Bachelor Thesis 2021

The Impact of Visualisation Type and Topic Relevance on Understanding and Decision-making in Context of Covid-19 Infection Rates

Theme 7: Visual Communication

Radboud University, Faculty of Arts

International Business Communication

First Supervisor: dr. P. J. F. de Swart

Second Assessor: dr. W. G. Reijnierse

Date: 07-06-21

Student: Isabel Blanken

Abstract

Visual representations of data have been of interest in many studies and appear to improve understanding as compared to presenting numbers alone. The way data is visualized can also have an effect on understanding, as well as decision-making. A relatively novel area of interest is the relationship between the topic relevance of the visualisation and understanding and decision-making. Filling this gap and adding to existing literature examining different types of visualisations, the current study aimed to investigate the impact of the same data presented as either stocks or flows and topic relevance (high versus low) on understanding and decision-making. A 2x2 between-subjects design was conducted with 162 participants who lived in the Netherlands using an online Qualtrics questionnaire. Findings revealed that stock graphs were understood better than flow graphs and that stock data led to more extreme decision-making scores. No significant effects were found for topic relevance on understanding, nor on decision-making. The current research project provides implications for data visualisation designers: the way a graph is designed can influence the way the message is perceived in the recipient. Flow graphs should be designed with caution. Albeit a successful manipulation check for topic relevance, the current study did not demonstrate a significant effect of the second independent variable: topic relevance. Future research could investigate topic relevance further and in more detail. All in all, the current research project has contributed to literature about data visualisations and how different formats of the same data can influence understanding and decision-making.

Introduction

Data is indispensable in the current digital age. Large data sets are collected and analysed for many different purposes: marketing efforts, communicating health risks, communicating economic developments, weather prediction, and so forth. However, how can one be completely certain that the intended message conveyed with data is received correctly in the recipient? It appears that numerical data is not always understood correctly or perceived with the intended purpose. Peters, Västtfjäll, Slovic, Mertz, Mazzocco and Dickert (2006), for instance, found that highly numerate individuals performed better than less numerate participants regarding accurate risk perceptions and probability judgements. Especially for topics such as health risks, correct interpretation and understanding of the provided information is essential. As the general public differs regarding numeracy skills (i.e. “the ability to process basic probability and numerical concepts”, Peters et al., 2006, p. 407), risk communication messages should be conveyed in a way that is graspable for multiple audiences.

Multiple studies have shown that adding visual representations of data can improve understanding and interpretation (e.g. Garcia-Retamero & Galesic, 2010; Okan, Stone & Bruine de Bruin, 2018). More specifically, visual aids are especially effective in risk communication, probability and climate contexts (Okan et al., 2018). Garcia-Retamero and Galesic (2010) found that the perceived threat was more accurate when visual aids were added in health risk communication, especially for people with low numeracy. The way in which the visual representation is constructed can also influence performance. When the number of people at risk and people affected were presented in addition to numerical information, risk estimates became more accurate. Increased accuracy of threat perception occurred for both icon arrays and bar charts when added to numerical information (Garcia-Retamero & Galesic, 2010).

So far, it appears that visual representations of data can improve (risk) comprehension and perceptions. There are many types of visual representations, and multiple studies have examined different types of visualisations and tested their impact on understanding, perception and decision-making (see e.g. Garcia-Retamero & Galesic, 2010; Padilla, Creem-Regehr, Hegarty & Stefanucci, 2018; Sun, Li, Bonini & Su, 2012). According to Peebles and Ali (2009), bar and line charts are the most common visual representation in a wide context (ranging from business to education). In their study, they compared three-variable bar and line charts against one another to see whether graph comprehension would differ. They showed that line graph viewers experienced more difficulties in correctly interpreting the data, due to different salient properties in line and bar graphs. However, a proportion of the participants, who were non-experts, had poor skills in graph reading. A follow-up study by Peebles and Ali (2015) using graph experts as participants showed no differences between line and bar charts regarding performance. Another study by Okan et al. (2018) found that graphical risk displays focusing only on the number of affected cases (called "foreground-only" graphs) increased risk perceptions and the avoidance of risks. They manipulated the extent to which the number of people at risk were also salient. When verbal labels were added to both foreground-only and foreground+background graphs, risk understanding improved, whereas absence of labels reduced risk understanding in foreground-only graphs. In this way, these studies have shown that different formats of visually presenting information can lead to different interpretations.

In addition to choosing different types of visualisations, such as line or bar charts, there are also options to present the chosen visualisation type in various ways; one can use absolute numbers in graphs or use relative numbers. A concrete example involves presenting data as either stocks or flows (Spiller, Reinholtz & Maglio, 2019). These stock and flow graphs are commonly used in time-series data and often serve as a tool in decision-making processes. In stock charts, the height of bars or lines represent the absolute quantity at each time point, whereas in flow charts, height represents the change in quantity at each time point. Spiller et al. investigated whether using flow versus stock charts of the same data would lead to different judgements. The topic chosen for the graphics was related to the gains and losses of jobs within a certain period, including Bush's and Obama's presidency. They found that the same data presented as either stock or flow resulted in opposing judgements; Obama's impact was viewed more positively when presented as flows and judged more negatively when the data was presented as stocks. In this way, they showed that the choice of format (stock vs. flow) can influence evaluations positively or negatively, which is an important practical implication for graph designers. According to Spiller et al. (2019), these opposing judgements might arise from cognitive conflicts that occur when, for example, a trend is increasing while negatively accelerating; the stock chart shows an increase, whereas the flow chart shows a decrease, while the raw data used in both charts remains increasing. As people tend to pay attention to salient parts of graphs (Lurie & Mason, 2007), such as an increasing or decreasing trend, these conflicting patterns can lead to different judgements, which is what Spiller et al. (2019) found. They explained that people might misinterpret flow data and perceive it as stocks. Spiller et al. also demonstrated that people subjectively understood stock charts better than flow charts.

Spiller et al.'s results could be extended to another context: health communication. Whether flow versus stock health charts might influence understanding and eventually decision-making is an important topic to investigate, especially when a pandemic is roaming the earth. Romano, Sotis, Dominioni and Guidi (2020) measured the effects of different graphical formats of covid-19 data on understanding. They tested covid-19 deaths displays in a linear versus logarithmic format and found that linear graphs increased understanding and led to more accurate predictions of corona-deaths developments. This effect can be explained by the fact that participants viewed the logarithmic curve as more flattening, while the linear curve reflected a clearer steep increase (Romano et al., 2020). As both graphs used the same data, the problem presented remains equally serious, however, the graphical formats seemed to influence graph perception in either a positive or negative way. Thus, their results clearly showed that the same data presented in different formats can lead to different judgments and performance.

During the current pandemic, the number of covid-19 infections are frequently presented at newspaper websites, and often in a stocks or flows format besides logarithmic versus linear representations. The way in which the data is presented and is interpreted might eventually influence public decision-making regarding, for instance, wearing masks, whether one is for or against prolonging the closing of stores and so forth. Decision-making in relation to visualisations has been of interest by different researchers (see e.g. Padilla et al., 2018; Stone, Bruine de Bruin, Wilkins, Boker & MacDonald Gibson, 2017; Sun et al., 2020). All of them show that the format of visual displays can implicitly influence decision-making. Sun et al. (2020) found an effect of graph-framing on decision-making. In their experiment, they manipulated the width and height between two data-points in the visualisation. The participants were asked which MP3-player they preferred based on a graph with *repair rate* on the y-axis and *storage capability* on the x-axis. Participants were either shown a graph on which the scales on the y-axis were accentuated (meaning that distance between MP3 1 and MP3 2 on the y-axis was larger than the distance on the x-axis) or a graph accentuating the scales on the x-axis. In this way, either the repair rate dimension had more influence on the decision-making or the storage capability dimension. Their results showed that, indeed, the graph format manipulation affected decision-making. Thus, in addition to understanding, the way in which a graph is formatted can affect decision-making processes.

