly polarized. In order to investigate this hypothesis further we designed the final experiment described below which on purpose focuses mainly on neutral or weakly polarized participants. The experiment also investigates our hypothesis with three independent topics in order to increase the generality of our findings.

5 Experiments

To incorporate the design decision as described in the previous section, we ran a topic selection procedure in which we asked the participants about their existing opinion on a variety of topics. See section 3.1 for more details about topic selection.

We conducted three independent studies, one for each topic selected. All the experiments were performed in a crowd-based setting with the primary goal to test our final hypothesis, H1, and additionally capture other interesting trends. The following section describes the experiments in detail.

5.1 Final Hypothesis

We progressively iterated the hypothesis as described in the previous section. Based on the knowledge acquired by running initial studies, we established a new hypothesis with modified study design. Following is the hypothesis we composed for the final user study, taking into account the new design decision: **[H1]** - Treatments with graphical representation of the data (charts) have a higher likelihood of persuading participants who belong to the NWP category and higher attitude change as compared to treatments with tabular representation of the data (tables).

5.2 Participants and Apparatus

The experiment consisting of three independent studies was conducted using Amazon Mechanical Turk (MT). We chose MT as our experimental platform as it allowed us to perform more iterations quickly and progressively to test our hypotheses on a diverse subject pool. In conducting research based on crowdsourced self-reported measures, we draw on an emerging research trend which demonstrates the viability of this approach [19, 27]. For instance, Paolacci et al. [32] compared results of classic experiments in judgment and decision-making using traditional and crowdsourcing methods and found that participants behave consistently.

The three studies were performed sequentially, in the following order - Incarceration, Video Games, Corporate Income Tax. We made sure that each participant participated in only 1 of the three studies.

We recruited 720 participants (240 for each topic) from Amazon Mechanical Turk who self-reported a United States location and whose previous task approval rate was equal to or exceeded 99%. Each experiment took 5-10 minutes and the participants were paid US $0.50 for participation.

5.3 Procedure

Once on the experiment web page, each participant proceeded through 9 stages of reading and responding. Figure 2 contains a flow diagram of all the stages the participants undergo during the experiment, which we briefly describe below.

On the web page, we provided introductory information about the overall experiment, payment details, contact information and a downloadable consent form. Once the participants agreed to participate in the experiment, we directed them to Stage 1 at which we asked for information about their gender, age and education level. All the studies were anonymous and we did not store any information through which participants could be identified. In Stage 2 we presented a cover story during which we introduced the selected topic and an explicit mention to their sources (Figure 3). Stage 3 contained the involvement questions. Stage 4 contained the pre-treatment, single-rated, attitude determination question which changed according to which topic was tested. They all followed the same structure asking: "*To what extent do you agree that* [...]", followed by topic-specific statements as follows: *Corporate Income Tax*: "*Lowering federal corporate income tax rate creates jobs*"; *Incarceration*: "*Incarceration does not reduce crime rates*". *Video Games*: "*Violent video games do not contribute towards youth violence*". After this, at Stage 5, we randomly assigned one of the two treatments: the persuasive message supported by textual evidence (tables) or graphical evidence (charts) as summarized in Table 3.1. Based on the information presented on the treatments page, we asked 3 attention check questions at Stage 6, each corresponding to one piece of evidence. After answering the attention-check questions, the participants were asked post-treatment attitude determination questions, which were the same as those presented in the pre-treatment stage. The participants responded to the involvement and attitude questions using Likert scales ranging from -3 to $+3$. On the next page, at Stage 7 we asked for feedback from the participants through open-ended questions regarding whether they thought their opinion changed, to what extent they thought it changed, and why they think it changed. Finally, at Stage 8, the participants responded to the simplified need for cognition scale. By restricting the participants to navigate between pages using the browser's forward/back button, we ensured that the participants could not go back to change their answers on the pre-test questions after seeing the treatment. Once the study was successfully completed, the participants were paid through Amazon Payments.

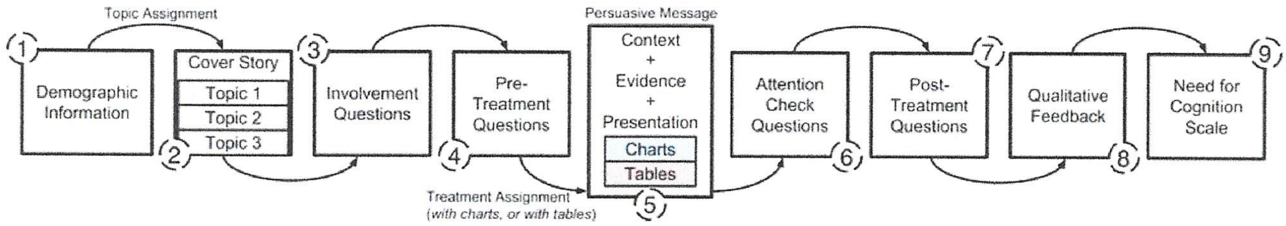


Figure 2. Stages of experiment (*consists of all the stages, numbered by their order of appearance that participants go through*)

