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The Role of Psychological Approaches in Data Journalism Visualisations

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ABSTRACT

Data journalism is the process of analysing, clarifying, and visualising data to convey a story and present the news more effectively. *Data visualisation*, the method that allows communicating large amounts of data, can improve viewers' understanding of news and can increase interaction (Bradshaw 2010). The minimalistic theory of the "data-ink" ratio, which can design effective data visualisations, explains that ink should only be used to display the data. Data visualisations with right selection of visual channels can influence memory, attention, and news comprehension (Pan, 2010; Smilek, Dixon & Merikle, 2002). The purpose of this study is to explore if and how visual designers assess psychological principles in journalistic data visualisation. Data visualisations from two well-known organisations (the BBC and the Guardian) presenting COVID-19 information were collected. The analysis was effectuated based on a 'decoding model' initiated by Munzner (2014) to identify their visual attributes. The findings concluded that media organisations consider and apply psychological metrics in the visual design process. Interesting colour differences between visualisations were identified and discussed. A limitation was that the sample of the study was small. Future research could include more data visualisations or could use interviews to understand better the way visual designers practice psychology.

Keywords: *Data Visualisation, Cognitive Psychology, Journalism, Visual Perception*

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1 INTRODUCTION

Data journalism is a field that has attracted significant attention both in the research and media industry. It is a tool that contributes to managing large numbers of figures by using numerical analysis, programming, and visualisation techniques (Appelgren and Nygren, 2014; Loosen, 2018). It was introduced by Simon Rogers in a post to the Guardian Insider Blog and defined it as *"a procedure of analysing, clarifying, and visualising the data of a story"* (Knight, 2015). Moreover, the study of Veglis and Bratsas (2017) explains that effective data journalism can be achieved by a series of six stages: (a) compilation, (b) data cleaning, (c) data understanding, (d) data validation, (e) data visualisation and (f) article writing. In other words, its goal is to gather the most important information, write reports and create visual images that allow one to understand the meaning of a story and recognise the most important information.

In order for journalists to better present the news, data visualisation has been included in newsrooms, media articles, and newspapers. Data visualisation refers to the procedure of presenting and communicating data by using graphical displays (Bradshaw 2010; Deuze, 2001). It is the most common form of communication, complements the narration of the story, and improves the handling of media information (Nguyen et al., 2019; Ivars-Nicolás, 2019), which leads to increased audience interaction and achieve an understanding of news.

In this field, there is a minimalist approach which is known as the 'data-ink ratio' theory. It was initiated by Tufte (1983), and he supported that *"data graphics should draw the viewer's attention to the sense and substance of the data, not to something else"* (Tufte, 1983, p. 91). According to him, effective data visualisation should follow five stages: (a) most importantly show the data, (b) increase the data-ink ratio, (c) remove non-data-ink, (d) erase redundant data-ink, and (e) revise and edit (Kosslyn, 2006). This indicates that visual designers should use ink only to display data and any excess ink dedicated to something other than the data (e.g., background color, iconography, or embellishment) should be removed.

However, previous research explains that the best selection of visual channels (e.g., color, shapes, color palettes etc.) can enhance human memory recall, attention, decision-making, and comprehension (Farley & Grant, 1976; Pan, 2010; Sutcliffe, 2020). Overall, this evidence is important in the work of data journalists because it allows the best communication to the audience. It is equally important to be aware of how human behavior and specifically, how visual perception works to understand what the mind prefers to see.

Our research aims to explore the extent to which psychology is used in journalistic visual design. Empirical knowledge from the field of cognitive psychology and deliberate perceptual approaches is further analyzed. The best psychological method was selected to evaluate journalistic visualisations.

1.1 How the human cognition works

Firstly, visual designers need to consider the human visual system because they aim to communicate visual data and affect people's perceptions. Specifically, 'attention', the cognitive function that is responsible to select and attend environmental information, can affect how we experience emotions and the world around us. However, the most crucial cognitive process is the pre-attentive processing because it is in control of recognising the visual parts of data visualisation. It represents an accurate visual system detection that happens, without our consciousness, at a very high speed specifically, under 250 milliseconds (Healey, 2006).