When communicating about covid-19 data, it is essential to ensure that the conveyed information arrives as accurately as possible in the minds of the recipient. However, even when graph designers would attempt to craft the most accurate and clear graphs evoking information processing with the intended purpose, they are confined by the extent to which they can control what the recipient will decode. That is to say, graph designers are confined by situational factors surrounding the recipient, which can interfere with graph perception. For instance, to one person, covid-19 data might be considerably more important because of covid infections in his or her family, whereas for another, covid-19 data is less irrelevant. Being less interested or involved in a topic might consequently influence graph perceptions.

This leads to the assumption that the visual presentation of data might not be the only factor that influences perception and understanding. Personal relevance and contextual factors are instances which might affect the way a graph is interpreted (Kennedy, Hill, Allen & Kurk, 2016). To date, little is known about the influence of personal topic relevance in relation to understanding and making decisions when presented with data visualisations. It is generally known that personal and individual factors indeed play a role in the process of perceiving visualisations (see e.g. Kennedy et al., 2016; Kennedy & Hill, 2018; Peck, Ayuso & El-Etr, 2019). A qualitative study by Peck et al. (2019) demonstrated that people tend to perceive and make decisions about visualisations mainly based on their personal experience. More specifically, participants were more drawn to graphical displays which were personally relevant; for instance, in Peck et al., when shown different graphs, participants with an alcohol addiction history were more interested in a display about alcohol addiction. Participants also tended to focus on their own geographical location when presented with a map of the whole country. Their findings are in line with Kennedy et al. (2016) who identified different factors which influence visualisation engagement. For instance, one factor was subject matter; when the subject of the visualisation was interesting to the participant, they were more engaged. These factors could be categorised into categories of shallow processing (i.e. visual elements evoking bottom-up attention), as discussed in Padilla et al. (2019). Padilla et al. outlined multiple studies that promote the idea that people can adopt two types of processing mechanisms when making decisions about visualisations. This is also called a "dual-process account of decision making" (Padilla et al., 2019, p. 7). The first processing type can be seen as shallow processing, which involves bottom-up attention that fixates on salient parts of data visualisations without using working memory. The second type is more knowledge driven and utilises working memory and careful processing. The researchers found that shallow processing impacted decision-making significantly in data visualisation contexts. Graph viewers might initially be focused on salient features, which could be colour, lines, but also information that stands out personally, and thereby neglecting less-salient features. All in all, these previous studies have shown that personal involvement can influence initial graph perception.

The aforementioned findings by Padilla et al. can be linked to the elaboration likelihood model (ELM). This model explains whether someone takes the central or peripheral route when exposed to a visualisation or text (Pandey, Manivannan, Nov, Satterthwaite & Bertini, 2014). The central route involves more in-depth processing, whereas the peripheral route utilises processing on a surface level, which can be linked to shallow processing in Padilla et al. (2019). Factors such as motivation and ability appear to influence the extent to which someone elaborates on a message. Motivation can be in turn dependent on the topic's personal relevance. Pandey et al. (2014) state that increased elaboration leads to a greater likelihood that the message will be logically and attentively processed. In Pandey et al., topic involvement is described as the extent to which a topic aligns with an individual's interests and values. Pandey et al. did not find any effects of topic involvement on attitudinal evaluations. However, this might be different in decision-making processes and understanding. As greater involvement (as a potential result of personal relevance) can evoke logical and more in-depth processing (Frewer, Howard, Hedderley & Shepherd, 1997), this might affect graph reading performance. Frewer et al., who investigated the effect of hazard type and source credibility on risk perceptions, found that if the participant believed that the information was not directly related to him or herself (as a consequence of perceiving a source as credible), they were less likely to involve with the risk information. Furthermore, in their qualitative analysis they showed that highly relevant hazard types were related to an increased need for cognition about the risk.

Another study by van Lent, Sungur, Kunneman, van de Velde and Das (2017) investigated the role of psychological distance of an epidemic on public attention and fear in the context of Tweets. Their concept of psychological distance was based on the construal level theory. This theory suggests that something becomes psychologically closer when it is spatially, temporally, socially or hypothetically close. They found that fear and public attention to the Ebola epidemic decreased as psychological distance increased. Based on this study, psychological distance plays a role in how severe outbreaks can be perceived. Hence, in addition to measuring whether different visualisation formats lead to different performances, topic relevance might play a role as well in viewing, for the purpose of this study, health communication charts.

As previous research has shown that data visualisation formats influence understanding and decision-making, the present study aims to build on this by extending the literature to covid-19 visualisations. As discussed earlier, stock versus flow graphs can lead to different interpretations of political data visualisations. However, little is known about whether this is also the case for covid-19 infection graphs. To fill the gap of topic relevance literature in relation to data visualisation, the present study examines whether personal relevance of the presented data influences understanding and decision-making in addition to the potential impact of visualisation type. Personal relevance in the context of covid-19 cases visualisations entails the perceived relevance of covid-19 data to the individual that views the visualisation. Information involving a viewer’s current living location might be more relevant to that individual than information about another place or country. Therefore, the current study addresses the following research question:

RQ: To what extent do topic relevance (high vs. low) and visualisation type (stock vs. flow) in the context of covid-19 influence understanding and decision making?

To answer this research question, six hypotheses have been formulated.

H1: Stock charts will be understood better than flow charts.

This is in line with findings of Spiller et al. (2019). However, they measured subjective understanding. This current study measures objective understanding.

H2: Visualisation type (stock versus flow) will influence decision-making.

For example, a decelerating increase of cases looks different on a flow graph than on a stock graph. In the stock graph, the increase is more salient, whereas in the flow graph, the decrease of acceleration is more salient. Based on the (potentially conflicting) salient trends, decisions might differ when one perceives a trend as negative in the flow condition, and positive in the stock condition. This hypothesis is built on Sun et al. (2020) who found that manipulating the width and height between data points in graphs resulted in different decisions made by participants. Participants focused on the most salient parts and judged accordingly.

H3: Higher topic relevance will increase understanding of the graph as compared to lower topic relevance.

For high topic relevance, it is expected that graph properties are more likely to be carefully scrutinized. This is based on Pandey et al. (2014) and Frewer et al. (1997) who stated that higher involvement leads to more in-depth processing. More in-depth processing facilitates viewing all graph properties instead of viewing salient parts only. Examining all graph parts, therefore, could increase understanding as compared to low-processing, viewing merely salient properties.

H4: Topic relevance (high versus low) will influence decision-making.

Higher involvement leads to increased elaboration on a message, and thus, increased attention (Pandey et al., 2014). The opposite counts for low involved graph viewers. This difference in attention and involvement might affect scores on a decision-making scale. For instance, if something is highly relevant to someone, making a decision about something that will affect their life (as it is relevant to them) can lead to decisions which are only beneficial to that person. Whereas, if something is irrelevant to them, decisions could be made more rationally; someone looks at it more objectively and less self-centred, potentially leading to different decisions. Thus, topic relevance can lead to different scores on the decision-making scale.