For the purpose of quantitative analysis, we take into account the following variables. In our study design, self-reported *pre-treatment attitude* and *presentation type* are independent variables. Other dependent variables include *attitude change* and *persuasion likelihood*. We define *attitude change* as the change in user's self-reported attitude, i.e., post-treatment attitude minus pre-treatment attitude, when exposed to a persuasive message. We define the other dependent variable, *persuasion likelihood*, as the ratio of the number of persuaded participants and total number of participants, when exposed to a certain persuasive message. Persuasion likelihood is further subdivided into *(+) change*, *no change*, and *(-) change*, i.e., the fraction of participants showing positive attitude change, no attitude change, and negative attitude change, respectively. *Total need for cognition* and *total topic involvement* are two additional variables obtained by summing up users' responses to the questions presented at Stage 3 and 9 respectively. These two variable together are used to analyze the *"degree of elaboration"*.

6 RESULTS

Out of the 720 participants (240 per topic), 183 answered all the attention check questions for the *Corporate Income Tax* topic correctly, whereas, 175 and 219 participants answered all the attention check questions for the *Incarceration* and *Video Games* topics respectively. The distribution of participants for each of these topics, segmented by treatment and initial attitude is given in Table 3. The table shows that, due to our topic selection procedure, we have a higher percentage of participants falling in the NWP category for both types of treatments as expected; whereas, due to the attention check step, the distribution of participants across treatments gets imbalanced.

In what follows, we present the statistical analysis of the effect of presentation type on the two selected dependent variables: *persuasion likelihood* and *attitude change* as defined above. We first present the results obtained with neutral/weakly polarized participants which show a positive effect of charts on both measures as we hypothesized. We then provide the results of analyzing polarized participants, which we included because they show some interesting and unexpected patterns; namely that tables display an increased likelihood and attitude change for participants in the NP class. We conclude with a discussion and interpretation of the results we obtained from our experiments.

Table 3. Distribution of participants (*who answered all the attention check questions correctly*) by treatment and initial attitude categories (NP, NWP, PP).

Corporate Income Tax

Treatment	Total	NP	NWP	PP
Charts	101	29	54	18
Tables	82	23	45	14

Incarceration

Treatment	Total	NP	NWP	PP
Charts	79	6	50	23
Tables	96	11	56	29

Video Games

Treatment	Total	NP	NWP	PP
Charts	103	12	55	36
Tables	116	13	63	40

6.1 Neutral/Weakly Polarized participants

Across all the three topics, we find a consistent trend in terms of the persuasion likelihood: its value is higher with charts than for tables. Persuasion likelihood for the three topics is shown in Figure 3. Table 4 provides the raw numbers and the percentages displayed in the figure. In Corporate Income Tax the percentage of positively persuaded participants is 66.67% for charts and 44.44% for tables; in Incarceration respectively 72% for charts and 41.21% for tables; in Video Games 63.63% for charts and 36.51% for tables.

To test for statistical significance of the observed patterns we use the *Freeman-Halton extension of Fisher's Exact Test*, testing the null hypothesis that presentation type has no effect on the participants distribution across the three possible outcomes ((+) change, no change, and (-) change). The findings are statistically significant at the $p < 0.05$ level for all three topics (Corporate Income Tax: $p = 0.024$; Incarceration: $p = 0.035$; Video Games: $p = 0.006$). The test on the aggregated data from the three topics also provides a statistically significant result using Chi-square test (as N >300) ($\chi^2(2, 323) = 20.7915$, $p = 0.000031$), with 67.29% participants positively persuaded through charts and 42.68% through tables.

Table 4. Persuasion likelihood of participants (*who answered all the attention check questions correctly*) in the NWP category.

Corporate Income Tax

Treatment	Total	(+) change	No change	(-) change
Charts	54	36/54 (66.67%)	18/54 (33.33%)	0/54 (0%)
Tables	45	20/45 (44.44%)	22/45 (48.88%)	3/45 (6.66%)

Incarceration

Treatment	Total	(+) change	No change	(-) change
Charts	50	36/50 (72%)	13/50 (26%)	1/50 (2%)
Tables	56	27/56 (48.21%)	26/56 (46.43%)	3/56 (5.36%)

Video Games

Treatment	Total	(+) change	No change	(-) change
Charts	55	35/55 (63.63%)	19/55 (34.54%)	1/55 (1.81%)
Tables	63	23/63 (36.51%)	38/63 (60.32%)	2/63 (3.17%)