Likewise, the same influence can occur through 'memory', in which a person stores and recalls information. Atkinson and Shiffrin (1968) support that memory has three main elements: sensory memory, short-term memory, and long-term memory. The processes of memory and attention are inter-related. In particular, as soon as an attractive visual stimulus enters our sight, sensory memory activates and holds the data within a second. In this phase, the 'pre-attentive processing' begins. Our senses have a primary role, and the human eye automatically pays attention to the information. Since the information is retained there for a very short period, data that is subject to a specific amount of attention moves directly to the working memory or short-term memory. In this stage, it takes about a minute to hold and process five to nine chunks of information (Baddeley, 2003).

For more permanent storage the information is stored in the long-term memory in which meaning or association is created. According to Heuer and Reisberg (1992), the higher the extent to which people are attached to stimuli, the bigger the possibility of storing information in their memory. Therefore, understanding visual perception and cognition can help to create more effective data visualisations.

1.2 Visual attributes of data visualisation

The basic visual channels of data visualisation that trigger the cognitive procedures are the shape, size, colour, and angle. Colors are so powerful in our brain that can instantly improve memory and attract attention (MacKay & Ahmetzanov, 2005; Pan, 2010). Farley and Grant (1976) introduced colors have the highest influence on attention. The findings of their study suggested that colorful multimedia presentations increased attention compared to non-colored presentations.

Furthermore, warmer colors (e.g., red, orange) are found to influence more attention compared to cooler (e.g., grey) (Greene, Bell & Boyer, 1983). Indeed, participants exposed to warm colors recalled more words than those who received cool-colored shades or white ones (Huchendorf et al., 2007) Pan's (2010) study adds that color is more recognizable and retainable in the brain rather than a shape. Overall, colors enhance memory retention, consumers' emotional experience as well as decision-making (Sutcliffe, 2020). Colors, contrast, or combination too can also, improve memory retention (Smilek, Dixon & Merikle, 2002). A higher level of contrast refers to the color hue or wavelength. The luminance is the color brightness (Hall & Hanna, 2004). Colored visuals with white background increased memory compared to colored ones with a colorful background (Lloyd-Jones & Nakabayashi, 2009).

In addition, it has been found a positive relationship between color and emotions (Eysenck, 2009). For example, green is associated with positive feelings (e.g., calmness, peace, hope, environmental friendliness) and data visualisations is mostly used to represent a gain. Red is related to positive feelings (e.g., excitement, desire) but also, to negative (e.g., danger, alarm) and in visual design, is used to show a loss.

1.3 Psychological models of visual perception

The study of Cleveland and McGill (1985) evaluates the effectiveness of charts by proposing the ability to see the whole and attend to individual attributes that help attention. Based on them, the most fundamental features are position, length, angle, and color (Cleveland & MacGill, 1985).

Based on this theory, a practical model was developed by Munzner (2014) and introduced that visual marks and channels should be selected based on the type of data (categorical, ordinal, or continuous data). Categorical data represents characteristics such as gender or marital status. It takes numerical values (“1” = male and “2” = female), without having a mathematical meaning. Ordinal values characterize discretely and ordered units such as ranking customer satisfaction, such as from the most positive to the middle response to the least positive. Continuous data represent measurements such as weight and describes by using intervals on a real number line (Rogers, 2014).

Data visualisations encode visual characteristics such as the position of plotting symbols, lengths and slopes of line segments, areas, texture, and color. When a graph is studied, the encoded information is visually decoded, and this process is called *‘graphical perception’*.

Munzner (2014) refers to the definitions of marks and channels (see Table 1). This table was developed based on Munzner’s (2015) book in which there is an analytical explanation in terms of visual channels. Specifically, Visual marks are geometric primitives (e.g., points, lines, and areas). Visual channels control their appearance to communicate data. Channels include the position (can be horizontal, vertical, or combined), colour (including luminance, hue, saturation), shape, tilt (orientation), and size (length, area, volume). Point marks can only be coded by position, size, and shape, line marks convey position and length (size - width) while area marks are completely constrained.

Position encodes all types of data. In contrast, shape only encodes categorical data because shapes (e.g., triangle, circle) are different. The size and color encode ordinal and continuous due to the natural ordering. However, hue is only appropriate for categorical data since they represent completely different categories.