H5: Visualisation type and topic relevance will interact relating to understanding.

As visualisation type can affect graph interpretation (Spiller et al., 2019), the effect of topic relevance might increase or decrease this effect. Low involvement can lead to focusing on salient parts only, which inhibits in-depth processing. Reversely, high involvement can increase attention and elaboration, which might reduce the difference between stock and flow graphs regarding understanding. To illustrate this effect: a flow chart could potentially be misinterpreted for stock charts, which has been found in earlier research (Spiller et al.). In the case of low-processing, the possibility of perceiving a flow graph as stocks is higher due to viewing only salient graph properties as compared to high-processing.

H6: Visualisation type and topic relevance will interact relating to decision-making.

An interaction effect is expected between visualisation type and topic relevance. However, the extent to which the two will interact remains to be explored. Based on Sun et al. (2020), different data representations can lead to different decisions due to different salient features. Topic relevance might moderate this effect as high topic relevance can increase attention (Pandey et al., 2014), potentially processing the information more in-depth, and therefore decrease the difference between stock and flow regarding decision-making scores. The more in-depth processing enables looking further than salient trends only, lowering the probability of being deceived by the differing salient trends of flows and stocks.

By focusing on both the data visualisation format (stock vs. flow) and topic relevance (high vs. low), this study adds to existing literature on visualisation communication. It also extends data visualisation studies in the context of risk and health communication. Results of this study can aid graph designers in creating effective graphs with the viewer in mind. It is imperative to ensure that a message is received according to the purpose of the message. Certain formats might distort data interpretation, which is detrimental in health communication contexts, especially during a pandemic. Results can also contribute to a greater understanding of how individuals perceive graphs. It can raise awareness of personal factors involved when evaluating and making decisions based on visualisations.

Method

Materials

This study contained two independent variables: visualisation type (stock versus flow) and topic relevance (low versus high). Two versions of bar charts presenting the same covid-19 cases data were used; one bar chart presented the data in stocks, whereas the other presented it in flows (see Figure 1).

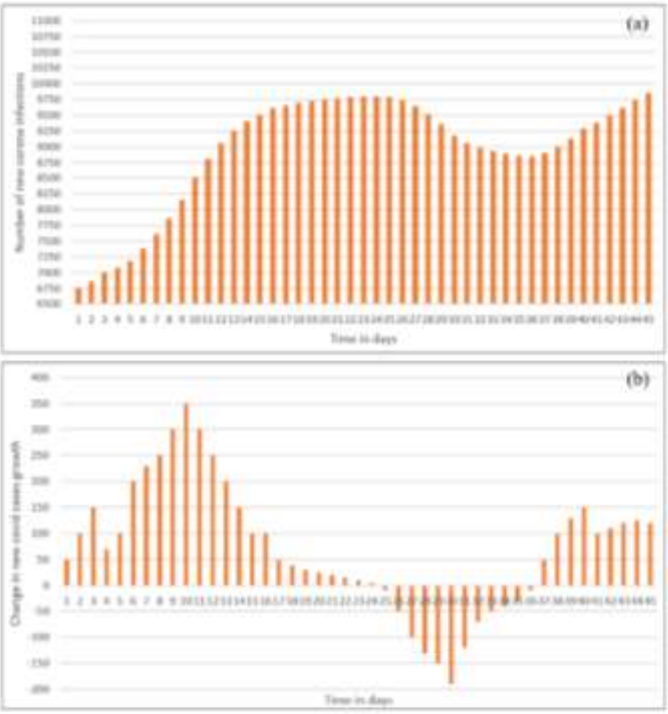


Figure 1: (a) depicts covid-19 cases data in stocks, whereas (b) presents the same data from covid-19 cases in flows. Starting value at day 0 in (b) is 6700.

In the stock graph, the y-axis describes the number of new covid-19 infections and the x-axis the time. The flow graph describes the increase or decrease in number of new covid-19 infections on the y-axis and time on the x-axis. Then, for each type of visualisation (stock versus flow), either a description of low topic relevance or high topic relevance was presented with the graph, resulting in four experimental conditions (see Table 1 for an overview).

Table 1. Overview of the four experimental conditions including the two independent variables tested in this study: visualisation type and topic relevance.

	Visualisation type		Topic relevance
Condition 1	Stock	+	High (NL)
Condition 2	Stock	+	Low (Z)
Condition 3	Flow	+	High (NL)
Condition 4	Flow	+	Low (Z)

Graphs belonging to the level of high topic relevance described the covid-19 data as belonging to the participant’s current home country (the Netherlands). Low topic relevance graphs described the same covid-19 data but then in the context of a foreign country. As participants live in the Netherlands, Zambia was chosen as the foreign country, corresponding with low topic relevance for the participant. Zambia was expected to be perceived psychologically far away as it is socially and spatially distant from people in the Netherlands. Therefore, Zambia was expected to be of low relevance to participants. This theory of psychological distance was based on (van Lent et al., 2017). The full version of the materials used for each experimental condition can be found in Appendix A. It must be noted that these materials existed in two language versions: Dutch and English. The one that was presented relied on the language choice of the participant.

Participants

A total of 162 participants took part in the current study (age: M = 27.85, SD = 12.73 ; range 18 – 66). More than half of the participants were female (60.5%), 37% were male, 1.9% labelled themselves as “other” and 0.6% rather did not mention their gender. More than half of the participants had an educational level of either university of applied sciences (24.7%) or bachelor university (37.7%); 14.8% attended or finished high school; 6.2% trade school; 15.4% master university; and 1.2% PhD. Only 14.8% of the participants took the English version of the survey, whereas the remaining respondents took the Dutch version. Fourteen of the recorded responses were excluded as they were not eligible to take part in this study. Furthermore, due to an error in the questionnaire, one participant did not fill in the questions about the manipulation check, which is why the data of this participant was omitted. The remaining number of participants used for the analysis was, therefore, 162.

Regarding the distribution of participants’ characteristics across the conditions, there was significant no association between topic relevance and gender (χ^2 (3) = 1.58, p = .665) or topic relevance and education (χ^2 (5) = 6.64, p = .249) or topic relevance and age (F (160) < 1, p = .617). Furthermore, there was no significant association between visualisation type and gender (χ^2 (3) = 1.69, p = .639) or visualisation type and education (χ^2(5) = 6.64, p = .249). However, age differed significantly across groups for visualisation type (F (150.52) = 2.90, p = .004). Participants were generally older in the stock condition (M = 30.45, SD = 14.41) than in the flow condition (M = 24.89, SD = 9.80).

Design

A 2x2 (visualisation type x topic relevance) between-subjects design was used to measure the impact on understanding of the graph and decision-making in relation to covid-19 cases data. As all the participants resided in the Netherlands, the high and low topic relevance was expected to be roughly the same for each participant (because Zambia was most likely to be less relevant to people living in Holland). Hence, participants were equally and randomly assigned to each of the four conditions. In reality, as this study was constructed by multiple students, there were six conditions (including the effect of graph framing). However, for the purpose in this paper, a 2x2 design was adopted.