Figure 4(a) shows the mean attitude change with standard error by treatment across all three topics. The mean attitude change in Corporate Income is 1.07 for charts and 0.68 for tables; in Incarceration it is 1.16 for charts and 0.95 for tables; in Video Games it is 1.10 for charts and 0.57 for tables. We analyze the results using confidence interval analysis of the mean difference of attitude change between charts and tables using bootstrap confidence intervals for non-normal distributions. The results are presented in Figure 5 (right-hand side). The mean difference for the three topics is the following: Corporate Income Tax: *Mean(charts - tables) = 0.386*, 95% CI = [-0.014, 0.796], $p = 0.087$; Incarceration: *Mean(charts - tables) = 0.214*, 95% CI = [-0.206, 0.638], $p = 0.271$; Video Games: *Mean(charts - tables) = 0.538*, 95% CI = [0.165, 0.922], $p = 0.005$ under *Mann-Whitney U-test*. The aggregated data generated by combining the three topics together is statistically significant (*Mean(charts - tables) = 0.381*, 95% CI = [0.150, 0.611], $p = 0.0008$).

6.2 Polarized participants

Similar trends, as those observed for the NWP category participants, were found for the PP participants. However, an unexpected and in-

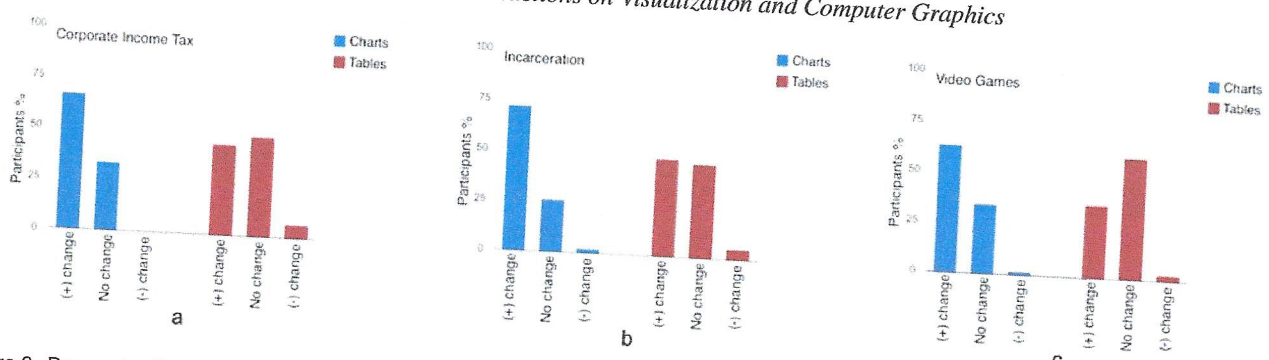


Figure 3. Persuasion likelihood of participants (*who answered all the attention check questions correctly*) in the NWP category by treatment type and topic (a = Corporate Income Tax, b = Incarceration, c = Video Games).

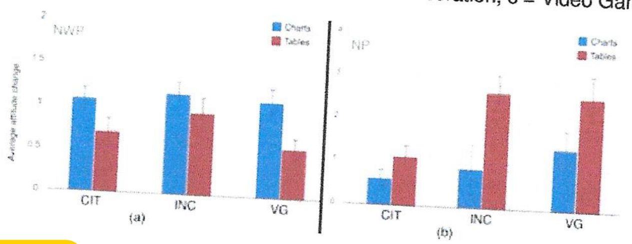


Figure 4. Mean attitude change chart of participants (*who answered all the attention check questions correctly*) in the a) NWP and b) NP categories by treatment type and topic.

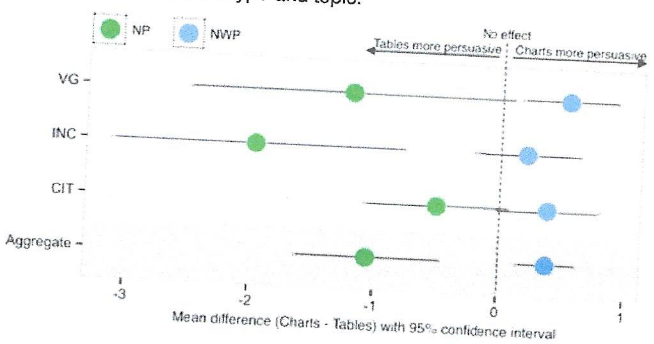


Figure 5. Topic-wise and aggregate effect size estimate for charts vs. tables on NWP and NP category participants.

teresting set of trends were observed for the NP category participants.

We replicated the analysis on the negatively polarized participants. A consistent trend in terms of the likelihood of the participants to be persuaded by the treatment was observed across all three topics, i.e., tables outperform charts and lead to higher persuasion likelihood. Figure 6 shows the persuasion likelihood for the three topics. Table 5 includes the raw numbers and percentages displayed in the figure. In Corporate Income Tax the percentage of positively persuaded participants is 37.93% for charts and 65.21% for tables; in Incarceration 33.33% for charts and 90.90% for tables; in Video Games 58.33% for charts and 92.30% for tables.