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Table 1. Visual attributes in design.

Visual Channels	Point	Line	Shapes	Colours	Area	Position

1.4 Colour palettes in data visualisation

Colour is perceived in three dimensions: *saturation, luminance,* and *hue* (Knoblauch, 2010). Saturation is the intensity of the colour and the extent it has been mixed with white. Intense colours such as black, grey, and white are saturated while earth tones are desaturated.

Luminance is the range from light to dark as well as the amount of black that is mixed with the colour. Hue is the primary and pure colours which are red, orange, yellow, green, blue, indigo, and violet. Luminance and saturation are effective for ordinal and continuous data because they have an inherent ordering. Hue is great for categorical data since there is no ordering.

Furthermore, the colour palettes are useful for effective data visualisation. The most known colour palettes are: *sequential, diverging,* and *categorical* (Few, 2010; Zeileis, et al., 2010).

A sequential colour palette is used for a gradient effect based on lightness and/or hue meaning we can separate higher values to darker colours and lower values to lighter colours. This palette is mostly preferred to depict ordinal, ration, or internal variables.

Diverging palettes are used for numerical data with ranging a particular interval that has a neutral midpoint and meaningful central value such as zero. In this case, a distinctive hue is used for each of the component sequential palettes to make it easier to distinguish between positive and negative values associated with the center.

The categorical palette is used to highlight categorical data for individual comparisons. They are derived from colors of different hues but uniform saturation and intensity that can be used to show dissimilar data points of an entirely different cause.

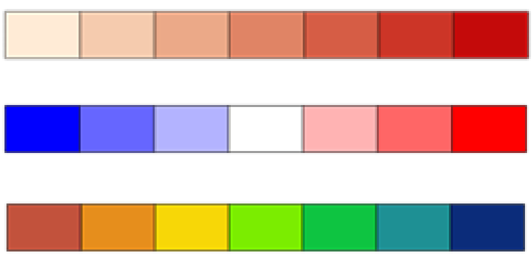

Figure 1. Types of color palettes in data visualisations.

2 METHODOLOGY

2.1 Data Collection Tools

The basic tool that is used to evaluate and discuss the effectiveness of the visualisations is the model of Munzner (2014) (see Table 3). The main four visual channels are encoded based on visual marks, type of data, and message willing to convey. When designers create data graphics, they specify the mapping of data items to visual channels and combine them with marks.

Point marks can only be coded by position, size, and shape, line marks convey position and length (size - width) while area marks are completely constrained (see Table 2).

Table 2. How marks are encoded based on the channels.

Marks	***Channels***		
Point	position	size	shape
Line	position	size (length)	
Area	N/A		

The visual channels are differentiated based on categorical, ordinal, or continuous attributes. These visual channels are ranked based on their effectiveness leading to an estimate of the information that was appropriately perceived. The position encodes all attributes, shape encodes categorical data, size which includes the length, the area, and the volume encodes ordinal and continuous, and finally, the colour which contains the luminance and saturation encodes ordinal and continuous. Hue is mainly used for categorical data.

Table 3. The channels encoded related to the attributes.

Channels		***Attributes***		
		categorical	**ordinal**	**continuous**
Position	X position	✓	✓	✓
	Y position	✓	✓	✓
Shape		✓		
Size	Length		✓	✓
	Area		✓	✓
	Volume		✓	✓
Colour	Luminance		✓	✓
	Saturation		✓	✓
	Hue	✓		

The Zeileis' et al., (2010) study guided us to our second evaluation method to better identify colour palettes. According to them, a sequential colour palette is primarily used to depict graphs with ordinal, ration, or internal variables (see Table 4). Diverging palettes are mostly used for continuous data while categorical palettes are mainly encoded to categorical data.

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Table 4. Selecting the right colour palette related to the attribute.

Colour Palette	Attributes		
	categorical	**ordinal**	**continuous**
Sequential		✓	
Diverging			✓
Categorical	✓		

2.2 Sample

The sample included data visualisations representing COVID-19 data designed by the BBC and The Guardian Digital Agency. These two media organisations were chosen because they are the most popular in the media industry and have a strong impact on the world. These are also, recent and updated data visualisations that allow us to understand the current tools visual designers use.