Instruments

Two dependent variables were measured: understanding of the graph and decision-making. They were measured using an online questionnaire in Qualtrics. Understanding was measured objectively by reviewing Okan et al. (2017) who measured objective risk understanding by asking eight questions about the data being presented. Romano et al. (2020) also measured objective understanding of covid-graphs using three questions. The current study posed five questions relating to understanding, inspired by Romano et al. and Okan et al. (2017), which could be applied to both charts. Example questions involve: “How many new corona infections were registered on day 3?” and “Compare the period from day 1 to day 10 to the period from day 11 to day 20. Which period shows a stronger rise in infections?”. All five understanding questions can be found in Appendix B. Decision-making was measured by asking the participants: “The authorities of the Netherlands/Zambia (depending on the experimental condition) are supposed to make a decision about whether they should reopen the non-essential shops or whether they should prolong the closing of non-essential shops for another 14 days. Based on the graph that you are seeing, what would your advice be?”. Their answer could be indicated on a 7-point scale (1 = definitely stay closed; to 7 = definitely reopen). The questions about understanding were asked after the decision-making to avoid participant priming; participants would think about the data more thoroughly when asked about understanding as compared to making decisions about graphs.

In order examine whether the topics used were indeed of higher or lower relevance to the participants (the Netherlands versus Zambia), participants were asked to indicate on a 7-point Likert scale to what extent they found the information presented personally relevant; to what extent the number of positive covid-19 cases in NL/Zambia were relevant to them; and to what extent they find the covid-19 rules in NL/Zambia important; all three questions added to the manipulation check of topic relevance. These questions were based on Frewer et al. (1997), who also measured topic relevance. Cronbach’s alpha was acceptable (α= .78). Hence, the mean of these three topic relevance questions was used for the analysis of checking the manipulation.

Procedure

A general message with a request for respondents and a corresponding survey-link was distributed across several social media channels: *LinkedIn, Facebook, Instagram,* and *WhatsApp*. The message contained a requirement that participation was only possible if the participant was older than 18 and was currently living in the Netherlands and provided information about the anonymity of participation. The experiment could be taken online through Qualtrics. There was no reward or monetary compensation for participation. First, participants were asked in which language they preferred to view the questionnaire. After that, the questionnaire continued; all subjects who agreed to participate, were 18 years or older and lived in the Netherlands were registered and automatically randomly assigned to one of the four conditions. Initially, participants were asked to give their consent to participate and were informed about the option to withdraw from the experiment at any time. They were also informed about the subject of the experiment: encountering health communication graphs, and finally were given contact information of a person to whom they can ask questions about the experiment. The questionnaire started by filling in demographic information, which was followed by showing the respective graph for the first time from one of the four conditions. The respondents then had to answer a question related to decision making. This was followed by answering five questions about understanding, while they could still view the graph. After finishing questions measuring the dependent variables, participants had to indicate to what extent they found the graph relevant by answering three questions. Finally, participants were asked several questions about graph perception and finished with graph literacy questions. However, graph perception and graph literacy were not analysed in the current research project. They were part of the joint questionnaire belonging to six thesis students, who all focused on different variables. At the end of the experiment, participants were thanked for their participation and time. They were also given the option to contact one of the thesis students if participants wanted to know more about the purpose of the study. Filling in the questionnaire took approximately ten to fifteen minutes.

Statistical treatment

Two two-way ANOVAs were conducted to measure potential interaction effects between visualisation type and topic relevance on understanding and decision-making. At the same time, these two-way ANOVAs measured main effects of visualisation type and topic relevance for both understanding and decision-making. To measure understanding of the participants, all answers to the five understanding questions were recoded as either ‘1’ (correct) or ‘0’ (incorrect). The multiple-choice questions were either correct or incorrect, whereas for the open questions, a correct answer depended on the condition that the participant was in. For instance, participants were not able to zoom in and zoom out properly and had to estimate certain numbers in the stock condition. Therefore, a range of good answers was perceived correct, whereas in the flow condition, no estimation was needed for the same question. Appendix B shows the correct answers (with range) for each question. The sum of correct answers were used for the understanding analysis, resulting in number of good answers ranging from zero to five for each respondent.

A t-test was conducted to test the manipulation check by investigating the difference between participants in the Zambia and Netherlands condition regarding their mean scores on perceived importance and relevance of the graph. Figure 2 shows the analytical model of the current research.

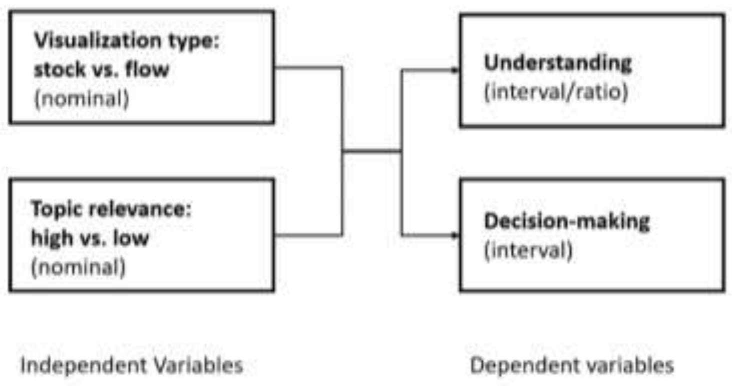


Figure 2: Analytical Model Current Research Project

Results

This study was set out to examine the effect of visualisation type (stock versus flow) and topic relevance (high versus low) on understanding of the graph and decision-making for people who live in the Netherlands.

Understanding

A two-way ANOVA with visualisation type and topic relevance as factors showed a significant main effect of visualisation type on understanding (F (1, 158) = 119.53, $p < .001$). Respondents in the stock graph version scored higher (M = 4.15, SD = 0.99) than respondents in the flow condition (M = 2.51, 0.90). No significant main effect was found of topic relevance on understanding ($F < 1$, p = .547), and the interaction effect between the two factors was also insignificant ($F < 1$, p = .538). Table 3 displays the means and standard deviations of participants' scores on understanding in function of topic relevance and visualisation type.

Table 3. *Means, standard deviations and n for understanding in function of visualisation (stock, flow) and topic relevance (low, high). Maximum number of understanding score = 5.*

Topic relevance	Low			High			Total		
	M	*SD*	n	*M*	*SD*	n	*M*	*SD*	n
Visualisation type									
Stock	4.15	0.97	46	4.15	1.03	40	4.15	0.99	86
Flow	2.42	0.81	36	2.60	0.98	40	2.51	0.90	76
Total	3.39	1.24	82	3.38	1.27	80	3.38	1.25	162

Decision-making

A two-way ANOVA with visualisation type and topic relevance as factors showed a significant main effect of visualisation type on decision-making (F (1, 158) = 11.32, p = .001). Respondents in the flow conditions, on average, indicated a less extreme response on the 7-point decision-making scale (M = 3.00, SD = 1.46) compared to respondents in the stock condition (M = 2.17, SD = 1.57). No significant main effect of topic relevance on decision-making was found (F (1, 158) = 1.21, p = .274). Similarly, the interaction effect between topic relevance and visualisation type was not significant (F < 1, p = .511). Table 4 depicts the means and standard deviations of participants' scores on decision-making in function of topic relevance and visualisation type.