For statistical significance of the results, we ran *Freeman-Halton extension of Fisher's Exact Test* testing the similar null hypothesis as the one tested for NWP. On the data obtained, we found that the results were statistically significant at the $p < 0.05$ level for only 1 of the 3 topics (Corporate Income Tax : $p = 0.092$; Incarceration : $p = 0.027$; Video Games : $p = 0.073$). Upon aggregating the data from the three topics, statistical significance has increased ($p = 0.00063$) with 42.55% participants positively persuaded through charts and 78.72% through tables.

Figure 4(b) shows the mean attitude change with standard error by treatment across all three topics. The mean attitude change in Corporate Income is 0.62 for charts and 1.13 for tables; in Incarceration is 0.67 for charts and 2.63 for tables; in Video Games is 1.41 for charts and 2.61 for tables. We analyze the results using confidence interval analysis of the mean difference of attitude change between charts and tables using bootstrap confidence intervals for non-normal distributions. The results are presented in Figure 5 (left-hand side). The mean difference for the three topics is the following: Corporate Income Tax: *Mean(charts - tables)* = *-0.510*, 95% CI = [-1.090, 0.071], $p = 0.083$; Incarceration: *Mean(charts - tables)* = *-1.970*, 95% CI = [-3.119, -0.779], $p = 0.023$; Video Games: *Mean(charts - tables)* = *-1.199*, 95% CI = [-2.498, 0.097], $p = 0.121$ under *Mann-Whitney U-test*. The aggregated data generated by combining the three topics together is statistically significant (*Mean(charts - tables)* = *-1.063*, 95% CI = [-1.637, -0.475], $p = 0.001$).

Table 5. Persuasion likelihood of participants (*who answered all the attention check questions correctly*) in the NP category.

Corporate Income Tax

Treatment	Total	(+) change	No change	(-) change
Charts	29	11/29 (37.93%)	18/29 (62.06%)	0/29 (0%)
Tables	23	15/23 (65.21%)	8/23 (34.78%)	0/23 (0%)

Incarceration

Treatment	Total	(+) change	No change	(-) change
Charts	6	2/6 (33.33%)	4/6 (66.66%)	0/6 (0%)
Tables	11	10/11 (90.90%)	1/11 (9.09%)	0/11 (0%)

Video Games

Treatment	Total	(+) change	No change	(-) change
Charts	12	7/12 (58.33%)	5/12 (41.66%)	0/12 (0%)
Tables	13	12/13 (92.30%)	1/13 (7.69%)	0/13 (0%)

6.3 Degree of Elaboration

We analyze *involvement* and *need for cognition* as proxies to determine a participant's degree of elaboration - an important component in the ELM model that predicts whether the message is processed though the central or peripheral route of persuasion. Although some previous studies have reported the effect of involvement on attitude change, such as [21], we were unable to reproduce that effect. The two variables, total involvement score (i.e., sum of the response scores of the 3 involvement questions) and attitude change, seemed to be negligibly correlated (Spearman's r(575) = 0.012, $p = 0.94$, 95% CI = [-0.065, 0.091]).

Schulman and Bickmore [35] observed no effect of need for cognition on persuasion. We also did not find any effect as the two variables, need for cognition score (i.e., sum of the response scores of the 18 need for question statements) and attitude change, seemed to be negligibly correlated (Spearman's r(575) = 0.003, $p = 0.77$, 95% CI = [-0.078, 0.084]).

6.4 Discussion

When initial attitude is not strongly polarized, charts seem to have a stronger effect than tables on persuasion likelihood and attitude change. Figure 3 shows a consistent trend, across all three topics, of

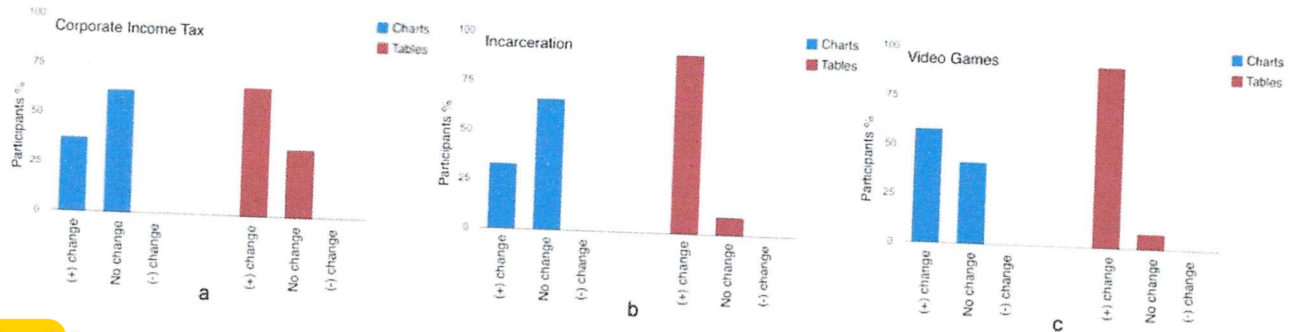


Figure 6. Persuasion likelihood of participants (*who answered all the attention check questions correctly*) in the NP category by treatment type and topic (a = Corporate Income Tax, b = Incarceration, c = Video Games).