It is worth noting that in the case of The Guardian, it is allowed to download content for non-profit use and with a complete reference to the source of the content. In the case of the BBC article, the visualizations that are included in the study are no longer available in the article, since this particular article has been updated regularly since it provides CONID-19 data. In any case, the complete reference of the article is included along with the access date.

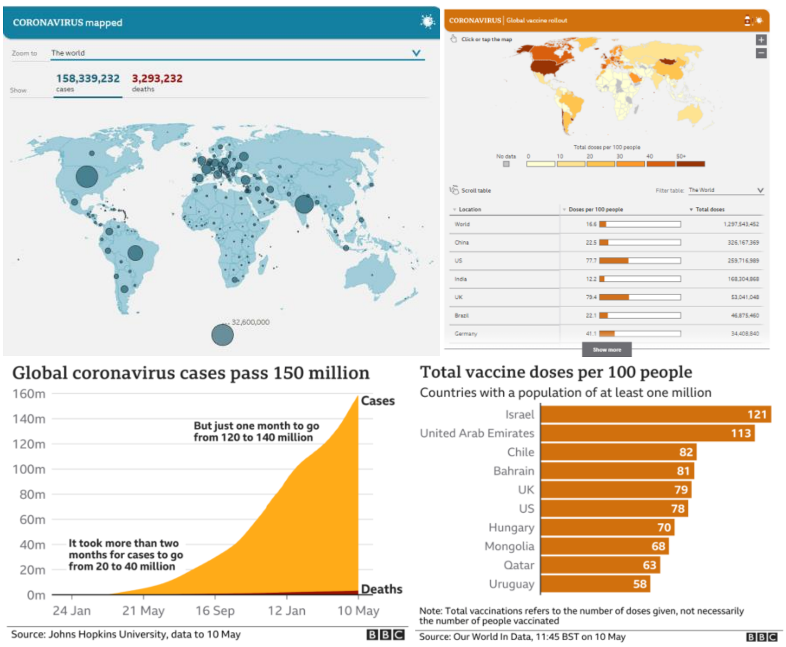

Figure 2. Data visualisations designed by the BBC (Farnsworth, 2021).

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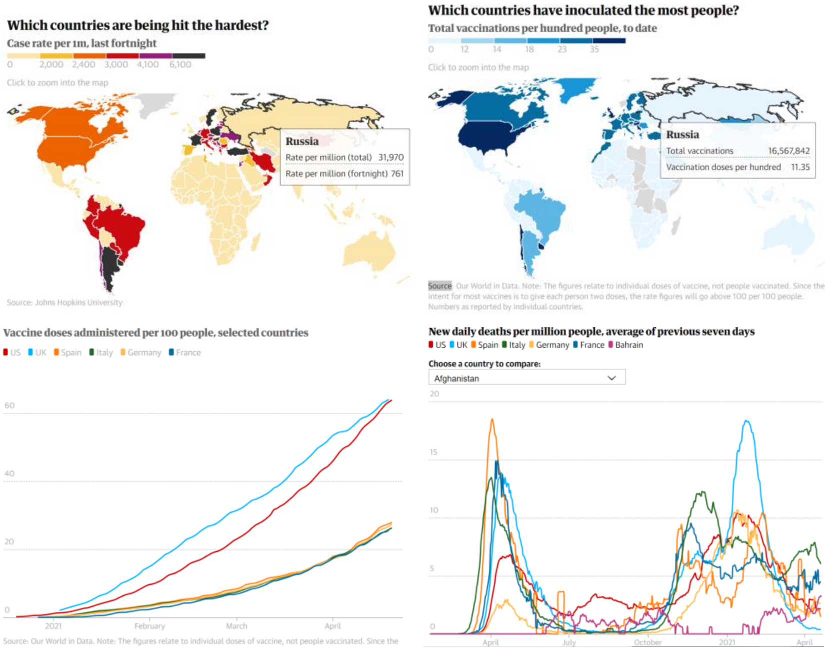

Figure 3. Data visualisations designed by the Guardian Digital Agency (Gutiérrez, Clarke & Kirk, 2021).