Table 4. *Means, standard deviations and n for decision-making (about prolonging non-essential stores) in function of visualisation (stock, flow) and topic relevance (low, high). 1 = definitely stay closed, 7 = definitely reopen.*

Topic relevance	Low			High			Total		
	M	*SD*	n	*M*	*SD*	n	*M*	*SD*	n
Visualisation type									
Stock	1.98	1.47	46	2.40	1.68	40	2.17	1.57	86
Flow	2.94	1.57	36	3.05	1.38	40	3.00	1.46	76
Total	2.40	1.58	82	2.73	1.56	80	2.56	1.57	162

Manipulation check: Topic relevance

An independent-samples t-test showed a significant difference between Zambia-group participants and Netherlands-group participants regarding their scores on perceived topic relevance (t (160) = 10.08, p < .001). Participants in the Zambia condition were significantly less personally involved with the country presented (in this case Zambia; M = 2.27, SD = 1.13) than participants in the Netherlands condition (with the Netherlands as the country of relevance; M = 4.24, SD = 1.35). Table 5 shows the means and standard deviations of topic relevance for participants in the Netherlands condition (conceptualised as high relevance) and Zambia condition (low relevance).

Table 5. *Means and standard deviations of perceived topic relevance in the Netherlands (high) condition and Zambia (low) condition. 1 = very low, 7 = very high.*

Country of graph	The Netherlands (high)	Zambia (low)
	n = 82	n = 80
	M (*SD*)	*M* (*SD*)
Perceived topic relevance	4.24 (1.35)	2.27 (1.13)

Discussion

The current study aimed to investigate the extent to which visualisation type (stock/flow) and topic relevance (low/high) influenced understanding of covid-19 graph data and decision-making.

First of all, in line with the expectations, stock charts were understood better than flow charts. This concurs with previous research findings by Spiller et al. (2019), who found that participants indicated to understand stock charts better than flow charts. The present study adds to their findings by providing evidence of increased objective understanding (asking questions about the graph data) when presented with covid-19 data. As stated by Lurie and Mason (2007), when presented with graphical information, people tend to focus on parts which are readily available and salient. Hence, a possible explanation for these findings could be that participants merely looked at the numbers at the y-axis of the flow graph and did not pay enough attention to what flow charts essentially depict; change in growth of new infections. Even though a block with a starting value of new infections at day 0 was provided (see in Appendix A: flow graphs), scores did not indicate accurate understanding of the flow data, and it could be the case that participants ignored or overlooked this information block.

Hence, these findings suggest that in general, people tend to experience more difficulties in understanding data presented as flows. Therefore, visual health communication designers can take this into account and design relatively more accessible graphs to communicate health data. It is essential that communication about health (risks) is perceived as accurately as possible in the recipient. As present findings have shown that flow visualisations mitigate understanding, this should be considered when deciding upon the way a message will be conveyed to the general public.

The second main finding aligned with the second hypothesis; visualisation type influenced decision-making. It was found that people in the stock condition indicated a more extreme score regarding the decision to prolong closings of the non-essential stores as compared to scores from participants in the flow condition. These results are in line with previous findings by Sun et al. (2020) who found that manipulating the way the same data is presented leads to different decisions. The scores in both conditions indicated a preference for prolonging the closings of the non-essential stores, which means a decision in the same direction, but the degree to which this decision was made differed between groups (stocks versus flow). A possible explanation for the more extreme scores on the decision-making scale in the stock condition could be that the numbers on the y-axis were higher than the numbers in the flow condition. These higher scores could have been perceived as more severe than the lower scores in the flow condition, and therefore, have led to more extreme scores on prolonging the closings in the stock condition. Moreover, the flow graph ended with a generally decreasing trend of infections, whereas the stock graph seemed to continue increasing. Again, the stock graph could have looked more hazardous in this way and thus led to more extreme scores on the scale. Furthermore, these salient features might have overridden features that provide important information about the graphs such as the title explaining what the data involves. These findings provide important implications for graph designers, as presenting the same data differently can lead to different decisions. Moreover, present results add to existing literature about how different visualisations can influence decision-making (see e.g. Stone et al., 2017; Sun et al., 2020). It must be noted that due to an error in Qualtrics, the decision-making question in the English flow condition was not adequate; it missed the part that described on which day the decision of prolonging the non-essential stores was based: day 45. However, when executing the analysis on decision-making without data from the English flow condition, the results were still significant, which indicates that this error did not necessarily influenced present results.

Contrary to expectations, this study did not demonstrate a significant effect of topic relevance on both understanding and decision-making, and thereby, hypotheses 3 and 4 were refuted. Similarly, no significant interaction effects were found of visualisation type and topic relevance on understanding and decision-making, refuting hypotheses 5 and 6. These results indicate that the effect of visualisation type on understanding and decision-making were not moderated or affected by topic relevance, which contradicts the expectations. Even though it was shown that Zambia was perceived as less relevant to participants compared to the Netherlands (demonstrating that Zambia and NL are effective opposites), respondents dealt with the questions similarly. These outcomes showed that the manipulation might not have been checked for in the experiment, which could be due to different factors; the unexpected insignificant outcome could be a result of the online experimental setting. Participants might have focused more on the understanding questions and their performance and unconsciously undermined or overlooked the title of the graphs, including the name of the country (representing the manipulation in this study). Further research could operationalize topic relevance with Zambia and the Netherlands in another way by using these countries in another context: data about current news messages (relating to either Zambia or NL) or visual information about the country's history. Simultaneously, future studies should try to ensure that Zambia and NL are salient parts of the information that is being presented. Another way of testing topic relevance could be to test health communication data about, for instance, breast cancer, and generate participants who are vulnerable to getting breast cancer. Previous studies examining topic relevance in relation to visualisations have focused on engagement and interest in the visualisation (see Peck et al., 2019; Kennedy et al., 2016). Although these studies found effects of topic relevance on information processing and interest, significant effects in this study were absent for understanding graphs and decision-making. However, these studies who found effects used many different types of graphs and/or were of exploratory nature (qualitative analysis). After all, topic relevance in relation to understanding and deciding about visualisation is scarce in the existing literature, and therefore could and should be explored further regarding its operationalization and impact.

Certain limitations have also been recognised in this study. For instance, the ecological validity of the results was somewhat questionable as the study took place in an experimental setting. Additionally, the experiment was held online through a randomized questionnaire, where participants' situational factors were unknown and could not entirely be controlled for, such as possible distractions in all sorts of ways. The unnatural setting of the experiment also limited the topic relevance manipulation. The question is whether respondents would also pay equally much attention to Zambia graphs as compared to NL graphs when reading about it in a newspaper or on social platforms in a real-world setting. Furthermore, the fact that participants were made aware of the fictional data could have influenced the results. It might have come across as less relevant or harmful when thinking about the fact that the data was fictional. Finally, when reviewing the distribution of participants' characteristics across the experimental conditions, a significant age difference was found between participants in the flow condition and stock condition. However, this age difference was approximately five years, which does not seem to indicate a huge potential impact on the results. Therefore, it does not appear to be a substantial limitation. Nevertheless, it creates areas for potential further research including the impact of age in relation to graph literacy, graph understanding and visualisation research.