charts having a larger likelihood of positive change than tables, with improvements ranging between 66.67%(CIT: Charts) - 44.44%(CIT: Tables) = 22.23% (CIT) and 63.63%(VG: Charts) - 36.51%(VG: Tables) = 27.12% (VG) when charts are used in place of tables. Charts seem to have a positive impact on attitude change also. Figure 5 shows the mean difference in attitude change between charts and tables conditions and their respective confidence intervals. The intervals represent plausible values for the mean difference and the estimated midpoint is about 7 times more likely than the values at both ends of the scale. All values for NWP (blue dots in the figure) fall on the positive side of difference thus showing a consistent trend across the three independent studies. When considering the three topics aggregated together we obtain an effect size estimate for the mean difference of 0.38 with 95% CI = $[0.15, 0.61]$. Considering that the maximum positive change participants in NWP can theoretically have is 4 (from -1 to $+3$ in the Likert scale) we have a potential improvement of 8%, ranging between 3% and 15%. These results suggest that the use of charts can lead to a moderate but consistent increase in persuasion with people who do not already have a strong opinion about the debated subject.

The results obtained from the segment of negatively polarized participants show some interesting and surprising trends. Figure 6 shows a reverse trend in terms of likelihood, that is, the table conditions have a higher percentage of participants with positive change than the charts across all three topics. Probably due to the small number of participants in NP, only one out of three topics presents statistically significant effects of presentation type on likelihood. When the three topics are aggregated, however, we do find a statistically significant effect ($p = 0.00063$) and an overall aggregated improvement of tables over charts of 36.16%. The results of attitude change follow the same trend (Figure 4) but they also display a much higher uncertainty. Figure 5 shows the estimated mean difference in NP (green dots in the figure) and their respective confidence intervals, done in the same way we calculated for NWP. From the figure we can see that all estimated mean differences fall on the left hand side, thus showing once again a reverse effect between the chart and table conditions. It is worth noticing, however, that the confidence intervals are much bigger for NP and that much smaller values are still plausible. When we aggregate the three topics together, we find an effect size estimate for the mean difference of -1.06 with 95% CI = $[-1.63, -0.47]$, which corresponds to a potential improvement of 17%, ranging between 7% and 27%, considering a maximum theoretical attitude change of 6 (i.e., for a participant with initial attitude -3 and post-treatment attitude equal to $+3$). It is also worth noticing that in NP one of the topics (INC) shows a stronger effect of tables, suggesting that topic may be a modulator for this effect.

In summary, our results suggest that presentation type may have an effect on persuasion and that the effect may be modulated by initial attitude. Due to our experimental set up, where we purposefully aimed at having a higher number of participants in the NWP category, we have much higher uncertainty in NP. It is worth noting, however, that both NWP and NP show very similar trends across three independent experiments and topics, thus increasing our confidence on the observed results. We deem very important, as part of future work, to replicate these results with an additional number of new topics and a more balanced distribution of participants across the initial attitude factor.

7 Qualitative Analysis

As outlined in Section 5.3, at the end of the experiment, the participants were asked to reflect about their change of attitude (or lack thereof) and to provide justification for their change. In this section we provide an analysis of their responses. The analysis provides numerous hints as to why people do or do not change their opinion and points to a number of useful guidelines on what designers should take into account when designing persuasive visualizations.

7.1 Why do people NOT change their opinion?

In order to answer this question, we sorted our results to single out participants who did not change their opinion and segmented them according to what kind of initial attitude they had. As a result of our analysis, we identified 5 kind of effects:

1) Skepticism (data/source). One very common justification for not changing opinion is related to a lack of trust towards the presented data, statistics and trends. This was particularly prevalent among participants with a negative initial opinion (strong or weak). Phrases like *"cherry-picked data"*, *"manipulated data"* appeared multiple times. For instance one participant in the NP class commented: *"It did not change, because evidence exists to support both opinions. Data is easily manipulated to support each."* Another participant in the same category: *"I don't base my thinking upon alleged 'facts' presented to me by an unknown entity"*. Similarly, a participant in the NWP category: *"The statistics I read did not change my opinion because I know that statistics can be manipulated to suit whatever outcome."*

2) Skepticism (logic). Another form of skepticism we have found is when the individual questions the logic rather than the data itself. Many such people believe that the topic under discussion was presented in a somewhat simplistic way and that reality is much more complex than what is presented in the persuasive message. For instance, some of the comments in this class include: *"It really didn't change it because that statistic doesn't represent the whole picture or the entirety of what has happened to the US economy."*; *"There are other factors about unemployment. Correlation does not imply causation"*; *"I'm skeptical of the data because it is too simple. There are many other factors that may influence unemployment rates"*.