2.3 Data Analysis

This is a qualitative content analysis since there is visual material that is categorised and recorded in such a way that can be analysed. The analysis was done in the above steps: recognising the type of data visualisation, identifying their visual elements specifically marks and channels, and defining their colour palette where possible.

Table 5. BBC's decoding process of data visualisations.

Data Visualisation	***Visual Elements***			***Attribute***
	Marks	*Channels*	*Palette*	
1st Choropleth map	*Area, Points*	*Position, size, hue*	*categorical*	*categorical*
2nd Choropleth map	*Area*	*Position, Size, Luminance*	*Sequential*	*Ordinal*
3rd Area Graph	*Area*	*Position, Area, Hue*	*Categorical*	*Categorical*
4th Bar Chart	*Lines*	*Position, Length, Size, hue*	-	*Categorical*

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3. RESULTS

BBC's data visualisations

In the case of the BBC's data visualizations the choropleth map represents the number of cases across the world (see table 5). The visual marks are both area and points. Points decode on the categorical attribute in which the size of the circle represents the number of cases of each country. Hue is used to show the area of the country on the map.

The choropleth map illustrates the global vaccine rollout. Since it uses a real number interval, the attribute type of this graph is ordinal, and the colour palette is sequential.

In the area graph, the attribute is continuous because it describes the global cases over a period. The visual mark is area. Hue is used to categorise and compare the cases over deaths.

The bar chart represents the total vaccine doses for each country. The visual mark is lines with their position being on the y-axis.

Table 6. The Guardian's decoding process of data visualisations.

Data Visualisation		***Visual Elements***		***Attribute***
	Marks	*Channels*	*Palette*	
1st Choropleth map	*Area*	*Position, Size, Luminance*	*Sequential*	*Ordinal*
2nd Choropleth map	*Area*	*Position, Size, Luminance*	*Sequential*	*Ordinal*
3rd Line graph	*Lines*	*Position, Length, Hue*	*Categorical*	*Categorical*
4th Line graph	*Lines*	*Position, Length, Hue*	*Categorical*	*Categorical*

The Guardian's data visualisations

Moving to the Guardian's data visualizations (see Table 6), the choropleth maps visualise the countries that are mostly infected and show the ones that were vaccinated so far. The visual mark used in the first two data visualisations is (geographical) area. The colour palette used is sequential to show an order from the lowest to the highest rate that hit the countries.

Similarly, in the second visualisation, the order is the number of vaccinations made in each country.

The line graph presents the countries that have been vaccinated per month as well as in the last line graph, shows the number of deaths that occurred so far per country. Categorical data was used, lines represent the countries' change over time so, the categorical palette was selected to differentiate countries.

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3 DISCUSSION

The findings of this study show that visual designers in media organisations take into account theoretical models related to *visual perception*. Both media organisations tend to follow the rules of the model such as appropriate selection of colours, colour palettes, and use different visual channels such as marks based on the purpose and attribute of a graphic.

For example, both used a choropleth map to illustrate the cases throughout the world. However, the main difference is the type of data used as in BBC's data visualisation, the number of cases of countries is represented in different *category* whereas The Guardian the number of cases is represented in an *order*. Therefore, in that case, the visual designers will use different colour palettes, consider the best colour selection considering elements such as luminance, saturation, and hue, as well as contain diverse visual attributes.

Furthermore, based on Munzner's model (2014), the visual mark of the graph defines to a great extent the visual channel that will be used. In the first data visualisation (see Figure 4), the visual appearance or channel of the points (visual mark) includes the shape which is different circles with bigger or smaller sizes together with the main hue (blue) to illustrate the number of cases of each geographical area.

In the second data visualisation, the visual area of each country has been illuminated based on the extent of the cases; therefore, to best convey this order, other elements have been used such as a sequential colour palette that provides a gradient effect of lower values being lighter-coloured and higher values being dark-coloured.