To conclude, the present research has shown that the type of visualisation significantly affects both graph understanding and decision-making. The current data have shown that flow graphs were poorly understood as compared to stock graphs. It was also found that people presented with flow data were more lenient towards the decision of reopening non-essential stores compared to stock graph participants. These findings provide important insights for graph designers of health communication: the way a graph is designed can decrease the intended purpose of the message as understanding can be influenced, as well as decision-making. Moreover, the results add to existing literature about visualisation types influencing understanding and decision-making. Contrary to the expectations, no significant effects were found for topic relevance, which was a relatively novel research area in the context of graphical visualisation studies. The lack of significant results of topic relevance in the present study creates opportunities and areas for future research. Even though no significant effects of topic relevance were found, the manipulation check analysis showed that Zambia and the Netherlands were evaluated significantly different regarding their perceived relevance. This means that Zambia versus the Netherlands for people living in the Netherlands is an adequate way to operationalize topic relevance, but how Zambia and the Netherlands are embodied in research materials should be carefully considered as the present study did not demonstrate significant outcomes. All in all, this study has contributed to the field of knowledge about visual communication and how it can affect understanding and decision-making.

References

Frewer, L. J., Howard, C., Hedderley, D., & Shepherd, R. (1997). The elaboration likelihood model and communication about food risks. *Risk analysis*, *17*(6), 759-770.

Galesic, M., Garcia-Retamero, R., & Gigerenzer, G. (2009). Using icon arrays to communicate medical risks: Overcoming low numeracy. *Health Psychology*, *28*, 210-216

Garcia-Retamero, R., & Galesic, M. (2010). Who profits from visual aids: Overcoming challenges in people's understanding of risks. *Social science & medicine*, *70*(7), 1019-1025.

Kennedy, H., & Hill, R. L. (2018). The feeling of numbers: Emotions in everyday engagements with data and their visualisation. *Sociology*, *52*(4), 830-848.

Kennedy, H., Hill, R. L., Allen, W., & Kirk, A. (2016). Engaging with (big) data visualizations: Factors that affect engagement and resulting new definitions of effectiveness. *First Monday*, *21*(11).

Lurie, N. H., & Mason, C. H. (2007). Visual representation: Implications for decision making. *Journal of marketing*, *71*(1), 160-177.

Okan, Y., Stone, E. R., & Bruine de Bruin, W. (2018). Designing graphs that promote both risk understanding and behavior change. *Risk Analysis*, *38*(5), 929-946.

Padilla, L. M., Creem-Regehr, S. H., Hegarty, M., & Stefanucci, J. K. (2018). Decision making with visualizations: a cognitive framework across disciplines. *Cognitive research: principles and implications*, *3*(1), 1-25.

Pandey, A. V., Manivannan, A., Nov, O., Satterthwaite, M., & Bertini, E. (2014). The persuasive power of data visualization. *IEEE transactions on visualization and computer graphics*, *20*(12), 2211-2220.

Peck, E. M., Ayuso, S. E., & El-Etr, O. (2019). Data is personal: Attitudes and perceptions of data visualization in rural Pennsylvania. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-12).

Peebles, D., & Ali, N. (2009). Differences in comprehensibility between three-variable bar and line graphs. In *Proceedings of the thirty-first annual conference of the cognitive science society* (pp. 2938-2943). Lawrence Erlbaum Mahwah, NJ.

Peebles, D., & Ali, N. (2015). Expert interpretation of bar and line graphs: the role of graphicacy in reducing the effect of graph format. *Frontiers in Psychology*, *6*, 1673.

Peters, E., Västfjäll, D., Slovic, P., Mertz, C. K., Mazzocco, K., & Dickert, S. (2006). Numeracy and decision making. *Psychological science*, *17*(5), 407-413.

Romano, A., Sotis, C., Dominioni, G., & Guidi, S. (2020). The scale of COVID-19 graphs affects understanding, attitudes, and policy preferences. *Health economics*, *29*(11),1482-1494.

Spiller, S. A., Reinholtz, N., & Maglio, S. J. (2019). Judgments based on stocks and flows: Different presentations of the same data can lead to opposing inferences. *Management Science*, *66*(5), 2213–2231. https://doi.org/10.1287/mnsc.2019.3284

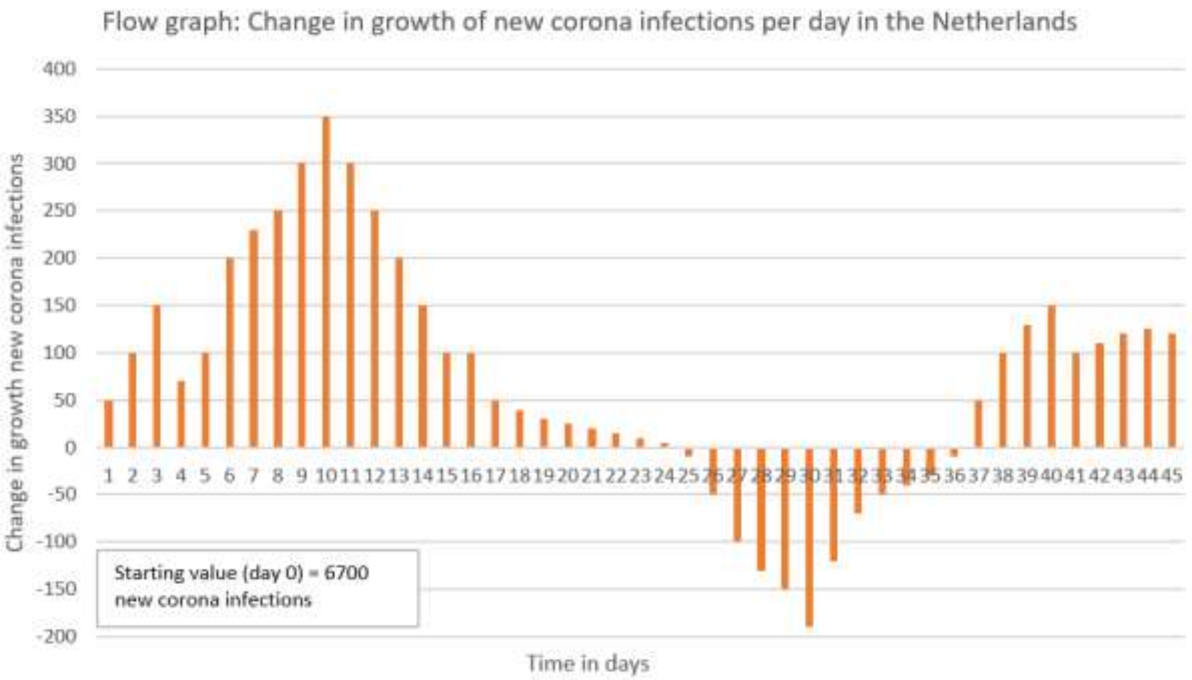
Stone, E. R., Bruine de Bruin, W., Wilkins, A. M., Boker, E. M., & MacDonald Gibson, J. (2017). Designing graphs to communicate risks: Understanding how the choice of graphical format influences decision making. *Risk analysis*, *37*(4), 612-628.