3) Anchoring to core beliefs. An often cited reason in persuasion research for people not changing attitude is that the persuasive message may go against the core values of the receiver. In our feedback, we found a good number of people who justify their attitude with reasons that have nothing to do with the data or the logic – they just refuse to consider it because it goes against what they believe to be true. For instance one participant commented: *"I stand firm in my beliefs about unemployment."*; *"I think it didn't change much for me because my thoughts and feelings about incarceration are kind of tied into my core being"*.

4) Complexity. Although not very common, we found cases of people who consider the whole logic presented in the persuasive message too complex to elaborate and/or they don't have enough background knowledge to form an opinion, even after reading the message. One participant in the NWP category stated: "*I didn't really understand it fully to form an educated opinion*".

5) Persuaded already. Finally, as we move on to people who are already persuaded, it became harder to persuade them even more about the advocated position. This is reflected in comments like: "*It didn't change my opinion. It just proved what I already believed*"; or "*It supported everything I believed so my opinion didn't change*"; or "*It gave more support for my previously held opinion*".

7.2 Why DO people change their opinion?

As shown by our statistics in Section 6, a large number of participants changed their attitude after being exposed to a persuasive message. We have categorized them into the following 3 effects.

1) Struck by evidence. Among the participants who reported a strong or slight negative initial attitude, we found a large number of *re-deemers*, that is, people that are struck by the evidence provided in the persuasive message and that for this reason are ready to change their opinion. Many mention a mismatch between their previous views and the message shown, and most mentioned the statistics as the driving factor for the positive attitude change. Quotes similar to these were common: "*It changed because the facts are clearly laid out in front of you*"; or "*You can't argue with statistics. If they support a different conclusion then the one you were believing, you have no choice but to change your belief*", or "*It changed because it was supported by research versus just believing what others are saying and forming my opinions based on those*". In this case, the participants acquired new knowledge and were positively influenced.

2) More persuaded. A positive attitude change can also be observed in participants who already held a slightly or strongly positive attitude in direction of the presented persuasive message. For them, exposure to more evidence reinforced their prior belief, which was already positive. Participants in this class reported responses such as: "*It changed because I was shown empirical evidence*", or "*It provided more evidence to reinforce ideas I had understood, thereby increasing my agreement.*"; or "*The facts just reinforced my opinion*"; or "*It only confirmed what I believed about video games not contributing to violence*".

3) Negative thoughts (boomerang effect). Finally, albeit in only a few cases, we found what persuasion researchers call the *boomerang effect*, that is, participants who are negatively affected by the message. In the literature, this is explained with the fact that an argument (especially if perceived as weak) can elicit negative thoughts about the topic under discussion and lead to a negative attitude change [33, p.32]. We have found this effect among participants with an initially favorable attitude when they feel that the statistics are incomplete: "*Nothing about how studies were conducted was in the information*". Also, mere exposure to statistics can lead to negative thinking that goes against the persuasive message: "*It really didn't change my opinion too much, I am just a little less sure than I was before reading the statistics.*"

7.3 The Persuasiveness of Charts and Statistics

After looking into common effects in attitude formation and change we searched for specific mentions to the graphical appearance of charts as a driver for persuasion. Some of the comments we collected seem to back up the findings we found in our results. Some participants explicitly mention the charts as being the main reason for their change: "*I already knew that increased incarceration didn't lower crime, but I wasn't sure of the statistics. To see it on the graphs is really eye opening.*"; "*I was influenced by the bar graph showing the reasons why the survey respondents played video games.*"; "*I would not know exact numbers on this issue - the graphs gave a visual and helped identify the numbers*"; "*Seeing the graphs conflicted with my previous opinion, so I feel like I need to reevaluate my stance in a way.*"

It is also important to mention that the graphical appearance of charts is not the only factor that has a strong impact on people's attitude. In our collected feedback, we found numerous references to statistics and numbers, suggesting that mere exposure to data does have a persuasive effect – maybe at least partially due to the increased sense of objectivity evidence supported by numbers carries. We found comments like: "*It was concrete data that seemed compelling.*"; "*Seeing numbers is a good indicator of change rather than just reading what someone has to say*"; "*It showed a large amount of different sources, which made it more credible*". More research is needed to disentangle what kind of specific effects each of these components have on persuasion.