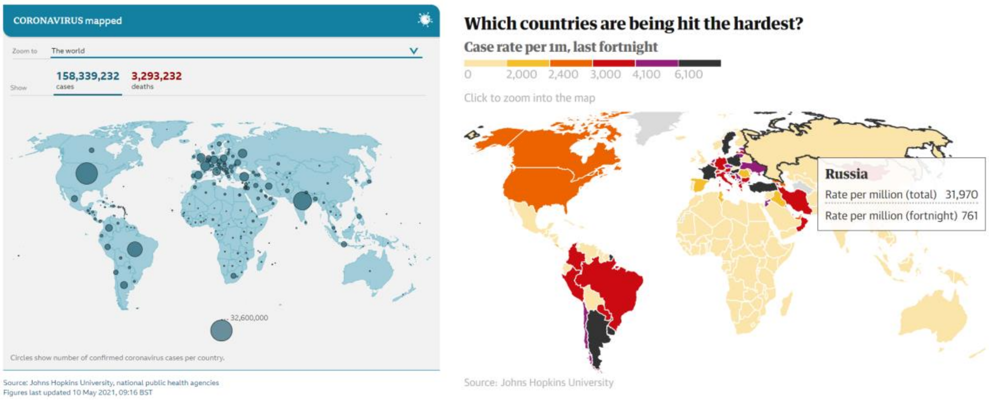

Figure 4. Comparison of data visualisations related to the infected cases.

In the next data visualisations (see Figure 5) that display the countries mostly vaccinated through an order of the total doses per hundred people, both have used the same visual marks and channels as well as a sequential colour palette due to their ordinal data. However, there is an instant observation upon the colour shades preferred to be used (*warm/cool colours*).

Based on our theoretical review, studies support that warm colours (e.g., red, orange) have a higher impact on attention compared to cool ones (e.g., blue, grey) (Greene, Bell & Boyer, 1983). Moreover, a more recent study by Huchendorf et al., (2007) found that participants who were exposed to warm-colour patterns recalled more words than those who received cool-coloured shades or white ones, which shows the positive impact of warm colour shades on memory recall. These studies confirm that colour shades can instantly affect the way humans attend, store, and remember information in their brains.

Another note-worthy reflection is the colour selected for the background. Research supports that coloured visuals with non-coloured backgrounds led to better memory retention compared to coloured ones with coloured background (Lloyd-Jones and Nakabayashi, 2009).

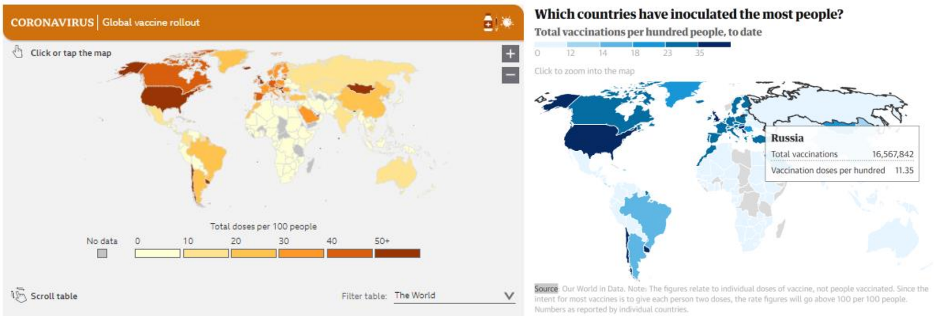

Figure 5. Comparison of data visualisations related to global vaccination.

Turning now to the bar and line graph (see Figure 6) that were used to demonstrate the vaccine doses per hundred people in different countries. The data in both data visualisation is categorical with similar visual marks used (lines). A difference can be found in the position of the visual marks since in the bar graph, the y-axis position was used, whereas in the line graph the x-axis position is best used.

The line graph has the hue to categorise and differentiate the countries although, the bar graph consists of a single colour (orange) to demonstrate the countries. In this case, however, it is quite difficult to make an accurate comparison because, in the second graph, the purpose is to learn if people are inoculated, compared to the first data visualisation that allows identifying the number of doses of countries.