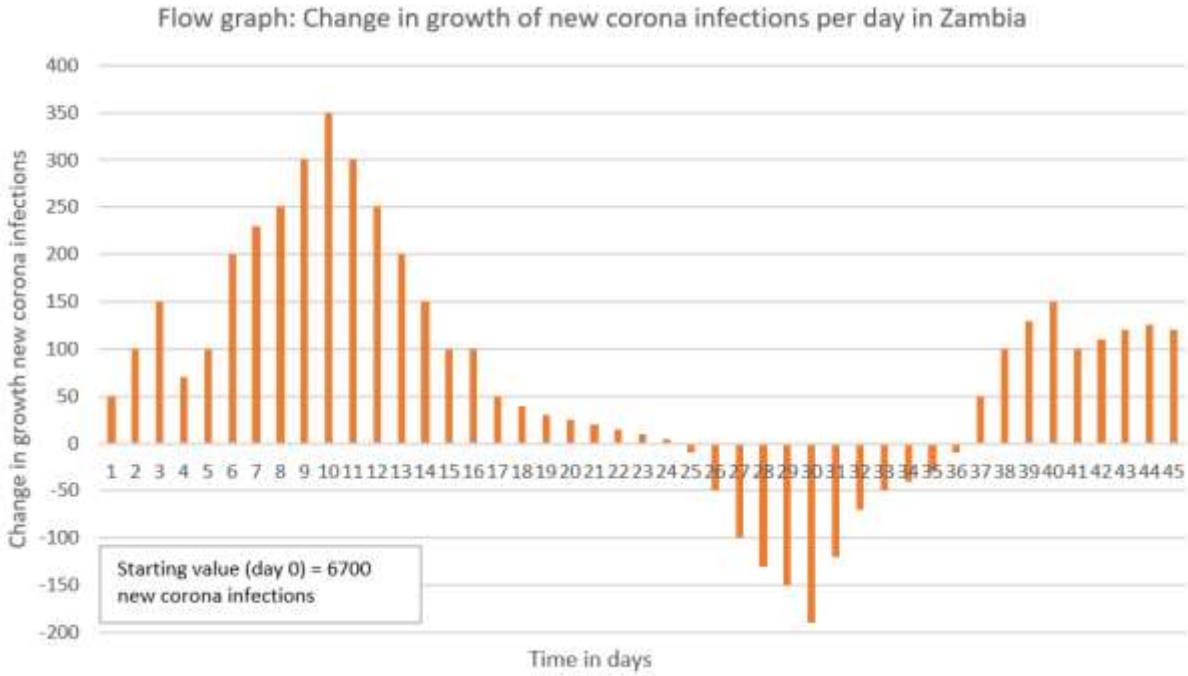
Sun, Y., Li, S., Bonini, N., & Su, Y. (2012). Graph-framing effects in decision making. *Journal of Behavioral Decision Making*, *25*(5), 491-501.

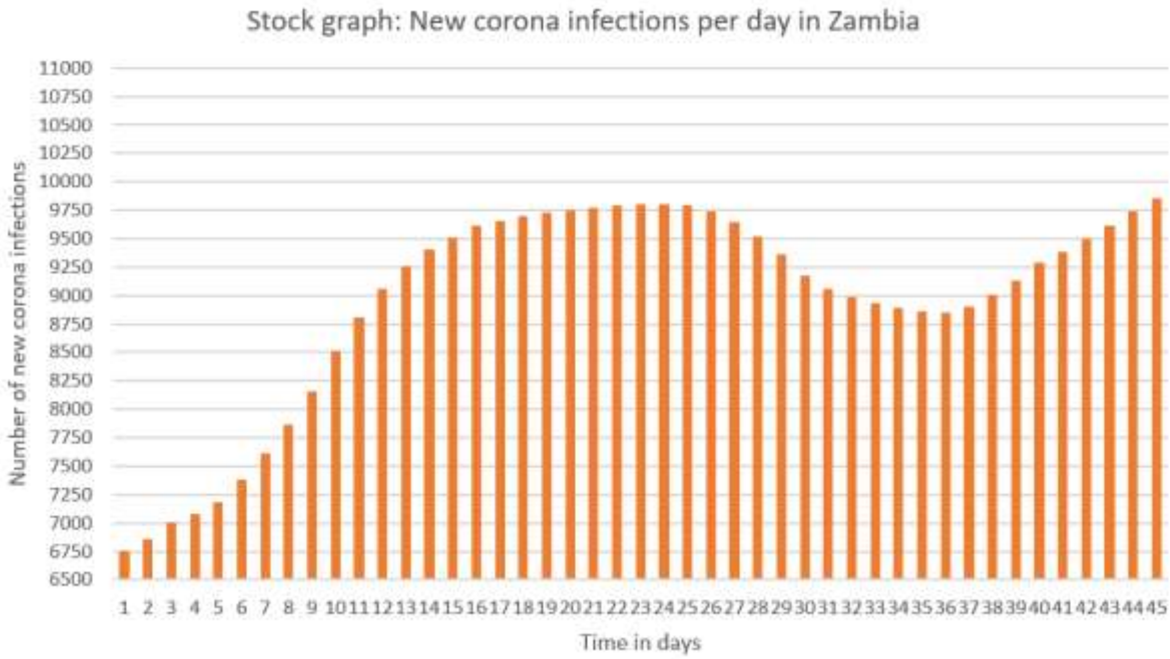
van Lent, L. G., Sungur, H., Kunneman, F. A., van de Velde, B., & Das, E. (2017). Too far to care? Measuring public attention and fear for Ebola using twitter. *Journal of medical Internet research*, *19*(6), e193. https://doi.org/10.2196/jmir.7219

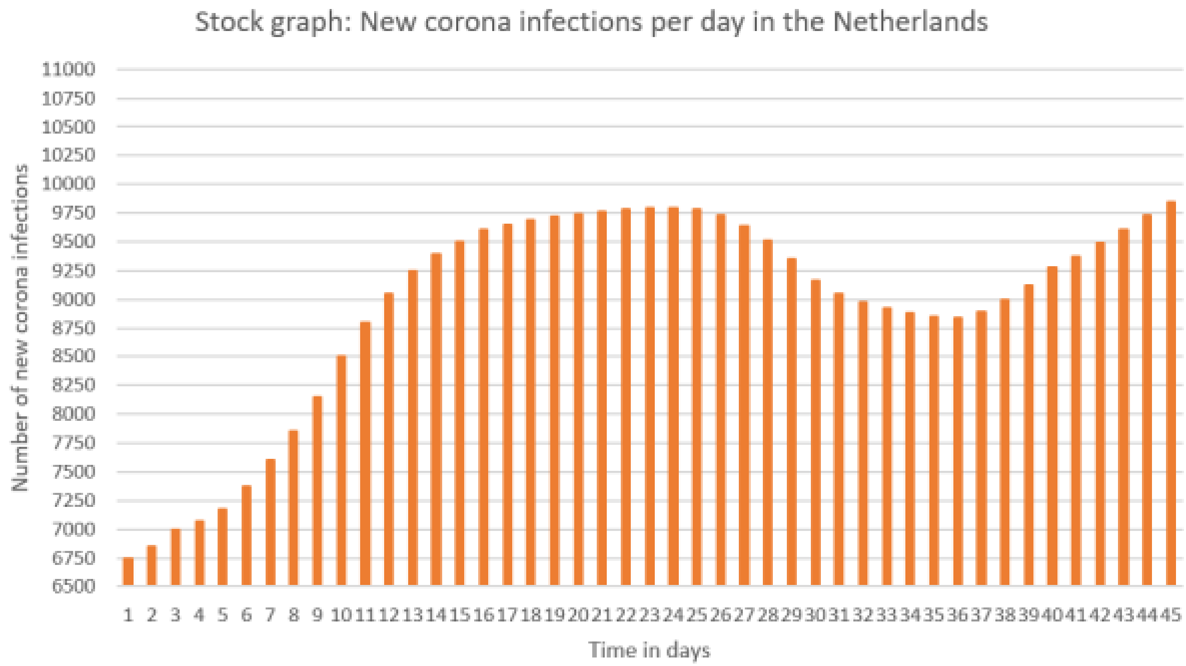
Appendices

Appendix A: Stimuli material (English version)