8 Conclusions, Open Issues and Future Work

The present study aims at better understanding the role of visualization in persuasion. Our experiments suggest that the persuasive power of data visualization is dependent on the initial attitude of the participant. We found consistent results that charts lead to higher persuasion when participants do not possess a strong initial attitude about the topic. Tables, on the other hand, seem to outperform charts when the participants have strong initial attitude against the persuasive message; although these results are much more uncertain and need further validation. We performed qualitative and quantitative analysis to understand the persuasion effect from various angles. We believe our study design and methodology will be very helpful for communicators and researchers. Communicators can gain a better understanding of which factors and processes may have an effect on persuasion, and researchers can adopt and expand our methodology to carry out further experiments on persuasion. During the span of this research, we came across multiple open issues, some of which are limitations to our study and point to interesting future research directions. Three very important open issues are briefly discussed below.

a. *Effect of Topic on Persuasion*: While on the one hand, our choice of three different topics leads to some degree of generality of our findings, it is important to keep in mind that all of them were selected according to a predefined set of criteria: by design, do not elicit too strong initial attitudes; they are all based on a cause-and-effect type of argument; and they all leverage statistics. Understanding the effect of topic on persuasion (in a visualization research context) is not the focus of this work and more research is needed to better tease out the effect of this factor.

b. *Role of Medium on Persuasion*: While our studies show an effect of presentation type on persuasion, we have no information yet on what causes the observed effects. More precisely, we do not know if the more persuasive effect of charts over tables, that we observed in the not polarized segment is mostly due to having more information available or just because the medium itself (its visual appearance) is more persuasive (an issue that mirrors the well-known ELM central-route vs. peripheral-route modes of persuasion mentioned in Section 2.1). In a similar fashion, we need to understand what leads negatively polarized participants to be more persuaded by tables than by charts.

c. *Multiple Dimensions of Persuasion*: Our analysis focuses exclusively on the attitude component of attitude change without taking into consideration the degree of confidence a participant has on his or her initial attitude and the subsequent change. Involving both dimensions will help better understand not only how people's opinions change but also whether the evidence and the method used to present it has an effect on their confidence.

As part of our future work, we plan to target these open issues. For instance, we will include a comprehension assessment to quantify the amount of information (and its accuracy) extracted from the data presentation. This will be used as a proxy to gauge whether charts lead to higher information transfer. Similarly, we will run studies with a control condition where no evidence is provided, to better quantify its effect. We will also experiment with other topics and structures to see what kind of influence they have on persuasion, especially examining the effect of credibility cues. Finally, we will investigate the role of confidence in persuasion.

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REFERENCES

[1] Tactical Technology Collective. https://www.tacticaltech.org/, 2013.

[2] S. Bateman, R. L. Mandryk, C. Gutwin, A. Genest, D. McDine, and C. Brooks. Useful junk?: the effects of visual embellishment on comprehension and memorability of charts. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 2573–2582. ACM, 2010.

[3] R. Borgo, A. Abdul-Rahman, F. Mohamed, P. W. Grant, I. Reppa, L. Floridi, and M. Chen. An empirical study on using visual embellishments in visualization. *Visualization and Computer Graphics, IEEE Transactions on*, 18(12):2759–2768, 2012.

[4] M. Borkin, K. Gajos, A. Peters, D. Mitsouras, S. Melchionna, F. Rybicki, C. Feldman, and H. Pfister. Evaluation of artery visualizations for heart disease diagnosis. *Visualization and Computer Graphics, IEEE Transactions on*, 17(12):2479–2488, 2011.

[5] M. A. Borkin, A. A. Vo, Z. Bylinskii, P. Isola, S. Sunkavalli, A. Oliva, and H. Pfister. What makes a visualization memorable? *IEEE Transactions on Visualization and Computer Graphics (Proceedings of InfoVis 2013)*, 2013.

[6] A. H. Eagly and S. Chaiken. *The psychology of attitudes.* Harcourt Brace Jovanovich College Publishers, 1993.

[7] L. S. Elting, C. G. Martin, S. B. Cantor, and E. B. Rubenstein. Influence of data display formats on physician investigators decisions to stop clinical trials: prospective trial with repeated measures. *BMJ: British Medical Journal*, 318(7197):1527, 1999.

[8] B. Fogg. Captology: the study of computers as persuasive technologies. In *CHI'97 extended abstracts of the SIGCHI conference Human factors in computing systems*, pages 129–129. ACM, 1997.

[9] B. J. Fogg. Persuasive computers: perspectives and research directions. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 225–232. ACM, 1998.

[10] B. J. Fogg. Persuasive technology: using computers to change what we think and do. *Ubiquity*, 2002(December):5, 2002.

[11] D. Frey. Recent research on selective exposure to information. *Advances in experimental social psychology*, 19:41–80, 1986.