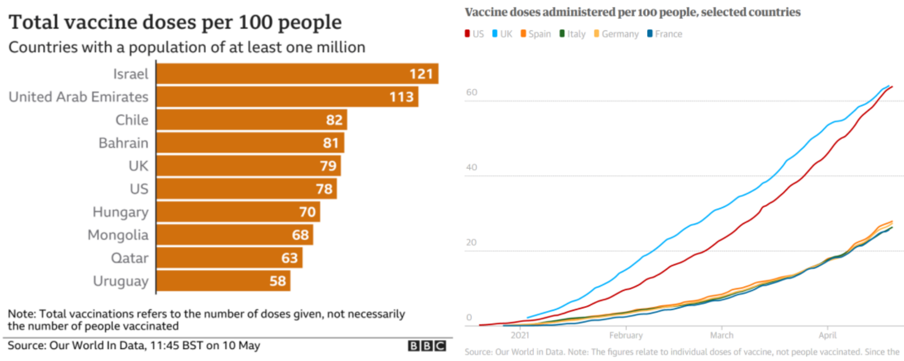

Figure 6. Comparison of data visualisations related to total vaccines doses per 100 people.

The final data visualisations (see Figure 7) represent the deaths over time. The line graph depicts the frequency of deaths of countries aiming to make individual comparisons and that is the reason it contains different hues and a categorical colour palette. Similarly, the area graph that shows the global cases and deaths throughout time, uses two hues and a categorical palette as well.

Another central aspect is the way colours are associated with a message, feeling, situation or event. Previous studies mention that red is mainly used in data visualisations to display a loss and it often creates viewers a feeling of danger or alarm (Eyesenck, 2009). In the current study, red has been used to visualise deaths because the visual designer possibly wanted to trigger feelings of awareness of the pandemic.

A previous study claims that emotions influence how people store data in their memory system and selection of the best colours in data visualisations can enhance cognitive procedures such as memory performance, encoding, and retrieval phases (Smilek, Dixon & Merikle, 2002).

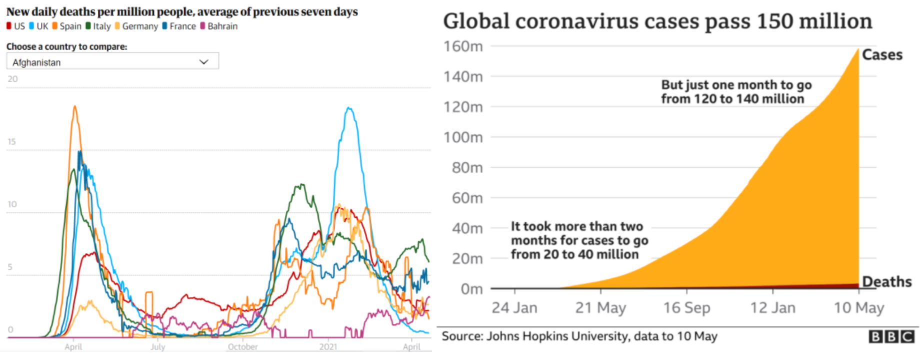

Figure 7. Comparison of visualisations related to cases and deaths per million people.

The findings indicate that media institutions follow and evaluate theories of psychology to create data visualisations more effectively and understandably. The model of Muznzer (2014) seems to be common in the media industry as visual designers include the rules of visual marks and channels in the design process. Indeed, the tool is effective not only to decode graphs but also, as a guide to creating an interactive data visualisation. Appropriate collection of colour, shape, position, and size of visual marks are significant in the creation of effective data visualisations.

4 CONCLUSION

To conclude, this study has explored the extent visual designers utilize basic principles of psychology to create effective data visualisations. Since the study is at an initial stage, it focused on a particular case study researching two well-known media organizations. The results show how powerful and helpful is to select the best approach in the design of the data visualisations. Also, our findings confirm that visual designers of media organisations consider psychological theories and rules such as ‘*pattern perception*’. Munzner’s model (2014) was found to be effective for decoding their data visualisations.

The most appropriate colours, shapes, positions, and sizes should be only selected based on the purpose of the graphic (Munzner, 2014). Overall, a strategic assortment of the most suitable features can improve the viewer's memory, attention, decision-making, and comprehension of the story (Pan, 2010; Sutcliffe, 2020).

Therefore, future studies are important to examine further the role of psychology in data journalism visualisations. Undowdbly this study the limitation since the sample is quite small which cannot give a holistic view. Nevertheless, it can act as a basis for future research that could include a larger and more diverse sample. Also, qualitative measurements such as interviews could be conducted to understand better the way visual designers in media institutions practice psychological models in their data visualisations.

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