Flow graph: Change in growth of new corona infections per day in Zambia
Change in growth new corona infections
Starting value (day 0) = 6700 new corona infections
Time in days


Stock graph: New corona infections per day in Zambia
Number of new corona infections
Time in days



Appendix B: Five understanding questions used, also including the correct answers

1. How many new covid cases were registered on **day 3?**
   - **a.** Correct answer *stock*: 7000
   - **b.** Correct answer *flow*: 7000
2. Look at **day 3** and **day 4**. Which day shows the biggest increase in new infections compared to the day before? (Option 1: day 3; Option 2: day 4)
   - **a.** Correct answer *stock*: day 3
   - **b.** Correct answer *flow*: day 3
3. Compare the period from day 1 to day 10 to the period from day 11 to day 20. Which period shows a stronger rise in infections? (Option 1: day 1-10; Option 2: day 11-20)
   - **a.** Correct answer *stock*: day 11-20
   - **b.** Correct answer *flow*: day 11-20
4. What is the difference in the number of new infections between **day 12** and **day 13**?
   - **a.** Correct answer *stock*: [150, 250]
   - **b.** Correct answer *flow*: 200
5. On which day did the decrease of covid-19 infections start to slow down?
   - **a.** Correct answer *stock*: [30, 31, 32]
   - **b.** Correct answer *flow*: [30, 31]

Appendix C: Statement of own work

CIW English

Statement of Own Work

Student name: Isabel Blanken

Student number: s1027661

PLAGIARISM is the presentation by a student of an assignment or piece of work which has in fact been copied in whole or in part from another student's work, or from any other source (e.g. published books or periodicals or material from Internet sites), without due acknowledgement in the text.

DECLARATION:

a. I hereby declare that I am familiar with the faculty manual (https://www.ru.nl/facultyofarts/stip/rules-guidelines/rules/fraud-plagiarism/) and with Article 16 "Fraud and plagiarism" in the Education and Examination Regulations for the Bachelor's programme of Communication and Information Studies.
b. I also declare that I have only submitted text written in my own words.
c. I certify that this thesis is my own work and that I have acknowledged all material and sources used in its preparation, whether they be books, articles, reports, lecture notes, and any other kind of document, electronic or personal communication.

Signed: 

Place and date: Huissen, 06-06-21

Appendix D: Checklist EACH

Checklist EACH (version 1.6, november 2020)

You fill in the questions by clicking on the square next to the chosen answer ☐

After clicking, a cross will appear in this square ☒

1. Is a health care institution involved in the research?

Explanation: A health care institution is involved if one of the following (A/B/C) is the case:

A. One or more employees of a health care institution is/are involved in the research as principle or in the carrying out or execution of the research.
B. The research takes place within the walls of the health care institution and should, following the nature of the research, generally not be carried out outside the institution.

C. Patients / clients of the health care institution participate in the research (in the form of treatment).

☒ No → continue with questionnaire

☐ Yes → Did a Dutch Medical Institutional Review Board (MIRB) decide that the Wet Medisch Onderzoek (Medical Research Involving Human Subjects Act) is not applicable?
☐ Yes → continue with questionnaire
☐ No → This application should be reviewed by a Medical Institutional Review Board, for example, the Dutch CMO Regio Arnhem Nijmegen → end of checklist

2. Do grant providers wish the protocol to be assessed by a recognised MIRB?

☒ No → continue with questionnaire

☐ Yes → This application should be reviewed by a Medical Institutional Review Board, for example, the Dutch CMO Regio Arnhem Nijmegen → end of checklist

3. Does the research include medical-scientific research that might carry risks for the participant? ☒ No → continue with questionnaire

☐ Yes → This application should be reviewed by a Medical Institutional Review Board, for example, the Dutch CMO Regio Arnhem Nijmegen → end of checklist

Standard research method

4. Does this research fall under one of the stated standard research methods of the Faculty of Arts or the Faculty of Philosophy, Theology and Religious Studies?

☒ Yes → **8: standard field research** → continue with questionnaire

☐ No → assessment necessary, end of checklist

Participants

5. Is the participant population a healthy one?

☒ Yes → continue with questionnaire

☐ No → assessment necessary, end of checklist → go to assessment procedure

6. Will the research be conducted amongst minors (<16 years of age) or amongst (legally) incapable persons?

☐ Yes → assessment necessary, end of checklist → go to assessment procedure

☒ No → continue with questionnaire

Method

7. Is a method used that makes it possible to produce a coincidental finding that the participant should be informed of?

☐ Yes → assessment necessary, end of checklist → go to assessment procedure

☒ No → continue with questionnaire

8. Will participants undergo treatment or are they asked to perform certain behaviours that can lead to discomfort?

☐ Yes → assessment necessary, end of checklist → go to assessment procedure

☒ No → continue with questionnaire

9. Are the estimated risks connected to the research minimal?

☐ No → assessment necessary, end of checklist → go to assessment procedure

☒ Yes → continue with questionnaire

10. Are the participants offered a different compensation than the usual one?

☐ Yes → assessment necessary, end of checklist → go to assessment procedure

☒ No → continue with questionnaire

11. Should deception take place, does the procedure meet the standard requirements?

☐ No → assessment necessary, end of checklist → go to assessment procedure

☒ Yes → continue with questionnaire

12. Are the standard regulations regarding anonymity and privacy met?

☐ No → assessment necessary, end of checklist → go to assessment procedure

☒ Yes → continue with questionnaire

Conducting the research

13. Will the research be carried out at an external location (such as a school, hospital)?

☒ No → continue with questionnaire

☐ Yes→ Do you have/will you receive written permission from this institution?

☐ No → assessment necessary, end of checklist → go to assessment procedure

☐ Yes → continue with questionnaire

14. Is there a contact person to whom participants can turn to with questions regarding the research and are they informed of this?

☐ No → assessment necessary, end of checklist → go to assessment procedure

☒ Yes → continue with questionnaire

15. Is it clear for participants where they can file complaints with regard to participating in the research and how these complaints will be dealt with?

☐ No→ assessment necessary, end of checklist → go to assessment procedure

☒ Yes → continue with questionnaire

16. Are the participants free to participate in the research, and to stop at any given point, whenever and for whatever reason they should wish to do so?

☐ No→ assessment necessary, end of checklist → go to assessment procedure

☒ Yes → continue with questionnaire

17. Before participating, are participants informed by means of an information document about the aim, nature and risks and objections of the study? (zie explanation on informed consent and sample documents).

☐ No→ assessment necessary, end of checklist → go to assessment procedure

☒ Yes → continue with questionnaire

18. Do participants and/or their representatives sign a consent form? (zie explanation on informed consent and sample documents.

☐ No→ assessment necessary, end of checklist → go to assessment procedure

☒ Yes → checklist finished

If you want to record the results of this checklist, please save the completed file.

If you need approval from the EACH due to the requirement of a publisher or research grant provider, you will have to follow the formal assessment procedure of the EACH.