[12] H. Hoeken. Anecdotal, statistical, and causal evidence: Their perceived and actual persuasiveness. *Argumentation*, 15(4):425–437, 2001.

[13] H. Hoeken and L. Hustinx. When is statistical evidence superior to anecdotal evidence in supporting probability claims? the role of argument type. *Human Communication Research*, 35(4):491–510, 2009.

[14] P. S. Houts, C. C. Doak, L. G. Doak, and M. J. Loscalzo. The role of pictures in improving health communication: a review of research on attention, comprehension, recall, and adherence. *Patient education and counseling*, 61(2):173–190, 2006.

[15] D. Huff. *How to lie with statistics.* WW Norton & Company, 2010.

[16] J. Hullman, E. Adar, and P. Shah. The impact of social information on visual judgments. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1461–1470. ACM, 2011.

[17] B. T. Johnson and A. H. Eagly. Effects of involvement on persuasion: A meta-analysis. *Psychological Bulletin*, 106(2):290, 1989.

[18] G. E. Jones. *How to lie with charts.* LaPuerta Books and Media, 2011.

[19] A. Kittur, E. H. Chi, and B. Suh. Crowdsourcing user studies with mechanical turk. In *Proceedings of the SIGCHI conference on human factors in computing systems*, pages 453–456. ACM, 2008.

[20] H. Lam, E. Bertini, P. Isenberg, C. Plaisant, and S. Carpendale. Empirical studies in information visualization: Seven scenarios. *Visualization and Computer Graphics, IEEE Transactions on*, 18(9):1520–1536, 2012.

[21] Q. V. Liao and W.-T. Fu. Beyond the filter bubble: interactive effects of perceived threat and topic involvement on selective exposure to information. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 2359–2368. ACM, 2013.

[22] L. Micallef, P. Dragicevic, and J. Fekete. Assessing the effect of visualizations on bayesian reasoning through crowdsourcing. *Visualization and Computer Graphics, IEEE Transactions on*, 18(12):2536–2545, 2012.

[23] M. Monmonier. How to lie with maps. 1996.

[24] J. W. Mullennix, S. E. Stern, S. J. Wilson, and C.-l. Dyson. Social perception of male and female computer synthesized speech. *Computers in Human Behavior*, 19(4):407–424, 2003.

[25] S. A. Munson and P. Resnick. Presenting diverse political opinions: how and how much. In *Proceedings of the SIGCHI conference on human factors in computing systems*, pages 1457–1466. ACM, 2010.

[26] R. E. Nisbett and L. Ross. Human inference: Strategies and shortcomings of social judgment. 1980.

[27] O. Nov, O. Arazy, C. López, and P. Brusilovsky. Exploring personality-targeted ui design in online social participation systems. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 361–370. ACM, 2013.

[28] B. Nyhan and J. Reifler. Opening the political mind: The effects of self-affirmation and graphical information on factual misperceptions. *Unpublished Working Paper*, 2011.

[29] D. J. O'keefe. *Persuasion: Theory and research*, volume 2. Sage, 2002.

[30] C. E. Osgood. *The measurement of meaning.* Number 47. University of Illinois press, 1957.

[31] D. J. OKeefe and S. Jackson. Argument quality and persuasive effects: A review of current approaches. In *Argumentation and values: Proceedings of the ninth Alta conference on argumentation*, pages 88–92. Speech Communication Association Annandale, VA, 1995.

[32] G. Paolacci, J. Chandler, and P. G. Ipeirotis. Running experiments on amazon mechanical turk. *Judgment and Decision making*, 5(5):411–419, 2010.

[33] R. E. Petty and J. T. Cacioppo. *Communication and persuasion: Central and peripheral routes to attitude change.* Springer-Verlag New York, 1986.

[34] R. E. Petty, J. T. Cacioppo, and M. Heesacker. Effects of rhetorical questions on persuasion: A cognitive response analysis. *Journal of personality and social psychology*, 40(3):432, 1981.

[35] D. Schulman and T. Bickmore. Persuading users through counseling dialogue with a conversational agent. In *Proceedings of the 4th international conference on persuasive technology*. ACM, 2009.

[36] H. W. Simons. *Persuasion.* Addison-Wesley Reading, Massachusetts, 1976.

[37] S. E. Stern, J. W. Mullennix, C.-l. Dyson, and S. J. Wilson. The persuasiveness of synthetic speech versus human speech. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 41(4):588–595, 1999.

[38] A. Vande Moere, M. Tomitsch, C. Wimmer, B. Christoph, and T. Grechenig. Evaluating the effect of style in information visualization. *Visualization and Computer Graphics, IEEE Transactions on*, 18(12):2739–2748, 2012.

[39] C. Zanbaka, P. Goolkasian, and L. Hodges. Can a virtual cat persuade you?: the role of gender and realism in speaker persuasiveness. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*, pages 1153–1162. ACM, 2006.